Michigan Economic Development Corporation Forestry Biofuel Statewide Collaboration Center
Task B1 Evaluation of Michigan Biomass Transportation Systems

Final Report

Michigan Tech Transportation Institute

Rail Transportation Program
Michigan Tech Transportation Institute • Michigan Technological University

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Executive Summary

Minimizing transportation costs is essential in the forest products industry, as the relatively low value and high weight of the products cause transportation to account for an exceptionally high portion of the overall cost. Forest products such as logs, chips, and residues (woody biomass) are one of the major business sources in Michigan, especially in the Upper Peninsula, and place different constraints on transportation and handling requirements.

This report details the transportation-related investigations conducted as part of the Forestry Biofuels Statewide Collaboration Center (FBSCC) project for the state of Michigan, supported by the U.S. Department of Energy (DOE) and the Michigan Economic Development Corporation (MEDC). The main objective of the transportation system evaluation under the FBSCC project framework was to identify and evaluate the capabilities of the Michigan transportation system to deliver woody biomass in general, and especially to nine biomass plants proposed through other parts of the study. The report concentrates on in-state movements only and uses either road (truck) transportation or combinations of either road with rail and/or marine transportation as the transportation chain alternatives.

The transportation analyses were divided to three main categories:

- **Infrastructure:** Inventory and assessment of current road, rail and marine transportation infrastructure in forest regions of Michigan with a main concentration on the northern part of Lower Peninsula.
- **Equipment:** Identification of the most suitable types of equipment for forest biomass transportation and evaluation of their availability in the State of Michigan.
- **Operations:** Operational and economic considerations and challenges for modal and multimodal transportation alternatives. This section also included developing general level estimates for delivery of woody biomass to the nine proposed facilities and review of the formation of transportation costs.

The research methods applied through this report included literature searches, interviews, database searches, field visits, surveys, and limited modeling of different transportation scenarios.

Literature Review

The first chapter provides a summary of conducted literature reviews, including specific reports reviewed as case studies for woody biomass transportation in the U.S. and Scandinavia. Biomass transportation has received little attention in literature and the majority of it has concentrated on truck transportation. Concentration on trucks is not a great surprise, as a majority of the trips are conducted by trucks. Multimodal freight transportation was largely absent in the literature reviews, with the exception of intermodal transportation of containers.

Based on literature reviews, a general comparison of perceived advantages and disadvantages of each transportation alternative was developed (Table 1). Although each situation must be evaluated individually, rail and marine transportation are typically considered cost-efficient for large quantities and for longer distances. Based on research conducted by Searcy 2007, rail transport is often more economically viable than truck for biomass movements over 300 miles (500 km) and ship is more cost-efficient than rail transport after 900 miles (1500 km). However, type of biomass and availability of facilities can significantly affect the total cost of transport case by case (Searcy, et al, 2007). For example, in woody biomass transportation, rail is often considered competitive for movements over 100 miles.

Table 1-General comparison of transportation modes

Mode	Pros	Cons
Truck	-high flexibility and accessibility -suitable for short distances -combinable with other transport modes -low fixed rate - high reliability and fast service	-costly for long distances -high variable rate -low capacity and volume per unit -higher risks of safety and security
Rail	-low variable rate -higher capacity in comparison to truck -suitable for mid and long distances	-less accessible and flexible than truck -high fixed rates -low commercial speed -infeasible for short distances -often requires interchanging between companies - complex contractual agreements
Marine	-very low variable rate -reliability -highest capacity in comparison to truck and rail -suitable mainly for long distances	-accessibility and flexibility -high fixed rates -very low commercial speed -infeasible for short and mid distances - limited equipment availability

The reports reviewed as case studies confirm the dominance of trucks as the preferred mode for biomass transportation. A study in New York recognized the potential for using rail in addition to trucks, but excluded it from the final recommendations due to unavailability of access points.

Transportation Infrastructure

The infrastructure analysis and respective maps of each transportation mode (road, rail, and marine) are presented in Chapter 2. Infrastructure is typically a fixed asset of transportation system and one of the most important and expensive components. Some examples of transportation infrastructure are highways and truck terminals, railroad tracks and yards, airports and marine ports. Figure 1 shows the main infrastructure available for biomass transportation in Michigan. It also represents the approximate locations of the biomass plants proposed in the study.

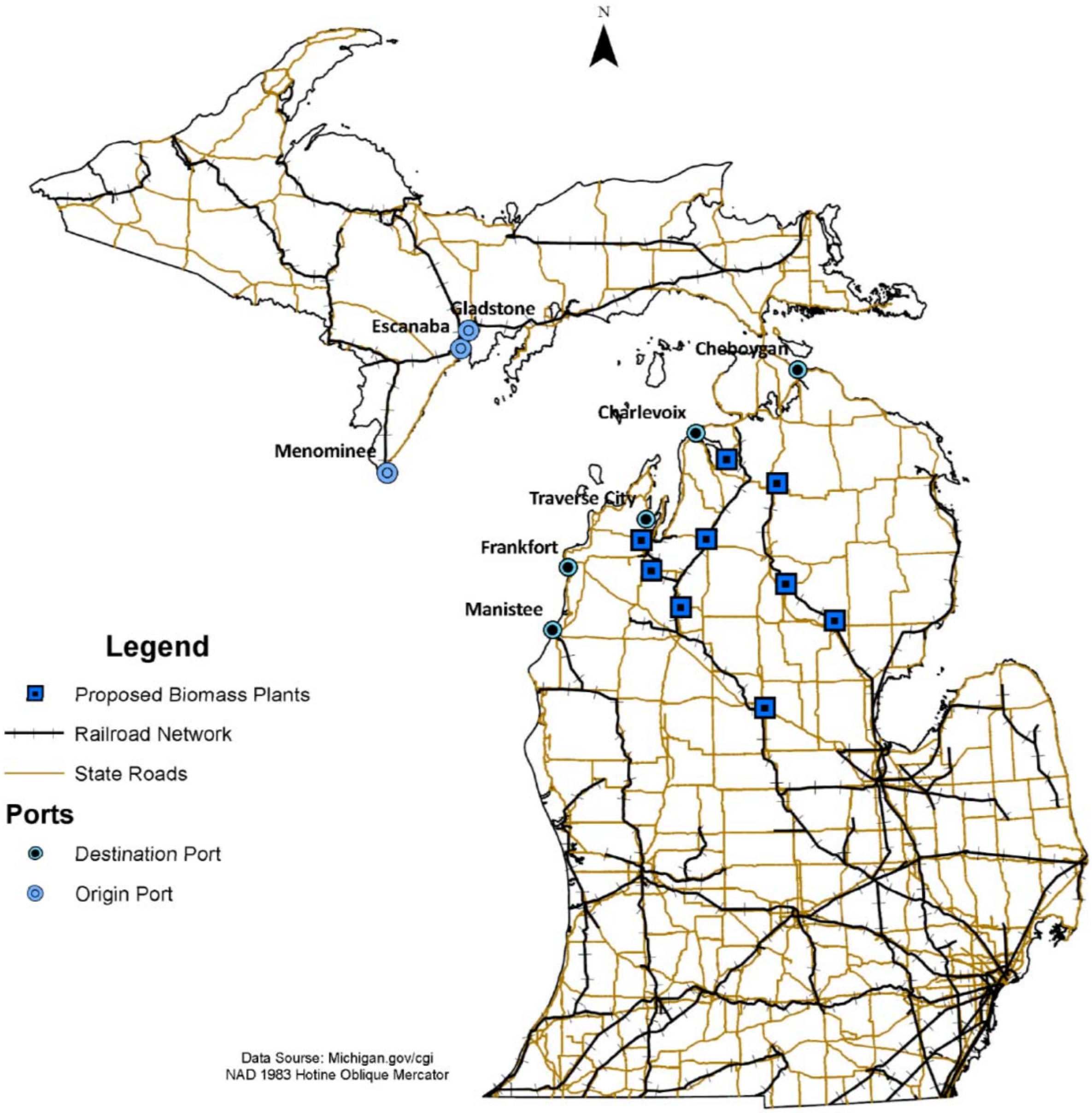

Figure 1- Snapshot of all potential transportation infrastructures that may be used for biomass transportation through the state of Michigan

The key **road infrastructure** for biomass transportation includes the all-season truck routes that are mainly part of state highway and interstate network. Truck axle loads and weight restrictions may affect the selected route and limit the truck movements, especially during the spring breakup season. Based on the analysis, bridge weight restrictions do not cause major limitations for truck movements, excluding the Mackinaw Bridge, which has a crossing toll and is limited to a maximum 72 ton (144,000 lbs.) Gross Vehicle Weight (GVW) limit.

The freight rail network in Michigan includes 4,412 miles of track which also supports three shared passenger rail corridors. The current network is owned and operated by 30 freight railroads, mainly in the Lower Peninsula. Only CN, Lake Superior and Ishpeming (LSI) and Escanaba and Lake Superior (ELS) operate in the Upper Peninsula (UP). The key rail infrastructure components are main lines and rail sidings (stations) and yards. Rail access at points of origin and destination (facility or plant) and interchange locations are the most critical locations to determine the capability of rail for biomass transportation. As there is no rail connection between the UP and the LP, the only railroads capable of serving the proposed plants are the ones operating in the LP, especially in the northern LP The greatest potential for biomass rail transportation in the LP is provided by Great Lakes Central and Lake State Railway, as all proposed biomass facilities are located in the vicinity of these two rail operators. Since most rail infrastructure in the northern LP is oriented in a north-south direction, it makes rail more usable for movements in these directions, and opportunities for cross-state movements would be limited. It also needs to be recognized that a rail network of any individual railroad is quite limited, so most movements typically require at least one interchange from one railroad to another, immediately reducing the applicability of rail transportation, especially if the maximum 100 mile radius harvesting criteria is maintained.

Marine infrastructure can be typically classified as port and dock facilities. Although there are several ports and docks located around the Great Lakes in the State of Michigan, not all of them are suitable and equipped for biomass transportation. The following attributes were used to refine the analysis for suitable ports and docks:

- Operational Characteristics: like dimensions of dock, depth of water, and conditions of dock
- Landside Connections: like access to the road and rail network, and adequate storage space
- Owner interest in using the dock for biomass transportation

After reviewing all existing ports and docks within the state of Michigan, three origin ports in the Upper Peninsula and five destination ports in the Lower Peninsula were identified to be potentially suitable for any further biomass transportation purposes in the state of Michigan. Since none of the proposed plant locations were on navigable waterways (with the possible exception of Traverse City), truck (or rail) drayage would have to be arranged from the port to the facility.

Transportation Equipment

Most suitable road, rail and marine equipment types for biomass transportation in Michigan were identified and reviewed in Chapter 3. **Trucking** is currently the main transportation mode and there are different types of trucks suitable for woody biomass transportation with various axle configurations. Chip truck trailer, chip truck, log truck and pup, and tractor-trailer are the main truck types with carrying capacity between 42,000 - 110,000 lbs. Increased demand for biomass transportation has also led to the development of new equipment types, such as the stump tuck developed in Scandinavia. In addition to the truck types, the loading and unloading facilities and technologies can also affect the overall productivity and speed of truck transportation. For instance, self-loading log trucks, tipping facilities in the mill or power plant to unload the chip trucks (Figure 2), and live floor technology in the chip trucks, are three examples that affect the overall productivity of truck transportation.

Figure 2- A type of chip truck tipper at woody biomass facility

According to the data received form Secretary of State (SOS) and previous studies, it has been estimated that over 1,000 log trucks are registered within the State of Michigan, with approximately a 2:1 split between the Upper Peninsula and Lower Peninsula. Outcomes of a survey that was conducted as part of the study suggested that most of the log trucks in the state of Michigan are equipped with self-loaders. It also revealed large variations between the average truck age, fuel consumption and annual mileage. Based on interviews with equipment manufacturers the capital costs for trucks and trailers vary significantly, from $30,000 for a trailer to $300,000 for log truck + pup trailer (Michigan specifications) and the demand for large biomass trucks has been weak, leading to limited inventory. However, smaller, more versatile trucks have been in higher demand and high powered “Michigan Special” tractors are also readily available.

Several different types of rail cars are capable of hauling woody biomass on railroads, but certain car types are preferred. Bulkhead flat cars and log cars are mainly used for logs and gondolas and hoppers for chips. The load capacity of each car varies between 75-110 tons and in some cases, volume limitations are reached before weight limits. Most rail cars require separate loading/unloading equipment and overall, logs are more widely transported by rail than chips, as unloading processes of chip cars tend to be either capital or labor intensive. Due to the interstate nature of rail assets, there are no dedicated rail cars that operate only in the State of Michigan, but rail service providers felt confident that in case of adequate demand, securing required equipment capacity would not be a problem. Currently, most rail cars for biomass transportation are owned by railroads, but the industry is shifting toward ownership by shippers, sometimes through pooling agreements, or leasing companies. The price of rail cars is not as diverse as trucks and it is placed between $70,000 up to $90,000 for new cars and $15,000 up to $50,000 for used cars.

Vessels and barges are defined based on their physical specifications, operational limitations and legal requirements. A most likely vessel for biomass transportation would be a barge that is propelled by a tug. The barges have relatively low operating costs and capacity between 1,000 and 10,000 tons. In comparison, large vessels may have capacity for up to 60,000 tons. One of the most significant legal requirements for marine transportation is the Jones Act that limits the pool of available vessels for transporting biomass between Michigan ports or with other states to U.S. flag vessels. More specifically, the Jones Act requires that any vessel transporting cargo for hire in the domestic trade should be:

- Registered in the U.S.
- Built in the U.S.
- Owned/managed by a U.S. company
- Crewed by U.S. citizens

The report provides current U.S. flag tug barges (as of October 2010) in the Great Lakes, with notations on size and suitability for the movement of biomass. Even though capacity for such movements exists, the barges may not be able to travel on all potential routes, as some of them may be engaged in long term contracts that render them effectively unavailable. In addition to current barges, a barge could be repositioned from an ocean coast or newly built, if a suitable market with an acceptable return on investment existed.

Modal and Multimodal Transportation Operations

Modal and multimodal transportation operations, including discussion on challenges and economics of transportation, are covered in Chapter 4. Operations refer to the combination of staff, information, tools, methodologies, techniques and finances needed to operate and maintain the overall transportation system in a safe and efficient manner. Figure 3 represents the alternative supply chains for biomass transportation. 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).

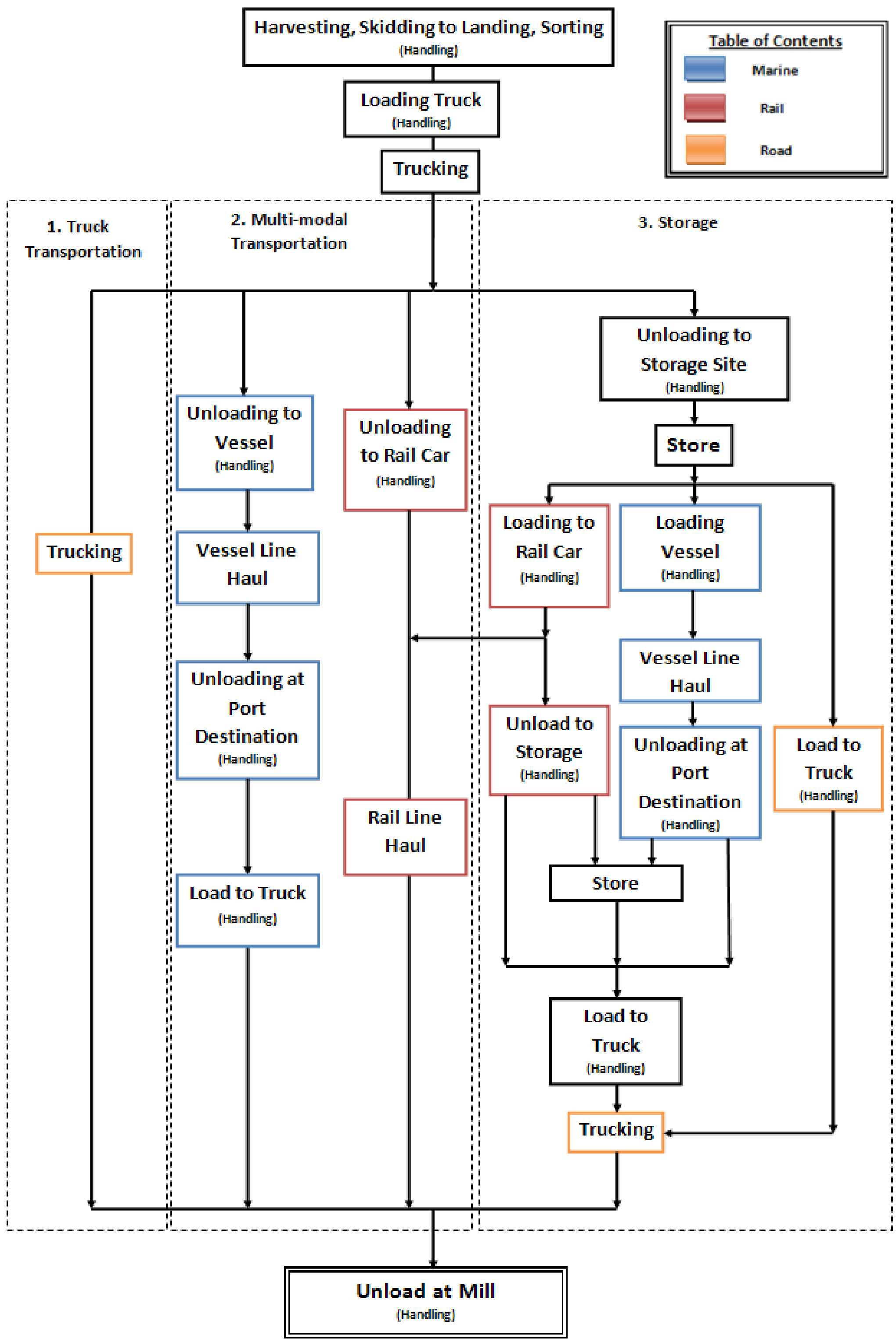

Figure 3- Alternative supply chains for biomass transportation

There are numerous considerations that affect 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's between truck to the other modes (rail and water) and number of switching or carrier interchanges during rail transportation.

In 2009, over 12 million tons of logs (more than 95% of the entire volume) were transported within Michigan by **trucks**, complimented by 3 million tons of other wood products. Operational characteristics of each truck for log and biomass transportation in Michigan can be typically summarized as:

- Eight to twelve hour operations per day and five days per week
- Two to three daily round trips between harvesting/log yard facilities and mills/power plants
- Trucks move with a payload for 25 percent of the daily operational time

The portion of transportation costs in the supply chain is highly dependent on the overall distance between origin (forest landing) and final destination (facility/plant). Several sources of data were used to define the average distance for current truck movements in Michigan which equaled 75-100 miles. This number correlated well with the 100 mile hauling radius used by the FBSCC modeling team and it suggested that most economical transportation method for biomass movements is by trucks, as such short distances are difficult to perform economically through multimodal alternatives.

Each transportation alternative faces operational challenges that must be considered in the decision-making process. Challenges related to truck transportation include:

- Un-optimized supply chain management
- Limited opportunities for backhaul movements
- Loading/unloading inefficiencies
- Mackinac Bridge, the vital link
- Spring weight restrictions

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 movement. However, the portion of woody biomass, lumber and forest products were minor with only 3% of rail imports and 5% of exports. Almost all rail movements took place in the UP Even though Michigan has almost 30 operational railroads, few of them offer high potential for woody biomass transportation services. The main opportunities for in-state movements exist in the northern part of LP and in the UP, which eliminates the majority of rail providers. Based on the logger survey, 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 UP and only 20% of their annual volume moved by rail. The major drawbacks to rail operations identified are reliability of rail service, limited rail access within main working areas, and low speed of delivery. Additional challenges for using rail transportation include:

- Short transportation distances, dispersed origins and numerous rail rates
- Rail car availability and transportation time / reliability
- Rail siding access to final destination
- Constructing new rail access to the facilities/plants
- Number of interchanges required en-route

Marine transportation benefits from economy of scale, but poses several operational requirements to be considered as a potential option for biomass transportation. In summary, marine transportation of biomass material is an option where the following key attributes are met in the design of the biomass supply chain:

- Navigable waterways connecting the supply to the demand locations with a depth of at least 15 feet for barge and tug operations.
- Port infrastructure that can support the volume of traffic
- Landside access from the ports to biomass supply and demand locations
- Suitable vessels to carry the biomass in the desired quantity
- The total landed cost of using marine transportation as part of the supply chain is competitive.

Similar to truck and rail operations, there are some challenges in front of marine transportation as:

- Infrastructure and vessel costs (very expensive)
- Vessel acquisition or new building equipment
- Marine haul business model challenges (risky business for operators)

Transportation Service Capacity for Proposed Biomass Plants

Nine potential biomass plant locations were identified as part of the FBSCC study. Since each plant was designed for specific annual feedstock demand (30, 40 or 50 million tons), the capacity and number of vehicles required to provide feedstock to each plant were estimated as part of the transportation analysis. Based on maximum demands for all biomass plants (50 million tons), the number of required loads by trucks, rail cars and barges was estimated (Figures 4 and 5) for each transportation alternative.

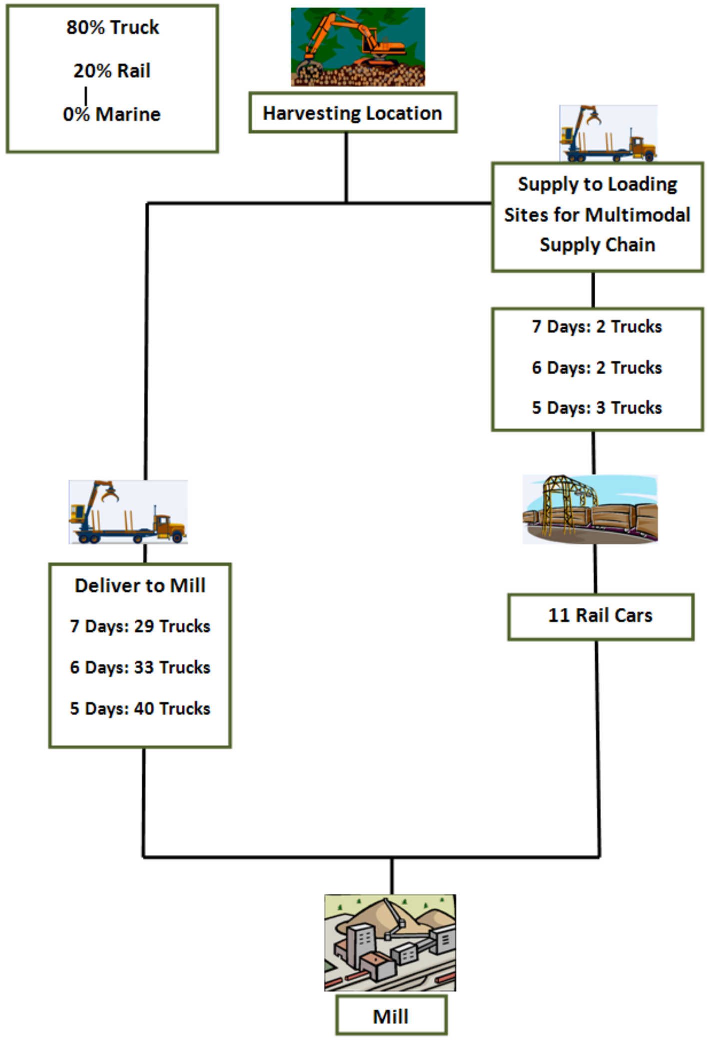

Figure 4 - Scenario 2: Number of trucks and rail cars needed to supply biomass for a 50 million gallon facility

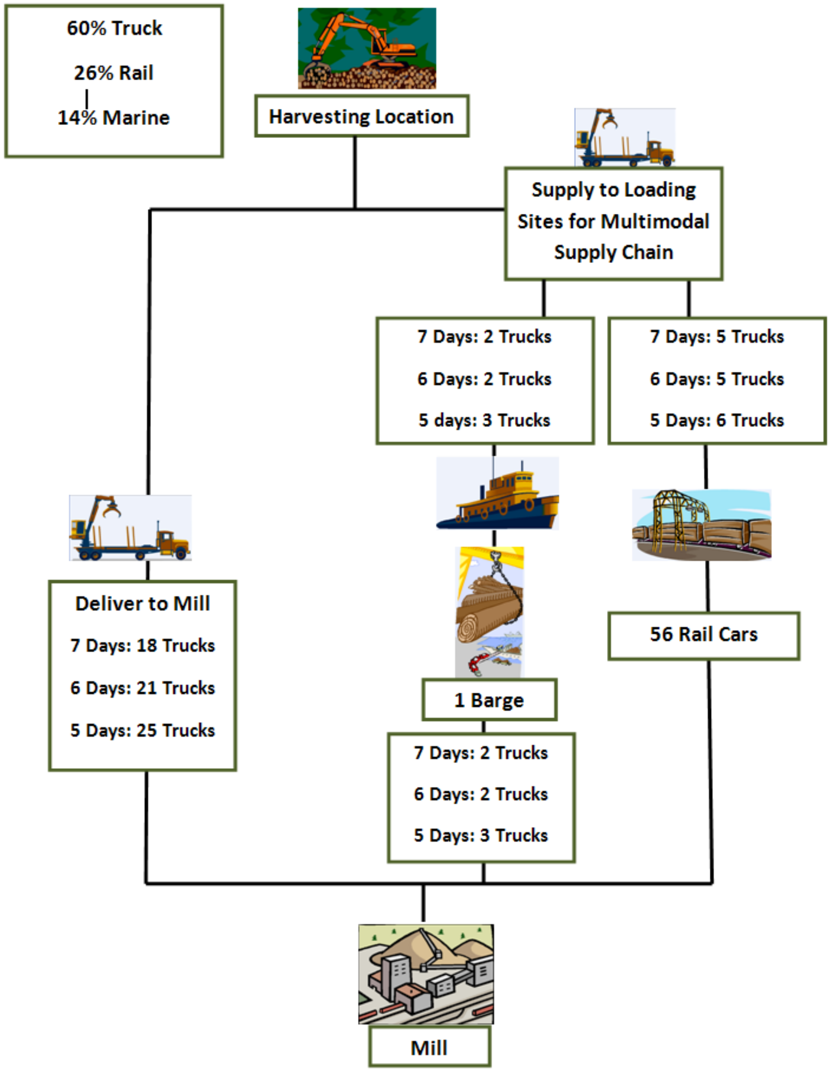

Figure 5 - Scenario 3: Number of trucks, rail cars and barges needed to supply biomass for a 50 million gallon facility

Based on the current inventory, serving a single new biomass plant could be accommodated by the current truck fleet, but if all nine would be implemented, the majority of available trucks in the LP would have to be dedicated to the plants. Alternatively, new trucks would have to be added to the current fleet. Both rail and marine transportation service providers were interested, but only if sufficient and continuous volumes existed.

The lack of detailed plant analyses prohibited a detailed transportation cost analysis as part of the study. **Transportation costs** for truck transportation is typically provided as rate per ton-mile, but rates for multimodal transportation like truck-rail combination have to be typically estimated case-by-case for each origin-destination pair. Instead of simply considering the transportation rates, evaluation should determine the total landed cost as presented in Chapter 4. An example of rate comparison between truck and truck-rail multimodal option within Upper Peninsula is provided in Figure 6.

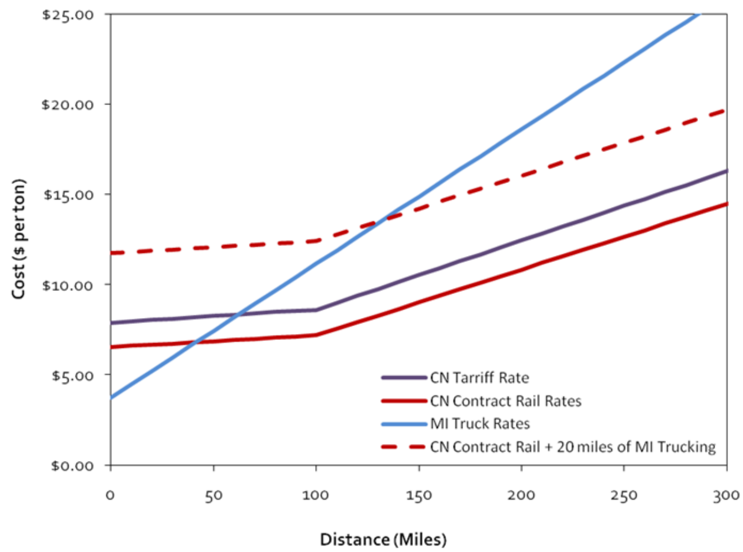

Figure 6 - Comparison of rail rate versus Michigan log truck rate data (steep blue line)

According to the given rates of truck and rail operator policies and rates (CN) in the UP, the multimodal truck-rail option for biomass transportation can be more cost-efficient when the total transportation hauling length is over 120 miles. 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. Shippers should be aware of this trend and adjust their supply chains based on fuel price changes.

Transportation Definitions and Terminology

This section summarizes some of the most common terminology used in the current report.

Road and General Transportation Terminology:

- **Bulk Transportation:** freight transportation in large quantities as in ships, railcars, tankers.
- **Cargo (Freight) Transportation:** goods or produce transported, generally for commercial gain, by ship, aircraft, train or truck.
- **Container:** A metal box used to unitize cargo for transportation. Provides easy transfer of complete container between different transportation modes, such as rail, ships and trucks.
- **GIS:** Geographic Information System (geospatial) designed to capture, store, manipulate, analyze, manage, and present various types of geographically referenced data.
- **GPS:** Global Positioning System used to track various kinds of transportation vehicles or assets.
- **L.P:** Lower Peninsula of Michigan
- **Leasing:** a legal agreement in transportation service which allows lessee to use a vehicle for a period of time, in return for a fee.
- **Lessee:** receiver of transportation asset in return for payment to owner.
- **Lessor:** the owner of transportation asset who let lessee to use the asset for a period of time.
- **Michigan Trunkline Highway:** all highways designated as Interstates, U.S. Highways and State Highways in the State of Michigan.
- **Multi-Modal (Intermodal) Transportation: In** multimodal transportation goods use more than one mode of transportation during its path from origin to destination. In intermodal transportation, the goods remain in the container from the origin to destination, even though container can be moved from ships to railroad cars and further to trucks.
- **Pup:** a short semitrailer used in combination with a dolly and another semitrailer to create a twin trailer.
- **State route:** A trunk line highway that is maintained and operated by respective State DOT authorities.
- **TEU:** Twenty-foot Equivalent Unit, a measure used for container capacity.
- **Tractor:** a truck having a cab and equipped with engine, used for pulling large vehicles such as vans or trailers.
- **Trailer:** a large unpowered transport vehicle designed to be hauled by a truck or tractor.
- **Truck tipper:** an inclining platform to raise the truck to a designated angle for unloading purposes.
- **U.P:** Upper Peninsula of Michigan
- **U.S. route:** an integrated system of numbered roads and highways in the United States within a nationwide grid.
- **Walking floor truck:** a type of truck with moving floor mechanism to assist in the unloading process.

- **Woody biomass:** woody biomass material, forest-based feedstock, woody chips and forestry biomass are used interchangeably in the report. May consist of logs, chips or residues.

Rail Transportation Terminology:

- **Demurrage**: is monetary charge for customers who keep rail car for loading purposes beyond allocated time.
- **Depot or Terminal:** one, or several stations, warehouses or yards where cars can be loaded, unloaded, maintained, inspected and interchanged. It may also refer to the Rail Terminal.
- **Interchange Points:** stations or yards where rail cars are transferred from one railroad company to another.
- **Main line:** a principle track, other than auxiliary track, utilized mainly for line haul rail transportation..
- **Rail Car:** any type of rail vehicle to carry freight or people, typically unpowered.
- **Rail siding:** an auxiliary track, usually used to allow train to pass each other on a single track or to load/unload rail cars in industrial lines.
- **RR:** Railroad.
- **Class I Railroad:** line haul freight railroads with 2010 operating revenue of $398.7 million or more
- **Regional (Class II) Railroad**: railroads with annual carrier operating revenues of less than $398.7 million* but in excess of $31.9 million (2010 value).
- **Local or Shortline (Class III) Railroad**: railroads with annual carrier operating revenues of $31.9 million or less (2010 value), and all switching and terminal companies regardless of operating revenues
- **Spur Track:** Any light duty track that branches off a main track, typically for industrial lines.
- **Switching (Terminal) Railroad:** a freight railroad company whose primary purpose is to perform local switching services or to own and operate a terminal facility within the limits of a yard. It generally consists of making up and breaking up trains, storing and classifying cars, serving industries within yard limits, and other related purposes.
- **Yard:** a system of tracks within defined limits for the purpose of storing and sorting cars.

Marine (or Water) Transportation Terminology:

- **Adrift**: A boat that is adrift is not fastened to anything or controlled by anyone.
- **Barge:** A long, large, usually flat bottom boat for transporting freight, (usually containers) that is generally unpowered and towed or pushed by other craft.
- **Basin:** An artificially enclosed area of a river or harbor designed so that the water level remains unaffected by tidal changes.
- **Breakwater:** A wall built out into the sea to protect the shore from the force of the waves.
- **Deadweight**: Total cargo capacity in short (net) tons of 2,000 pounds.
- **Dock:** A platform extending from a shore over water in port, supported by piles or pillars, used to secure, protect, and provide access to ships or boats for loading, unloading or repairs.

- **Draft:** The depth of water that a vessel requires to float freely; the depth of a vessel from the water line to the keel.
- **Drayage:** Is the transport of goods throughout a short distance, often as part of a longer overall move. It may also refer to the fee charged through handling and loading/unloading of such activity.
- **Dredge:** To remove mud or sand from the bottom of a river, harbor, etc.
- **Harbor:** An area of water next to the land where the water is calm and enough deep, so that ships are safe when they are inside it.
- **Pier:** A structure that is built over and into the water so that boats can stop next to it or people can walk along it.
- **Port:** Main marine infrastructure, a place where ships can be loaded and unloaded, including all of facilities and structures such as docks.
- **Shoaling:** A small hill of sand just below the surface of water that makes it dangerous for boats.
- **Tug:** A small strong boat used for pulling or guiding ships into a port, up a river, etc.
- **Vessel:** A large passenger or freight-carrying ship, boat, etc; typically equipped with powered engines.
- **Wharf:** A landing place or pier where ships may tie up and load or unload.

Introduction

This report details the transportation-related work conducted as part of the Forestry Biofuels Statewide Collaboration Center (FBSCC) project for the state of Michigan. The FBSCC project has been financially supported by the U.S. Department of Energy (DOE) and the Michigan Economic Development Corporation (MEDC). The overall goal of the FBSCC is to improve the long-term forest feedstock supply infrastructure to sustainably provide woody biomass for biofuel production in Michigan. Researchers sought to support the developing biofuel industry in identifying current operating procedures and opportunities to increase feedstock supply chain efficiencies, reducing costs, and assuring sustainability of the production, harvesting, processing, and transportation of woody biomass from Michigan's forests and energy plantations. An effective stakeholder collaboration structure is also being established to offer partners opportunities to participate in applied R&D projects designed to answer common challenges facing the biofuel industry.

The FBSCC project addressed several objectives and research milestones in areas of:

- Forest biomass assessment
- Improving harvesting, forwarding, and transportation systems
- Improving forest feedstock productivity and sustainability
- Engaging stakeholders across the value chain

1-1- Statewide Evaluation of Michigan Biomass Transportation Systems

Forest biomass can be procured in a variety of forms (chipped wood, harvesting residues, round wood logs), each with different constraints in terms of density and handling requirements. The main alternatives for transportation are trucks, rail and/or marine. Biomass is often procured in locations with limited access to major roads, rail sidings, or port facilities and each transportation mode requires a separate set of equipment, infrastructure and operational considerations.

The objective of the transportation systems evaluation under the FBSCC project framework was to identify and evaluate the capabilities of the transportation system to deliver feedstock to a factory gate in the State of Michigan. The specific tasks conducted under transportation analysis included:

- **Inventory and assessment of current road, rail and marine transportation infrastructure in forest regions of Michigan**. In addition to mapping the physical location of transportation infrastructure, researchers made efforts to incorporate other relevant information that affects the productivity of the system, such as highway and bridge weight restrictions, location of rail landings and yards and condition of docks and access roads.
- **Identification of most suitable types of equipment for forest biomass transportation**. In addition to identifying the best types of equipment, the team also investigated the availability of appropriate road vehicles, rail cars and marine vessels in the State of Michigan. Factors potentially restricting efficient use of transportation modes, such as insufficient service levels, were documented and discussed with transportation industry representatives.

- **Operational and economic considerations**. The transportation team investigated operational and economic considerations when selecting between main transportation alternatives. Transportation mode selection depends on various factors, such as the overall volume of transportation, modal access, the availability of storage space and level of inventory needed.
- **Multimodal considerations**. Road, rail and marine (water) transportation are all potential transportation alternatives for forestry biomass. However, it is recognized that when rail or marine transportation is used, the overall transportation chain becomes multimodal by nature. The investigations identified potential synergies and challenges between modes that allow efficient use of a multi-modal transportation network.

In addition to a statewide evaluation, the team also provided supporting data and guidance to a modeling effort that identified nine potential locations for new biomass facilities. Locations were chosen based on perceived feedstock supply availability, proximity to major roads, railroads (<1 mile) or access to major waterways (< ¼ mile), location within population centers of a minimum size, and no existing or planned biomass facility located nearby. Figure 1-1 presents the nine biomass facility sites considered by the supply chain modeling team, all located in the northern part of Lower Peninsula (LP) of Michigan. Detailed transportation evaluations to deliver biomass to these facilities were out of scope for the project, but preliminary analysis and considerations for multimodal transportation supply chain were developed by the team.

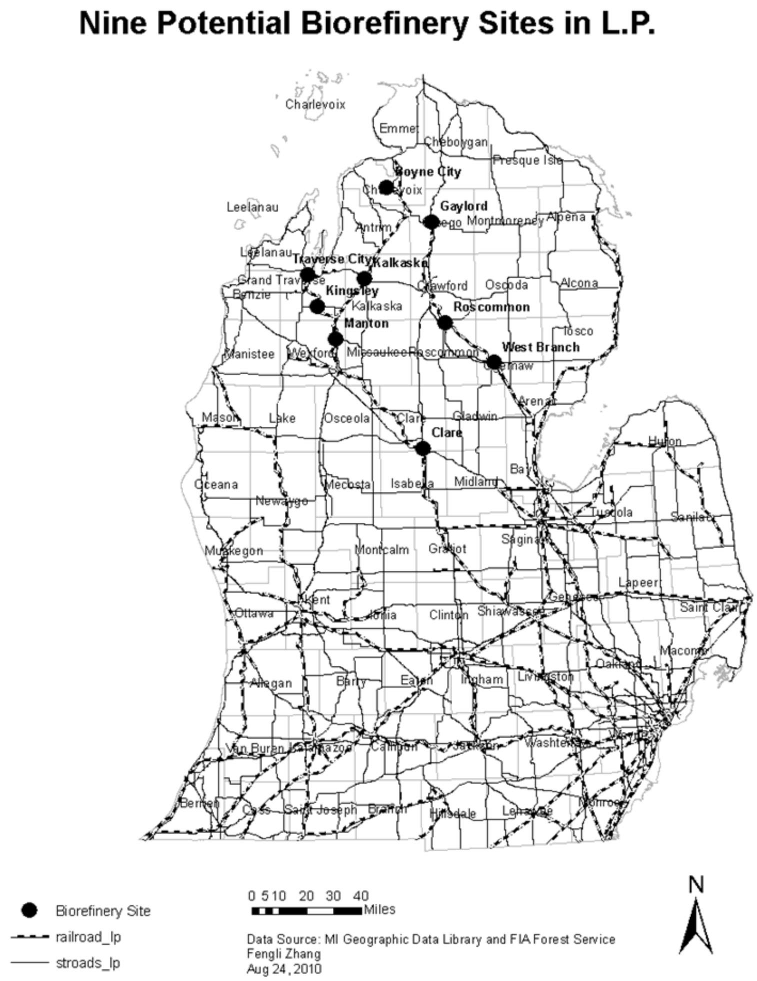

Figure 1-1- Proposed location for biomass facilities by FBSCC project

1-2- Limitations of the Study

Transportation analysis conducted during the project had the following limitations:

- The FBSCC supply chain model team determined that feedstock supply would be limited to a radius of 100 miles from each proposed facility. This reduced the opportunities for multimodal transportation which are typically more effective over longer trips, resulting in a greater focus placed on truck transportation.
- The forest-based feedstock considered included wood chips, round wood and forest residues with a primary focus on round wood and wood chip transportation.
- The transportation evaluation was limited to the movements within the State of Michigan. Rail and marine transportation often take place across state and even national borders, as higher fixed costs of these modes can often be overcome by their lower marginal costs for additional volume and distance. The "in-state" movement restriction increased the focus on truck transportation in this study.

- This report was not tasked with an examination of the cost of infrastructure damage or development such as highway damage from increased truck movements or the cost of dock development. Neither has this report assessed the impact of increased energy costs on the supply chain, or assessing the external costs, such as air emissions, accident rates, water pollution or congestion impacts for marine, truck or rail supply chains. These factors may raise the costs for any of the modes and should be considered in the final supply chain analysis.
- Only transportation of woody biomass as feedstock to the facility was researched, not the transportation of the final product out of the facility. In reality rail, and in some cases, marine transportation, would gain significant benefits if both inbound and outbound movements were considered in the analysis.

1-3- Outline and Structure of Report

The specific tasks and the chapter where outcomes are discussed are presented in Table 1-1. The remainder of Chapter 1 provides a summary of literature review conducted as part of analysis, including specific case studies. Infrastructure and equipment analysis for each mode is presented in Chapters 2 and 3, respectively, followed by modal and multimodal operations and economics discussion in Chapter 4. More detailed information of various data collected during the study is included in the appendices.

Table 1-1- Project tasks and structure

Task #	Task	Chapter 1 Introduction	Chapter 2 Infrastructure	Chapter 3 Equipment	Chapter 4 Operations & Multimodal	Chapter 5 Conclusions	Attachment
1.1	- Contact study area railroads, ports and road agencies to inquire infrastructure data		■				■
1.2	- Identify most suitable equipment for biomass transportation (based on tasks A1 and A3)			■			
1.3	- Perform literature review on biomass transportation	■					■
1.4	- Identify data readily available on transportation infrastructure		■				
1.5	- Collection of key infrastructure parameters (weight restrictions, rail/port facilities, capacities)		■				
1.6	- Develop GIS layers of main transportation infrastructure		■				
1.7	- Identify data sources for transportation equipment			■			
1.8	- Interview selected transportation providers to define potential service capacity				■		■

1.9	- Identify key operational challenges for biomass transportation						
1.10	- Inventory of the equipment available in the state of Michigan						
1.11	- Industry inquiry to collect rate information for biomass transportation						
1.12	- Synthesis on challenges and synergies between alternative modes						
1.13	- Summary of transportation operations and available equipment						

1-4- Literature Review

The literature review consisted of more than 30 reviewed papers, articles, books and other references related to the biomass and forest product transportation. The review concentrated on North America and Scandinavia and included topics, such as forest product and biomass transportation, transportation methodologies and transportation cost. Case studies from Finland and New York were reviewed and are summarized in this section. A more detailed summary of each reviewed article is included in Appendix A.

1-4-1- Transportation

In general, transportation is "a system that provides for the movement of people (passenger), goods (freight), or both." (TRB, 2003) There are five major modes of transportation; road, rail, marine (or water), air and pipelines. All modes can provide both passenger and freight transportation, except pipelines, which are only for freight transportation. In some references, road and rail modes are also called “ground transportation”. Since the current research concentrates on woody biomass material, there is no need to discuss passenger transportation systems or pipeline transportation. Freight air transportation is also omitted, as it is typically used for valuable freight material like express mails and parcels. Hence, the report focuses on road, rail and marine modes as likely options of forest biomass transportation.

Each mode of transportation can be divided to three main system components; infrastructure, equipment and operations. Infrastructure is typically a fixed asset and in many cases the most expensive component of system. Some examples of transportation infrastructure are highways and terminals, railroad tracks and yards, airports and marine ports. Equipment includes vehicles used for carrying people and goods, such as trucks, containers, trailers, rail cars, cargo planes, barges and vessels. Transportation operations refer to the combination of staff, information, tools, methodologies, techniques and finances needed to operate and maintain the overall transportation system in a safe and efficient manner. More details about each transport system component, as they relate to biomass transportation are provided in following chapters.

1-4-2- Multimodal (Intermodal) Transportation

Freight can be transported from origin to destination via a single mode, or by multiple modes. Multimodal (or intermodal) 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 (The United Nations Trade Facilitation Network, 2011). Intermodal transportation refers to a specific type of multimodal freight transportation that utilizes containers and trailers either for domestic or international movements. In multimodal transportation, cargo gets transferred from one vessel to another; the goods in intermodal transportation remain inside the same transportation unit (container) that gets transferred between ships, railroad cars and trucks (Jones, et al, 2010).

Table 1-2 presents a general comparison of advantages and disadvantages of each main transportation alternative. Although each scenario must be reviewed individually, rail and marine transportation are typically economical and cost-efficient for large quantities and for longer distances. Based on a research conducted by Searcy 2007, rail transport is often more economic than truck for biomass movements over 300 miles (500 km) and ship is more cost-efficient than rail transport after 900 miles (1,500 km). However, type of biomass and availability of facilities can significantly affect the total cost of transport case by case (Searcy, et al, 2007). For example, in woody biomass transportation, rail is often considered competitive for movements over 100 miles.

Table 1-2- General specifications of biomass transportation modes

Mode	Pros	Cons
Truck	-high flexibility and accessibility, -suitable for short distances, -combinable with other transport modes, -low fixed rate - high reliability and fast service	-costly for long distances -high variable rate -low capacity and volume per unit -higher risks of safety and security
Rail	-low variable rate -higher capacity in comparison to truck -suitable for mid and long distances	-less accessible and flexible than truck -high fixed rates -low commercial speed -infeasible for short distances -often requires interchanging between companies - complex contractual rules
Marine	-very low variable rate -reliability -highest capacity in comparison to truck and rail -suitable mainly for long distances	-accessibility and flexibility -high fixed rates -very low commercial speed -infeasible for short and mid distances - limited equipment availability

1-4-3-Biomass Transportation

Biomass material is divided to three major categories:

- agricultural biomass (such as corn stover and switchgrass)
- woody biomass (such as forest products like wood chips, branches and residues)
- other material like urban wastes, rubber residues and tire-derived material

In different countries and based on the region, different types of biomass material are applied for varied purposes. For instance woody biomass has been used extensively in Scandinavian countries like Finland and Sweden, so a significant portion of transportation and logistics research and transportation equipment and systems development has taken place in these countries. In the U.S., different states and regions have varying interests in biomass transportation applications. In southern states, agricultural biomass is more important, while in northern areas such as Michigan, forest loose residues and woody biomass are in greater demand. This study focuses on woody biomass material and its respective transportation systems.

Although the truck, rail and marine transportation systems can all be used for moving biomass, trucking tends to be the main and most cost-efficient system for almost all types of biomass material. Historically, rail transportation played a larger role in delivering woody biomass materials due to its cost efficiency, especially for high volumes. For instance, the Biomass Transportation and Delivery Fact Sheets refer to a study in 1985 which showed that rail rates for fuel wood transport were about 35 percent lower than trucks for haul lengths averaging 80 miles (Stokes et al, 1993). In past years, the market share of trucking has been grown quickly and in 2005, approximately 90% of pulpwood was transported to U.S. mills by trucks (Schroeder, et al, 2007). Due to these trends, it is not surprising that a majority of biomass transportation literature discusses road transportation (truck), while rail, marine and multimodal transportation have received limited attention.

Transportation of biomass has typically two main challenges; providing suitable access to equipment to remove the material and making transportation economical, if the access roads are in poor condition (Wynsma, et al, 2007). Transportation of logs differs from the transportation of chips and loose residues. Typically, whole trees or cut-to-length sections are loaded for transportation by truck or in some cases, truck-rail or truck-barge systems for delivery to mills or manufacturers (Wynsma, et al, 2007). Residues, on the other hand, are currently a low value by-product of commercial timber harvesting operations and often left unharvested. If there is a high enough demand for chips/harvesting residue, loggers can add chippers/debarkers and get chip trailers or trucks to transport them, even though these operations increase operational and company costs (Jeuck, 2009).

Several methodologies for chip and loose residue transportation are currently applied in different regions and countries. Maertens points out that the Technical Research Center of Finland (VTT) issued a report explaining different methods of chip and loose residue supply chain and transportation. These are outlined in Figure 1-2 and the following paragraphs.

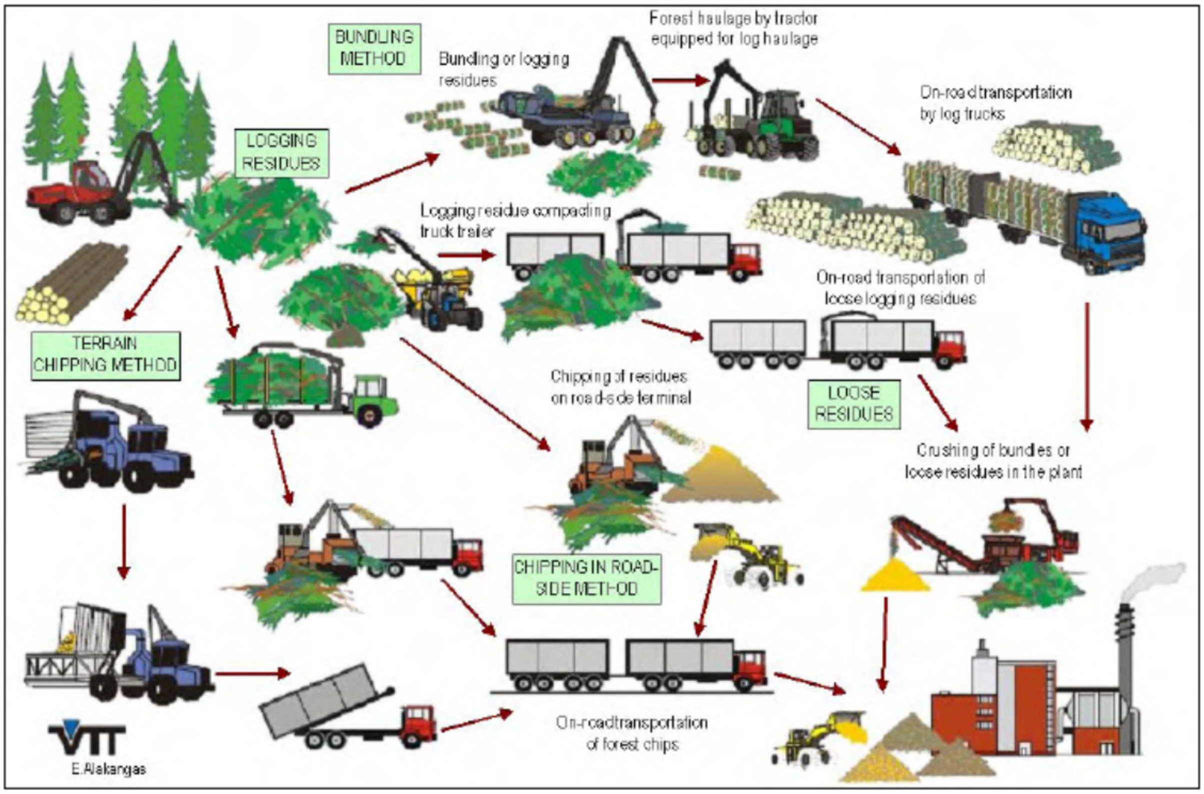

Figure 1-2- Woody biomass supply chains, by Alakangas, VTT-Finland (Cook, 2010)

Type of transportation for biomass depends heavily on the location, where it is converted to chipping. In general, chipping and related transportation can be divided into terrain, roadside, chipper-chip, terminal, loose residue and bundling methods.

Terrain Chipping: In this method, when the detachable chip containers of a terrain chipper are full, they are moved to the roadside by the terrain chipper to be loaded and transported to the heating and power plants by chip trucks (Parikka, 2006). Terrain chippers are relatively small (15-20 m^3) and typically used at small harvesting sites with short forwarding distances. Generally, it is not a good idea to use terrain chippers during tough winter times because the quality management of residue chips is affected by snow and can cause quality problems (Maertens, 2009).

Roadside Chipping: In roadside chipping, chips are directly loaded into chip trucks and transported to their final destinations (Figure 1-3). This method is the most common delivery system in Finland and has several benefits, such as flexibility (used for all types of harvesting conditions) and availability of different types of machinery to perform roadside chipping. On the other hand, the large storage space required for logging residue is a disadvantage.

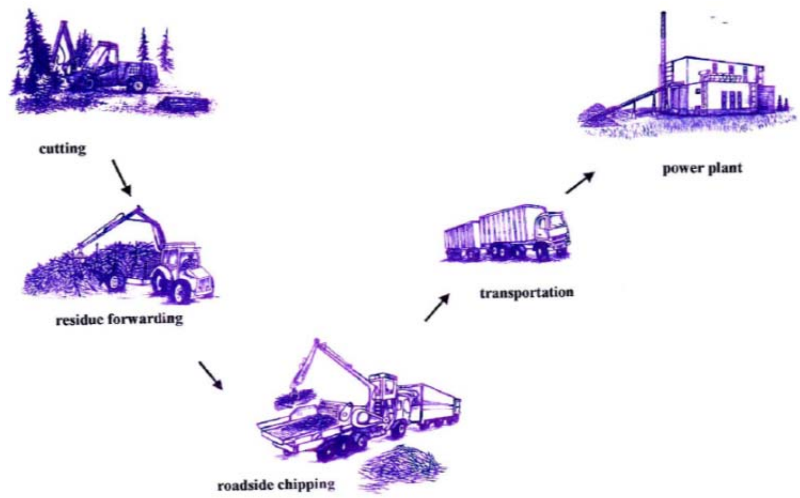

Figure 1-3- An example of harvesting-transportation cycle for chips material toward final destination (Parikka, 2003)

Chipper-chip truck: In this method, chipping and transportation equipment are combined together but the machine is heavy (37 tons), limiting the load capacity to 23 tons. The chipper-chip truck is more useful and efficient for transportation distances less than 30 km (Figure 1-4) (Maertens, 2009).

Figure 1-4- A chipper-chip truck during chipping and loading branches and residues[1]

Terminal chipping (loose residues): In this method, chips are comminuted in centralized terminals. Loose residue is transported as bulk material without any specific processing from roadside to the final destination. Since the density of loading in this method is low, it is not recommended for long distance transportation in comparison to the chips. New, large tandem trailers of 150-170 m^3 (5300- 6000 ft^3) can compress loose residue and provide more efficient use of cargo space.

1 : United Nations Development Program, Bioenergy, Republic of Belarus Government Project, accessed time: Aug. 2011 http://energoeffekt.gov.by/bioenergy/htdocs/en/trainings_finen.htm

Bundling: Bundled wood transportation is an economical transportation mode which is more common in Scandinavian countries, but the relatively high bundling cost has hindered its implementation (Figure 1-5). In the United States, only one commercial company was equipped with this method as of 2007 (Wynsma, et al, 2007). Some studies show that bundling method can provide the lowest total production cost for wood fuel, as it allows the same handling and administrative route as used for conventional round wood logging and transportation (Parikka, 2006). Since the density of bundling transportation with ordinary timber trucks is acceptable (between 60 to 65 bundles per truck), this method holds promise for long-distance hauling (Maertens, 2009).

Figure 1-5- Logging residue bundles stacked up and ready to be transported (Maertens, 2009)

1-4-4- Freight and Forest Product Transportation in State of 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 distribution of freight movements between modes for different categories is provided in Table 1-3.

Table 1-3- Shipments within, from, and to Michigan by mode in 2009 (FHWA, 2011)

		Within State		From State		To State	
State	Mode	Weight (Thous. ton)	Percent	Weight (Thous. ton)	Percent	Weight (Thous. ton)	Percent
MICHIGAN	Truck	195,257	84.46%	62,089	61.12%	78,424	49.07%
	Rail	15,033	6.50%	17,527	17.25%	52,696	32.97%
	Water	2,637	1.14%	5,584	5.50%	318	0.20%
	Air (include truck-air)	46	0.02%	12	0.01%	11	0.01%
	Multiple modes & mail	4,414	1.91%	7,923	7.80%	9,155	5.73%
	Pipeline	9,433	4.08%	7,462	7.35%	17,518	10.96%
	Other and unknown	4,375	1.89%	981	0.97%	1,693	1.06%
Total		231,195	100.00%	101,578	100.00%	159,815	100.00%

According to the FHWA, 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 (Table 1-4). The volume of woody biomass transportation in Michigan is unclear as categories for such movements were not identified in the data.

Table 1-4- Commodity movements in Michigan (FHWA, 2011)

		Within State		From State		To State	
State	Mode	Weight (Thous. ton)	Percent	Weight (Thous. ton)	Percent	Weight (Thous. ton)	Percent
MICHIGAN	Cereal grains	22,617	9.78%	6,406	6.31%	3,080	1.93%
	Other ag prods.	6,950	3.01%	2,883	2.84%	2,427	1.52%
	Natural sands	7,594	3.28%	616	0.61%	572	0.36%
	Gravel	17,213	7.45%	9,488	9.34%	507	0.32%
	Metallic ores	13,485	5.83%	32	0.03%	6,566	4.11%
	Gasoline	14,612	6.32%	948	0.93%	495	0.31%
	Fuel oils	7,203	3.12%	899	0.89%	2,458	1.54%
	Coal-n.e.c.	12,477	5.40%	3,464	3.41%	30,838	19.30%
	Basic chemicals	7,673	3.32%	4,179	4.11%	7,642	4.78%
	Logs	**12,356**	**5.34%**	**407**	**0.40%**	**26**	**0.02%**
	Wood prods.	**3,632**	**1.57%**	**2,342**	**2.31%**	**2,276**	**1.42%**
	Nonmetal min. prods.	15,468	6.69%	6,661	6.56%	3,143	1.97%
	Base metals	10,219	4.42%	10,798	10.63%	10,183	6.37%
	Motorized vehicles	7,341	3.18%	7,586	7.47%	8,740	5.47%
	Waste/scrap	22,749	9.84%	2,319	2.28%	2,595	1.62%
Total		231,195	100.00%	101,578	100.00%	159,815	100.00%

1-5- Case Studies

Many countries in Europe as well as in North America have plans to improve biomass transportation for mills, power plants and other facilities. This section provides two biomass transportation related case studies conducted in Finland and in the U.S.

1-5-1- Finland

In Finland, wood is the second most important source of energy and several types of supply chains for woody biomass productions are used. A study was conducted to review the different alternatives for forest biomass production and transportation (Figure 1-6).

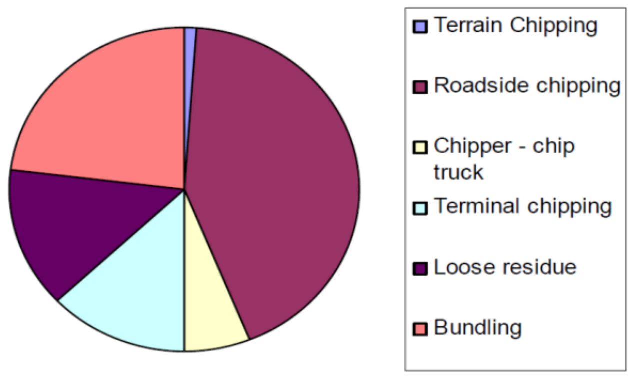

Figure 1-6- The proportion of supply methodologies of wood biomass material, 2004-Finland (Maertens, 2009)

Based on a research conducted by Ranta and Rinne in another study in Finland, transportation costs form approximately one-third of overall supply chain costs for forest chips and bundles, while for loose residues such as unprocessed chips, it may increase to almost half of the total cost. Figure 1-7 presents the most economic methods to transport woody biomass materials in Finland. Bundles provide the most economical transportation and loose residues the least economical transportation.

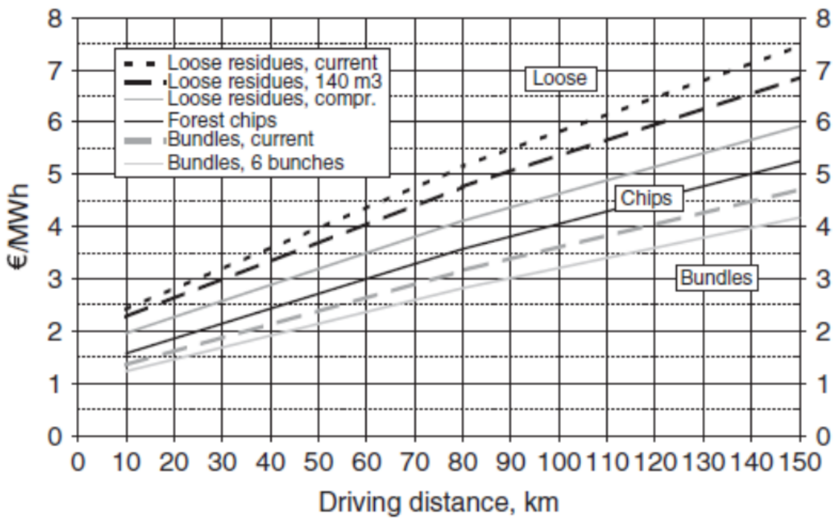

Figure 1-7- Transportation cost of alternative wood raw material options in Finland (Ranta, 2006)

The study also concluded that chipping in forest is more suitable for small scale operations. The best solution for transportation is to use large truck–trailer vehicles to transport different kinds of uncomminuted material to the plant, separately or mixed, instead of custom-built compressing equipment trailers. (Ranta, Rinne, 2006). Table 1-5 shows estimated trucks required for biomass transportation in Finland by 2010, based on actual demand of woody biomass transportation in 2003. Based on Ranta and Rinne, transportation of loose residue is expected to increase at the expense of transportation of chips made in woods, while the portion of bundled transportation is expected to remain stable. The overall transportation volume is expected to more than double over the period.

Table 1-5- Estimation of trucks needed for biomass transportation in Finland (Ranta, Rinne, 2006)

Raw material type	**Current 2003**			**Estimate 2010**		
	Amount (m^3)	Share (%)	Trucks no.	Amount (m^3)	Share (%)	Trucks no.
Residue bundles	360,000	18	25	700,000	14	40
Loose res. & stumps	200,000	10	15	2,000,000	40	110
Forest chips	1,440,000	72	80	2,300,000	46	110
Total	2,000,000	100	120	5,000,000	100	260

1-5-2- State of New York

Appendix F of the “Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York” study discusses transportation and distribution (T&D) implications of increased biofuel feedstock and fuel production in the state of New York. It contains all biomass types including woody, agricultural and grass material. Based on three predefined scenarios for biofuel industry, the relevant transportation infrastructure requirements were evaluated in the report. The respective scenarios were: (Corbett, et al, 2010)

- **Scenario 1**: smaller scale feedstock production in comparison to the Scenarios 2 and 3 with four biorefinery locations in the state.

- **Scenario 2**: in this scenario feedstock availability for biofuels is greater than Scenario 1 and the biofuels industry is centralized, with few (but high capacity) biorefinery locations in the state.
- **Scenario 3**: “a distributed biofuels industry, with a greater number of lower capacity biorefinery locations in the State Feedstock.” In scenario 3 the average transportation distances are expected to be shorter than expected in centralized biofuels industry scenarios.

Transportation assumptions for all scenarios included:

- A full truckload carrying 22 tons of wet (moisture content at time of harvest) feedstock
- Feedstock is wet during the transport from origin county to destination county
- Alternative truck or feedstock weight configurations have not been examined.

Based on the above assumptions the average distance and ton-miles of transportation for each scenario and each selected mode is summarized in Table 1-6.

Table 1-6- Average distance and total ton-miles of transportation, based on feedstock type, scenario and mode (Corbett, et al, 2010)

Scenario	**Mode**	**Average distance of transport (mile) to deliver feedstock material**							**Total ton-miles**	**Mode of Transport %**
		Corn Stover	**Grass**	**Willow**	**Softwood**	**Hardwood**	**Corn Grain**	**Soybeans**		
Scenario 1a	Truck	24.3	n/a	46.5	38	37.2	122.7	227.4	312,686,129	100%
	Barge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0%
Scenario 1b	Truck	79.4	59.6	59.4	57.4	57.7	122.7	227.4	904,526,088	100%
	Barge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0%
Scenario 2a	Truck	79.3	69.7	60.9	57.5	61.4	122.7	227.4	1,453,422,236	98.80%
	Barge	179.2	179.2	179.2	178.7	176.1	n/a	n/a	16,987,955	1.20%
Scenario 2b	Truck	79.5	70.2	60.9	57.5	61.4	122.7	227.4	1,460,960,249	98.80%
	Barge	179.2	179.2	179.2	178.7	176.1	n/a	n/a	17,958,718	1.20%
Scenario 3a	Truck	24.4	26.3	22.7	39.3	30.1	122.7	227.4	658,127,426	98.80%
	Barge	146.9	158.1	179.2	179.2	179.2	n/a	n/a	5,358,149	1.20%
Scenario 3b	Truck	25.1	26.2	22.2	39	30.2	122.7	227.4	658,264,312	98.80%
	Barge	179.2	156.3	179.2	179.2	179.2	n/a	n/a	5,401,586	1.20%

The table reveals that trucks were used as the main transportation mode of feedstock delivery, based on a least cost production model. Although most feedstock production centers have access to the rail infrastructure, researchers questioned the true potential to use rail systems, as it depends on available rail transfer facilities and proximity of rail lines to feedstock collection points. Since all the current rail transfer facilities are mainly used for container transportation rather than bulk freight in New York, the rail system was not selected. If operation of at least two new bulk transfer facilities between rail and other modes was established, the use of single mode or multimodal rail transportation could be eventually increased. (Corbett, et al, 2010)

Table 1-7 presents a general comparison between average feedstock transportation rates for all three transportation modes considered in the study.

Table 1-7- Average freight rates for feedstock movement via truck, rail, and ship (Corbett, et al, 2010)

Mode	Truck	Rail	Ship
Cost per TEU-mile	$0.87	$0.55	$0.50
Cost per Ton-mile, Feedstock Transport	$0.11	$0.07	$0.06
Cost per Ton-mile, Fuel Transport	$0.08	$0.05	$0.05

The study concluded that the number of trucks expected to enter the biorefinery is extensive for each scenario. For instance, refineries in Scenario 2 will receive 500 to over 850 trucks per day. This can increase the traffic congestion along the highways near biorefineries and aggravate risk of highway degradation and damages.

2.0 Transportation Infrastructure

Tasks covered in the chapter include:

Task	Description
B 1.1	Contact study area railroads, ports and road agencies to inquire infrastructure data
B 1.4	Identify data readily available on transportation infrastructure
B 1.5	Collection of key infrastructure parameters (weight restrictions, rail / port landings,
B 1.6	Develop GIS layers of main transportation infrastructure (road, rail and marine)

2-1- Introduction

Infrastructure is one of the most important and expensive components of transportation systems. In this chapter, the state of Michigan transportation infrastructure is reviewed for all three major transportation modes; road, rail and marine. Infrastructure data was collected from several sources, including databases (Roadsoft® software, Michigan Department of Transportation (MDOT), GIS Data Depot (http://data.geocomm.com), Oak Ridge National Laboratory Center for Transportation Analysis (CTA) (http://cta.ornl.gov/cta/index.shtml). In addition, transportation service providers and forest products companies were interviewed. All interviews and discussions conducted in this project are represented in Appendix B.

2-2- Road Infrastructure

As discussed in the previous chapter, roads are the most common transportation mode used for biomass materials. This section identifies road and highway infrastructure in the State of Michigan, concentrating on forest areas in the upper part of the Lower Peninsula and the Upper Peninsula (UP). All components of the transportation infrastructure were collected and organized in geospatial databases and provided for use by modeling team members. Road network data for the entire state of Michigan was obtained through RoadSoft asset management software. All publicly-owned roads in Michigan were included, along with a database of the legal description, functional classification, primary name, width, and ownership of each road segment. In addition, the seasonal and bridge weight restrictions were identified, including special considerations required by Mackinac Bridge.

The most important routes for biomass transportation include the all-season truck routes. Figure 2-1 presents the complete Michigan road network with all season truck routes and their relative location to proposed biomass facilities highlighted.

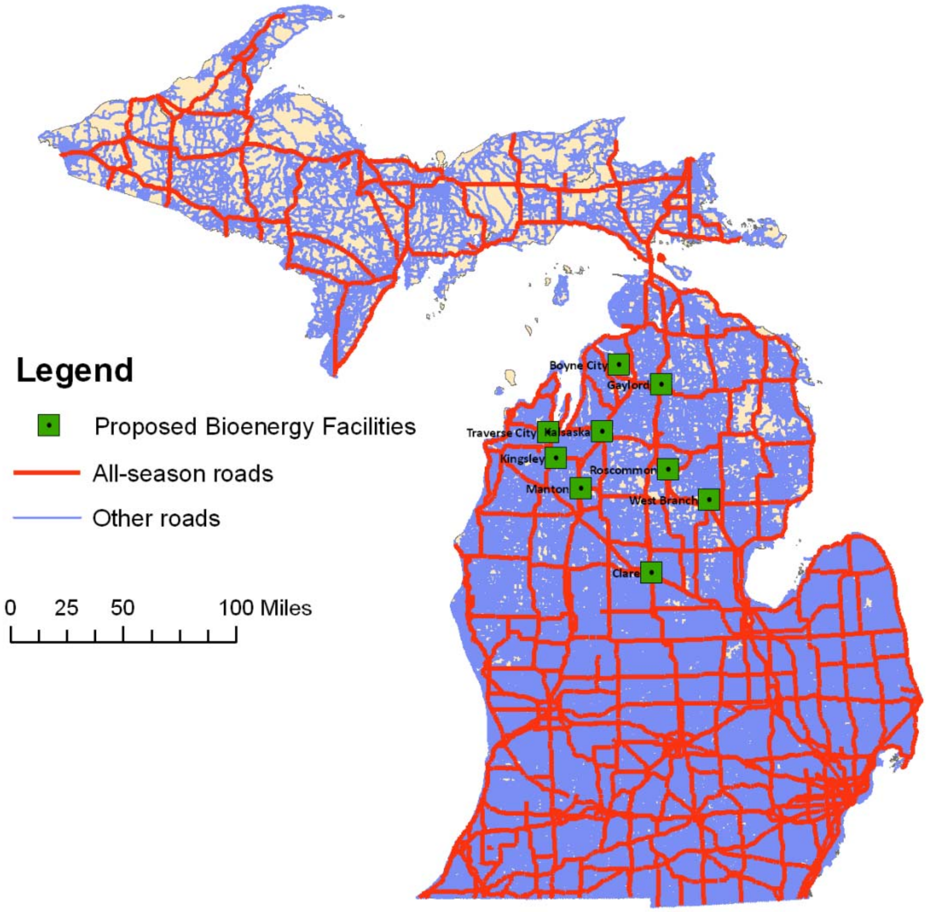

Figure 2-1- Michigan publicly-owned road network, all-season truck routes as designated by the MDOT

<u>2-2-1- Road Classifications</u>

There are two types of classification for all roads throughout the state, the National Functional Classification (NFC) and the National Classification. Road classifications are used to separate different types of public roads from each other, based on their intended function. The NFC is the most relevant classification, as its designation of a given road also determines whether the road is eligible for federal funds, either as part of the National Highway System (NHS -- usually limited to principal arterials) or through the Surface Transportation Program (STP). Most federal aid is limited to principal arterials, minor arterials, and urban collectors, but rural major collectors may also have some limited eligibility for federal funds. Classifications are important for biomass transportation considerations, as they often define the speed limits and allowed maximum axle loads. Specific attention should be paid to road networks that provide access to the facilities, as limitations may prevent full weight truck traffic from entering the facility.

The **National Functional Classification (NFC)** divides the road network to three categories, based on the mobility and land access. Different categories and some key parameters are presented in Figure 2-2 and Table 2-1.

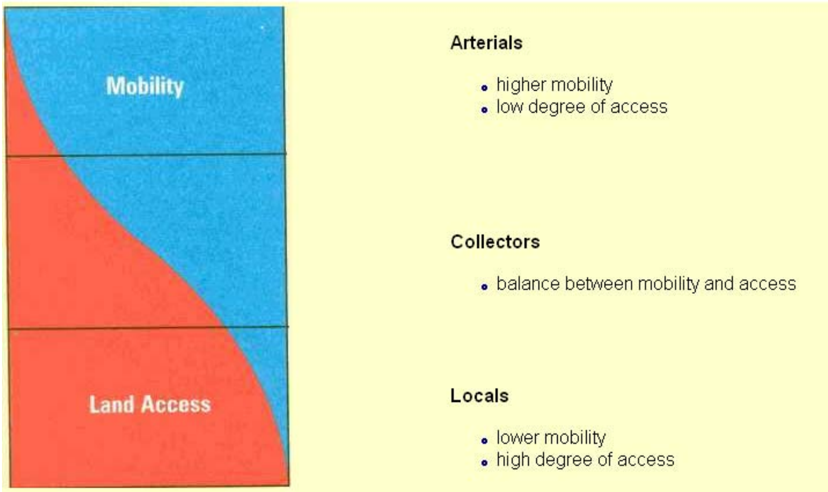

Figure 0-1. Road classification (FHWA, 2011)

Table 0-1- NFC Road Classification (FHWA, 2011)

Classification	Function	Speed Limits	Examples
Local	Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no connectivity	20-45 mph	Residential streets
Collector	Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials.	20-55 mph	County roads, connecting streets
Arterial	Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control.	50-75 mph	State highways

2-2-2- Truck Axle Load and Seasonal Weight Restrictions

The main parameter used to protect the roads from extensive dynamic loads caused by trucks is limits on axle loads. MDOT provides clear instructions for axle load combinations and restrictions for all classes of trucks and places maximum allowable weight restrictions on selected state roads each spring to decrease damage from frost heaving. In addition to road classifications, these load restrictions should also be considered when selecting locations for biomass facilities. Figure 2-3 and Figure 2-4 present examples of maximum axle loads outside and during weight restrictions for two types of trucks.

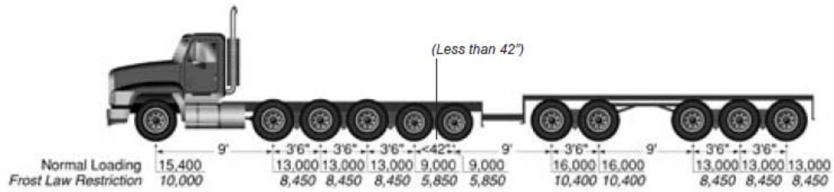

Figure 2-3- Typical Michigan log truck combination (MDOT, 2010)

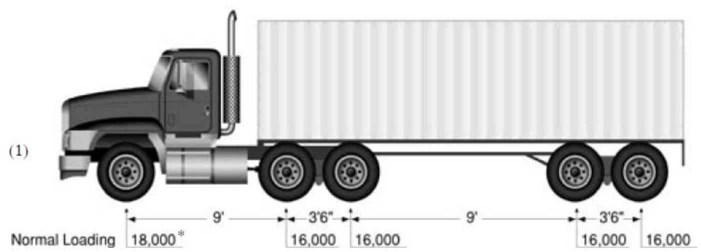

Figure 2-4- Typical Michigan tractor-trailer combination (MDOT, 2010)

The website of County Road Association of Michigan (CRAM) provides a list of roads with weight restrictions on a county by county basis. In addition, MDOT releases a truck operator map that highlights all truck routes and seasonal classification to help verify applied restrictions (Figure 2-5). The roads and restrictions are divided as follows:

- Routes designated as "All Season Routes" (green and gold on MDOT Truck Operator's Map), have no reduction in legal axle weight.
- Routes designated as "Seasonal" (solid or dashed red), have weight reduction of 25 percent for rigid pavements and 35 percent for flexible pavements.

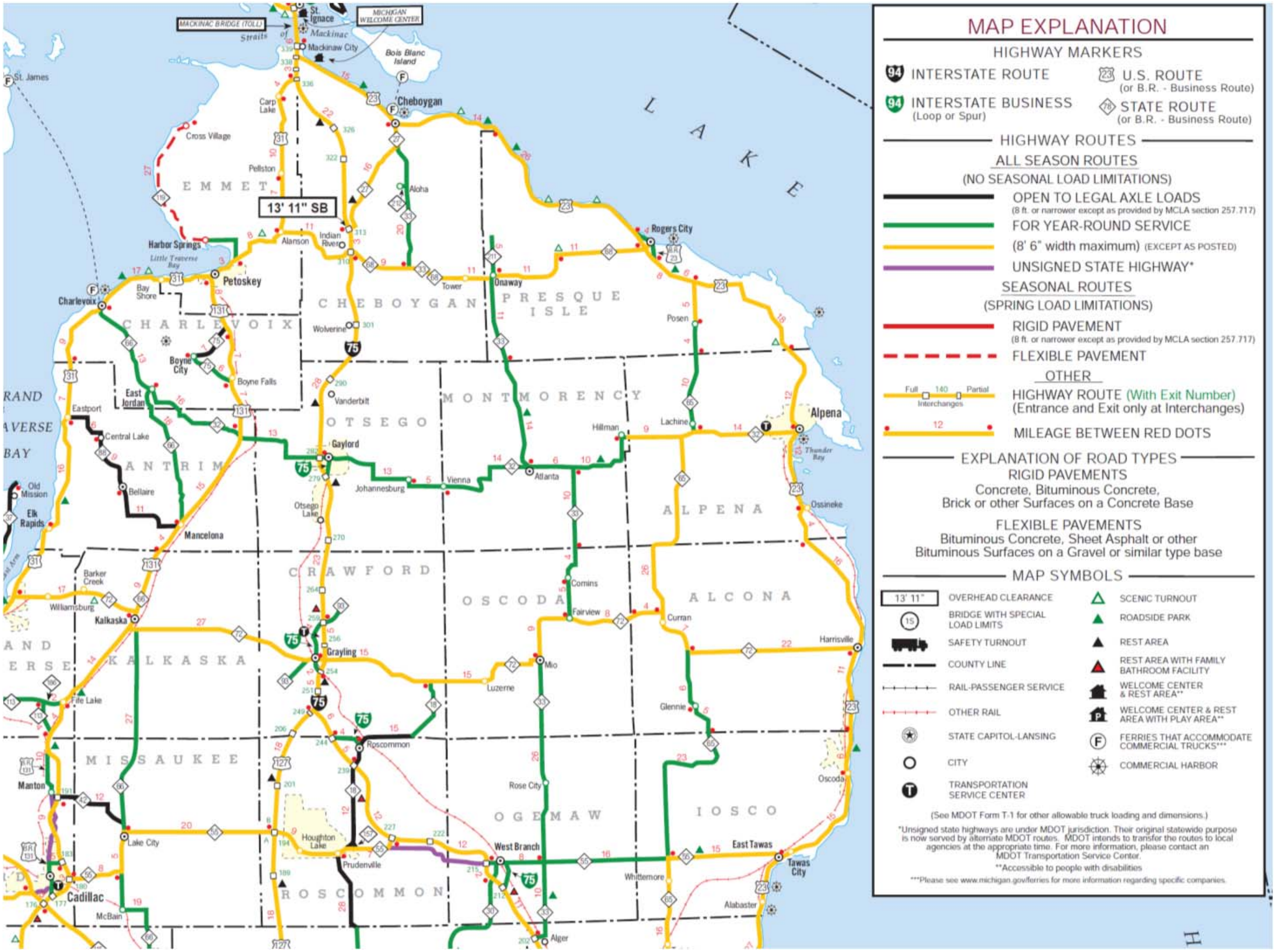

Figure 2-5- Michigan truck operator’s map for the northern part of the Lower Peninsula (MDOT, 2011)

2-2-3- Mackinac Bridge

The Mackinac Bridge is the only road link between the Upper and Lower Peninsula, creating a vital link for truck traffic. The team discussed bridge related restrictions with Mackinac Bridge Authority (Appendix C). The limiting factors caused by the bridge included:

- Maximum 72 ton (144,000 lbs.) Gross Vehicle Weight limit.
- All trucks have to pay $4.50 per axle and there is no discount for trucks that pass over the bridge more frequently.
- Large commercial trucks require an escort over the bridge unless the trucker has a permit from the bridge authority to pass on their own.

Based on the data received from the authority, forest product trucks (both chip and log trucks) move over the bridge at a constant rate with an approximately 50-50% split between north and southbound movements. The team also reviewed the records of vehicle crossings by the number of axles and determined that there were no significant changes in truck volumes during the spring break.

2-2-4- Other Bridge Restrictions

Bridge weight restrictions can limit the movement of heavy 10 and 11-axle log trucks, commonly used for log and biomass transportation in the state of Michigan. The research team obtained information on bridge restrictions through data collected on Pontis software and stored in RoadSoft. Only 10 percent of the 2,803 bridges in the main study area (UP and northern part of LP) had no weight restrictions. The maximum weight for a fully-loaded 11 axle log truck is 82 tons (164,000 lbs.), so the team decided to identify bridges that had either 60 or 70 ton maximum limits. Table 2-2 presents the number of bridges with those weight restrictions. Based on more detailed investigation, none of these bridges were located on all-season truck routes, so excluding the Mackinac Bridge, weight restrictions pose a minor hindrance for biomass transportation by trucks. The approximate locations of bridges with critical weight restrictions are presented in Figure 2-6.

Table 2-2- Bridge Weight Restriction Data in UP and northern LP

Restriction Level	Bridges Flag / Total Bridges
Any potential weight restriction	281 / 2803
Max. 70 tons for 2-unit truck	242 / 2803
Max. 60 tons for 2-unit truck	209 /2803

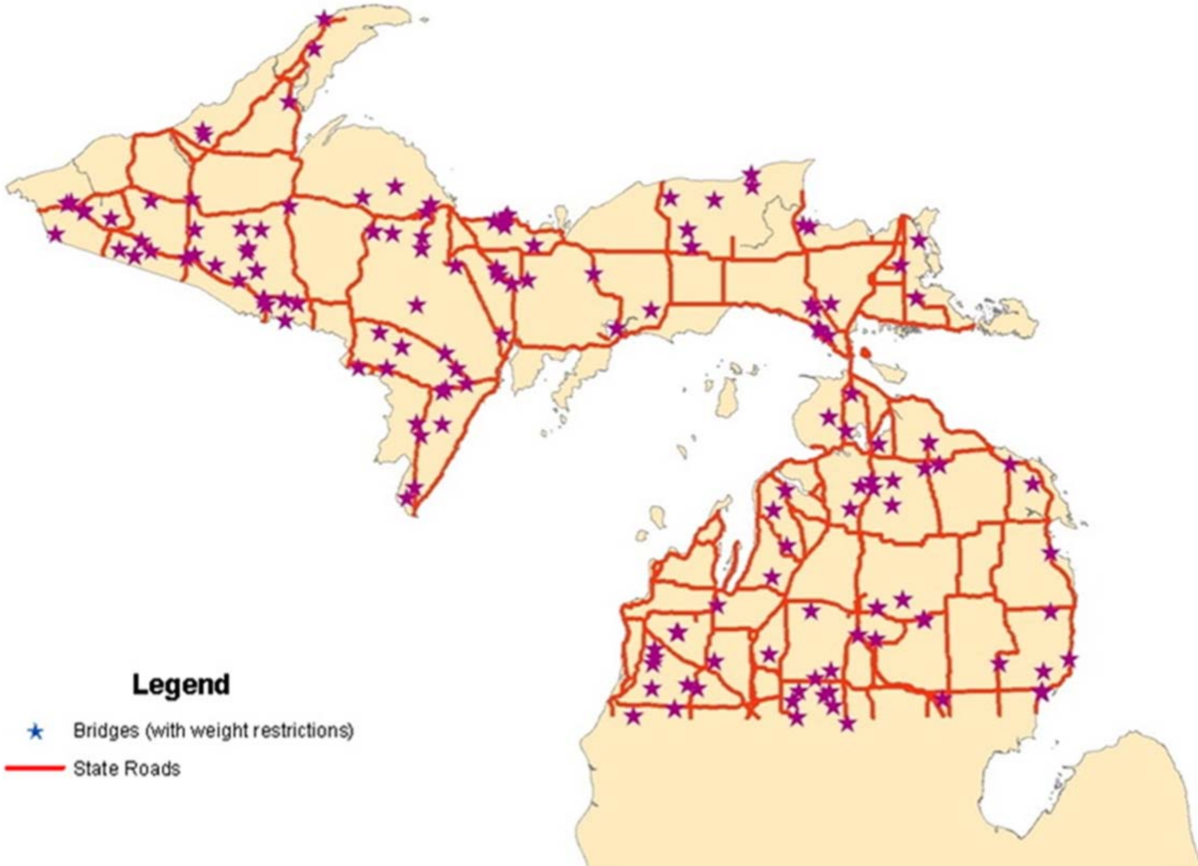

Figure 2-6- Bridges with gross vehicle weight restrictions of 60 tons or less

2-3- Rail Infrastructure

This section summarizes current rail systems in the state of Michigan. The information includes location of track networks and identifies the operators and owners. It also provides a more detailed review of the rail sidings and terminals along the lines with potential to serve the nine proposed facilities.

2-3-1- Michigan Rail Lines (Current and Past)

Michigan has one of the most expansive rail systems in the U.S. in terms of track mileage, currently ranking 12th among the 50 states. The first rail operation in Michigan was started by Erie and Kalamazoo Railroad in 1837 and the rail network was at its largest in the early 20th century with over 9,000 miles of rail lines. According to the Michigan State Rail Plan (HNTB, 2011), over 50 percent of those miles have since been abandoned or removed. Michigan rail lines are almost exclusively used for freight transportation, similar to the rest of the U.S. rail network. There are only three intercity passenger corridors, all in the southern part of the state.

The current network is owned and operated by 30 private freight railroads. In addition, the state of Michigan owns about 530 miles of track which are currently leased for operators. Most of the railroad companies operate in the Lower Peninsula. CN, Lake Superior and Ishpeming (LSI) and Escanaba and Lake Superior (ELS) are the only three rail companies with operations in the UP The freight rail network in Michigan includes 4,412 miles of track which also supports three shared passenger rail corridors.

Table 2-3 provides the division of Michigan rail networks between different owners and operators. The majority of freight rail transportation is conducted by large Class I railroads, but for in-state biomass transportation, smaller Class II and Class III railroads hold most promise, as excluding CN in the UP, none of the other Class I railroads serve the forested areas in the Northern LP or UP

Table 2-3- Total Freight Rail Mileage by Class in Michigan (HNTB, 2011)

Railroad	Class I- Freight	Class II- Regional	Class III- Shortline	Switching &Terminal	UP/LP
Adrian & Blissfield Railroad				30	LP
Ann Arbor Railroad Company			47		LP
Canadian National/Grand Trunk	1,017				LP/UP
Canadian Pacific Railway/Soo Line	1				LP
Charlotte Southern Railroad			4		LP
Conrail Shared Assets Operations				98	LP
Coopersville & Marne Railway Company			14		LP
CSX Transportation	569				LP
Delray Connecting Railroad				1	LP
Detroit Connecting Railroad			3		LP
Escanaba & Lake Superior Railroad			226		UP
Grand Elk Railroad			123		LP
Grand Rapids Eastern Railroad			65		LP
Great Lakes Central Railroad		396			LP
Huron & Eastern Railway			406		LP
Indiana & Ohio Railway		44			LP
Indiana Northeastern Railroad Company			70		LP
Jackson & Lansing Railroad Company			45		LP
Lake State Railway Company			231		LP
Lake Superior & Ishpeming			44		UP
Lapeer Industrial Railroad				2	LP
Marquette Rail, LLC			133		LP
Michigan Air-Line Railroad				8	LP
Michigan Shore Railroad				68	LP
Mid-Michigan Railroad, Inc.			56		LP
Michigan Southern Railroad Company				18	LP
Norfolk Southern Railway	642				LP
Saginaw Bay Southern Railway			67		LP
West Michigan Railroad Company				15	LP
Total by Class	**2,229**	**440**	**1,511**	**240**	**LP/UP**

2-3-2- Sidings and Terminals

Besides rail lines, sidings and terminals (or yards) are key facilities for freight loading, unloading and handling activities and for configuration of freight trains. The main differences between rail siding and terminal are defined in Table 2-4.

Table 2-4- Similarities and differences between rail siding, station and terminal definitions

Name	**Main application**	**Size & # in network**	**Applications for Biomass**
Rail siding	Short stretch of railroad track used for loading / unloading, to store rolling stock, or to enable trains on the same line to pass	- Different lengths and configurations (at least one track in addition to mainline) - Numerous sidings in the network	Most logical location for biomass loading/unloading and in some cases for limited storage
Terminal (Yard)	Large rail facility for classifying, storing, interchanging and re-arranging trains. It may include facilities for maintaining and inspecting trains, tracks and other infrastructure.	-Numerous tracks and connections - Typically accessed by interchanging railroads	Location for internal switching or for potential interchanges from one railroad to another

The key locations for biomass transportation are sidings and potential interchange locations between different railroads. Unfortunately, there is no complete list of operational sidings in the state of Michigan, but the research team used questionnaires and Google Earth maps to develop a partial list of more than 100 currently available sidings for biomass loading/unloading activities (Figure 2-7). Additional sidings exist in the southern parts of the state, but they are mainly outside forest regions, so they are of little usability for woody biomass transportation. Specific locations for interchange activities were not investigated, as the main concern for biomass shippers is whether interchange is required, not the specific location for the activity.

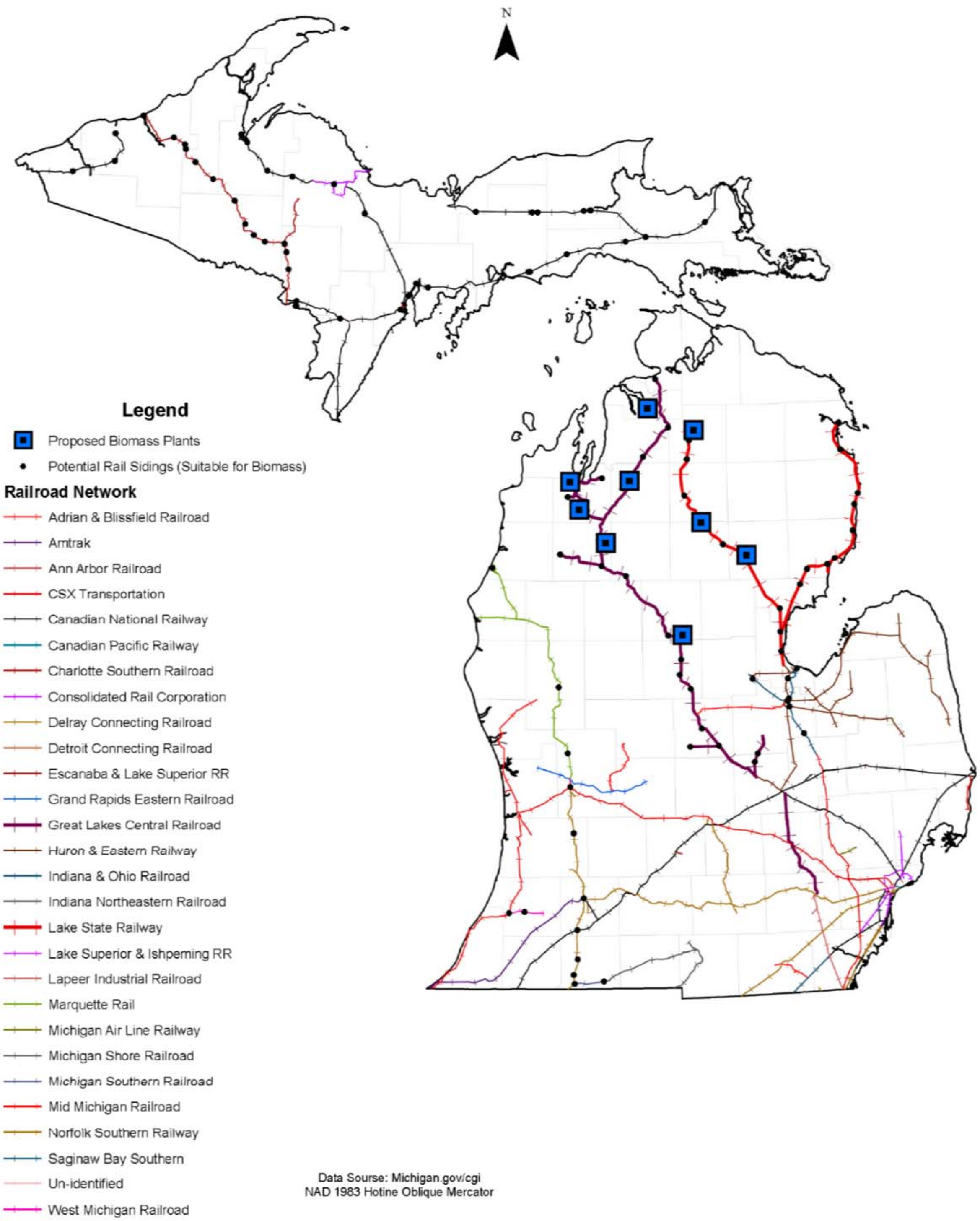

Figure 2-7- A GIS map of rail network and siding locations in the State of Michigan

2-3-3- Michigan Shortline Railroad Data

Since all proposed biomass plants are located in the northern LP, a more detailed investigation of rail lines in those areas was conducted. These areas are served by several shortline railroads listed in Table 2-5. To evaluate infrastructure and equipment capacity of these railroads, the team developed a railroad questionnaire that was sent out to all operating Michigan shortline railroads (Appendix D). Class I railroads were excluded, as the current project concentrates on in-state moves and all proposed plants are located in the northern LP

Six out of the thirteen companies responded to the questionnaire. Relevant infrastructure data provided by each company is summarized in Table 2-5. Unfortunately, relevant information on several rail lines owned by Rail America Corporation was not made available to the research team.

Table 2-5- Summary of shortline railroad infrastructure data

Rail Operator	**Infrastructure**		
Railroad	**Miles of Track**	**Public sidings capable for Biomass**	**Private Sidings capable for Biomass**
Grand Elk Railroad	123	40	40
Great Lakes Central Railroad	396	Most GLC sidings	N/A
Lake State Railway (including Saginaw Bay Southern Railway)	300	24	A Lot
Michigan Southern Railroad	18	3	2
West Michigan Railroad	15	1	1
Marquette Railway	130	8-9	--

Figure 2-7 and Table 2-5 reveal that most rail infrastructure in the northern LP is oriented in north-south directions. This makes rail more usable for movements in these directions. The greatest potential for biomass rail transportation in the LP is provided by Great Lakes Central and Lake State Railway, as all proposed biomass facilities are located in the vicinity of these two rail operators. However, it needs to be recognized that the network of any individual railroad is quite limited, so most movements typically require at least one interchange from one railroad to another, immediately reducing the applicability of rail transportation, especially if the maximum 100 mile radius harvesting criteria is maintained. For a more detailed analysis of suitable rail infrastructure for biomass transportation, the following characteristics should be evaluated:

- Rail access at points of origin
    - Distance from harvesting sites to nearest rail sidings
    - Siding capacity (how many rail cars can be loaded and stored?)
    - Cargo handling equipment (most of the time self-loaders would have to be used at sidings)
    - Storage space available around siding
- Rail access at facility
    - Existence of railroad tracks in the facility (railroad facilities at plant locations are a "requirement" for economical rail transportation)
    - Track capacity at facility (how many cars can be stored at the facility at any given time?)
    - Maneuverability (can car switching be done within facility, or does it require entering main rail line?)
- Service along the line (discussed more as part of operational considerations)
    - How regularly is rail service provided by the railroad operator?

- Does the route require interchange from one railroad to another?

2-4. Marine Infrastructure

This section reviews the marine infrastructure components and requirements. It focuses mostly on ports and docks in the state of Michigan and at potential origins and destinations around Lake Superior and Lake Michigan.

Greenwoods Guide to Great Lakes Shipping, 2010, Great Lakes Navigation System Five Year Development Plan Fact Sheets, US Army Corps of Engineers, 2008 and 2011, NOAA Coast Pilot #6, 2010 and Port Series #49 Lake Michigan Ports, US Army Corps of Engineers, 1995 were used as data sources for investigations, along with accessing port websites to explore existing dock facilities.

2-4-1- Potential Ports and Docks

Nine potential locations to construct and operate an ethanol facility were identified in the lower peninsula of Michigan, but none of the proposed locations are on navigable waterways with the possible exception of Traverse City. Table 2-6 lists the biorefinery locations and their distances from the nearest port. Most ports examined, if not all, had shipped logs at some point during their history, but most of the infrastructure has been abandoned or converted to other purposes after the 1960s. Two exceptions to the trend were log shipments that took place in the 1990s from ports of Frankfort and Menominee/Marinette.

Table 0-1- Nearest ports to proposed Biorefinery Sites

BioRefinery potential location	Nearest Port	Distance in miles to Nearest Port	Alternate Commercial Port	Distance to Alternate Port	Alternate Port	Distance to Alternate Port
Manton City	**Traverse City**	**37**	**Frankfort**	**64**	**Manistee**	**64**
Roscommon Village	**Traverse City**	**66**	**Bay City**	**84**	**Charlevoix Harbor**	**85**
Kingsley Village	**Traverse City**	**17**	**Frankfort**	**38**	**Manistee**	**55**
Kalkaska Village	**Traverse City**	**25**	**Charlevoix Harbor**	**44**	**Frankfort**	**66**
Mancelona Village	**Charlevoix Harbor**	**31**	**Traverse City**	**37**	**Cheboygan**	**76**
Gaylord City	**Charlevoix Harbor**	**42**	**Cheboygan**	**62**	**Alpena**	**71**
Clare City	**Bay City**	**48**	**Traverse City**	**92**	**Manistee**	**93**
West Branch City	**Bay City**	**52**	**Traverse City**	**93**	**Alpena**	**95**
Traverse City	**Traverse City**	**0**	**Charlevoix Harbor**	**38**	**Frankfort**	**40**
Boyne City	**Charlevoix Harbor**	**32**	**Cheboygan**	**55**	**Traverse City**	**68**

2-4-2- Preliminary Port and Dock Infrastructure Analysis

The parameters of the study limited ports to only those located in Michigan. A review of the port's attributes was undertaken including visits to all the potential locations and discussions with vessel operators. The first cut of origin ports was made by determining if the port was a Federal commercial or recreational port as defined by the U.S. Army Corps of

Engineers (U.S. Army Corps of Engineers- Detroit District, 2011), as only commercial ports were evaluated. This eliminated recreational ports such as Petoskey Harbor. The selected commercial ports were then further evaluated to see if they had a maintained depth of at least 15 feet, had commercial dock space and landside infrastructure with a potential for woody biomass operations. Some private harbors were also examined, but in each case they would have to be contacted in the next stage of the research to determine if the owners had an interest in having their harbors and docks used. The following attributes were used to refine the analysis for suitable docks:

- Operational Characteristics
    - Dimensions of dock: length, size of apron
    - Depth of water alongside dock
    - Cargo handling equipment
    - Condition of dock – ability to secure vessel (safe berth)
- Landside connections
    - Can trucks deliver and pick up logs?
    - Can rail cars deliver or pick up logs?
    - Is there adequate on-dock storage space for logs?
- Owner interest in using the dock for the proposed purpose
    - Current use and future plans
    - Properly zoned for log operations
    - Access areas zoned for log operations

Figure 2-8 represents all of origin and destination ports identified as suitable for biomass transportation.

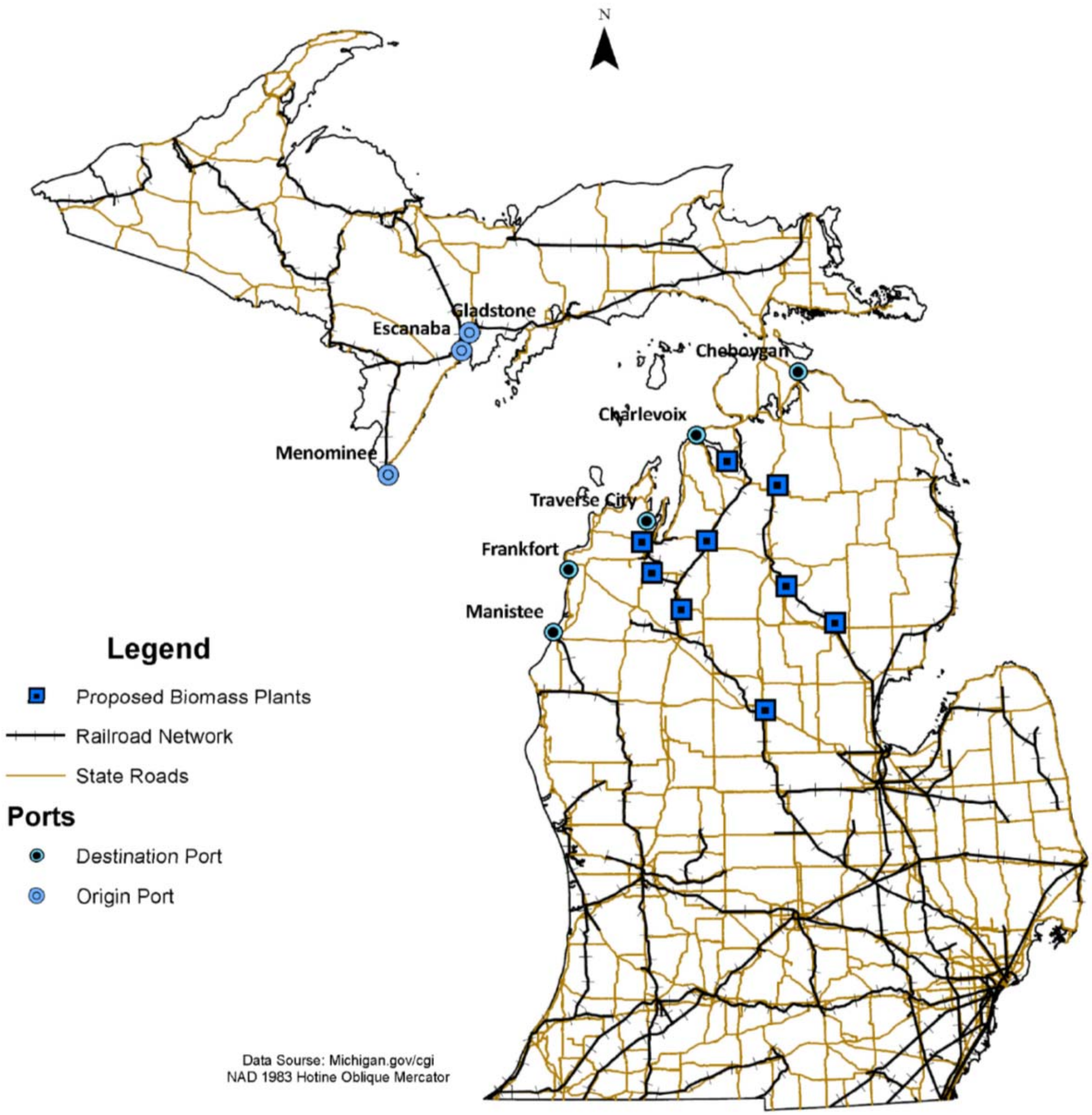

Figure 2-8- Snapshot of all potential origin and destination ports for biomass multimodal transportation

The five identified ports and docks that are located in the LP can be considered as **destination ports** for the multimodal woody biomass transportation. Table 2-7 represents a summary of these ports. More details of each port are represented in Appendix E.

Table 2-7- List of potential Ports/Harbors considered as maritime destination for project

Port/ Harbor	Location	# of docks*	Advantages	Conditions/ Concerns	Water depth
Charlevoix Harbor	East shore of Lake Michigan- MI	2	- commercial harbor with facilities in the town of Charlevoix - all docks have highway connections - ranked 31st among the Great Lakes Harbors with 1.5M tons of commerce in 2007	lack of maintenance (dredging) may reduce the allowable draft	Over 100 feet
Frankfort Port	East shore of Lake Michigan, MI	2	- commercial port connected to Lake Michigan by an entrance channel - all docks have highway connections - It has shipping or receiving logs records in 1995 by US Army corps of Engineers.	this area may be undeveloped	20 feet
Traverse City Harbor	Grand Traverse Bay, MI	1	-three active deep-draft facilities - owned and operated by Traverse City	- current petroleum products handling in the harbor may complicate the biomass operations	18 feet
Manistee Harbor	east shore of Lake Michigan MI	4	-protected by breakwater - several deep-draft facilities -all docks have highway connections - some docks have rail connections but the condition of the rail service is unknown.	principal cargo handled in the port is coal, with occasional shipments of salt, sand, limestone and machinery	25 feet
Cheboygan Harbor	western Lake Huron, MI	2	Two docks out of three may have the potential to handle biomass	-home port of the U.S. Coast Guard's - principal cargo handled in the port is coal, with occasional aggregates	21 feet

*: number of docks suitable for biomass water loading/unloading activities

A suitable **origin port** will need to have the same attributes as the destination port and a sufficient capacity storage area for buffer stocks. In addition, a port must be far enough from the destination port to make the economies of marine transportation viable. A rail connection at the origin port is advantageous, as rail can provide access to more distant wood baskets in the UP A list of potential origin ports/harbors is summarized in Table 2-8 and more details on listed ports are provided in Appendix E.

Table 2-8-List of potential ports/harbors considered as maritime origin for project

Port/ Harbor	Location	# of docks*	Advantages	Conditions/ Concerns	Water depth
Menominee	17 miles NW of the Sturgeon Bay Ship Canal, MI	5	- three deep-draft facilities -All docks have highway connections and some have railway connections - in the early 1990s logs were shipped from one of the docks of this harbor	-Shoaling has been reported upriver - principal cargo: coal, with occasional shipments of pig iron, salt, limestone	19 feet
Escanaba	Escanaba, MI	2	- several deep-draft facilities - All docks have highway connections and some have railway connections	- principal cargo handled in the port is coal and limestone	28 to 40 feet
Gladstone	the west side of Little Bay de Noc, MI	2	- two deep-draft facilities - All docks have highway connections	- principal cargo of port: barrels, asphalt, coal, salt, limestone -One of the docks is tanker and unlikely to be ready for biomass movement	22 feet

*: number of docks suitable for biomass water loading/unloading activities

In addition to the larger ports identified above, several smaller ports with potential for biomass movements were identified by Mr. Dan Glawe during interviews with researchers from Michigan Technological University. These ports are highlighted in Table 2-9 with more detailed explanation in Appendix E.

Table 2-9- Suggested ports from Dan Glawe

Port Location	Notes From Dan
Detour	Good deep water port near Kinross (located in Upper Peninsula)
Cedarville	Good deep water port near Kinross (located in Upper Peninsula)
Frankfort	Shut down
Ludington	Only Deep water port on West side of Lower Peninsula
Manistique	Tough to get into due to having to go up river
Rogersville (Rogers City)	Would have potential for deep water port
Bay City	Is ok
Alpena	Not too good, The bay has a lime stone bottom

3.0 Transportation Equipment

Tasks covered in the chapter include:

Task	Description
B1.2	Identify most suitable equipment for biomass transportation
B1.7	Identify data sources for transportation equipment
B1.10	Inventory of the equipment available in the study area
B1.13	Summary of transportation operations and available equipment

Transportation equipment is often the second most expensive component of transportation systems. It typically refers to "vehicles", such as tractors and trailers, rail cars or barges. This chapter reviews the main types of equipment suitable for biomass transportation by road, rail and marine.

The parameters discussed include:

- Technical and operational specifications
- Equipment cost
- Availability of different types of vehicles within the project area

Information presented in the chapter was collected from technical reports and documents issued by Midwest Departments of Transportation and from inquiries and interviews with forest product companies, equipment dealerships, transportation service providers and the Secretary of State (SOS).

3-1- Road Equipment for Woody Biomass Transportation

Trucking is the main transportation system for the delivery of logs and biomass. The weight/volume ratio of woody biomass varies significantly. Figure 3-1 shows the general size capacity of each type of woody biomass material with the same weight.

Figure 3-1- Different size capacity of materials with same weights (Schroeder et al, 2007)

Table 3-1 provides an overview of the most common types of equipment available for woody biomass transportation and respective load capacities.

Table 3-1- Road Transportation equipment suitable for biomass transportation

Type of Biomass	Equipment Type	Weight Limit (lbs.)	Typical Axle Combinations
Chips/Forest Residue	chip tractor and trailer	80,000 - 156,400	5 to 11
Chips/Forest Residue	chip truck	42,000 - 70,000	2 to 5
Pulp/Logs/Biomass Bundles	log truck and pup	80,000 - 164,000	11 (6 axle truck with 5 axle pup)
Pulp/Logs/Biomass Bundles	tractor trailer	80,000 - 164,000	Multiple axle configurations

3-1-1- Pulp/Logs/Biomass Bundles

In Michigan, pulp and saw logs are most commonly transported by an 11 axle log truck and pup configuration (6 to 7 axles on the truck with 4 to 5 axles on the pup trailer (Figure 3-2)). These vehicles have the maximum allowable loads with a gross vehicle weight of 164,000 lbs. Most of these trucks have the capacity to self-load or unload, increasing their versatility.

Figure 3-2- 11 axle log truck (6 axle truck + 5 axle pup) with selfer loader

(Photo by: H. Pouryousef - Feb. 2011)

Tractor-trailer combinations are also used to transport round wood. Trailers come in a variety of configurations, including loader and crib style applications (Figure 3-3 and Figure 3-4). The crib style design is developed to improve the safety of log transportation. In crib trucks, logs are hauled lengthwise, the sides of the log-hauling truck are staked, and the truck is fitted with headboards and bulkheads at the front and back of the trailer (Michigan Association of Timbermen, 2011).

Trailer axle configurations vary from 2 to 8 axles with different spacing between axles to enable different gross vehicle weights. For complete listing of truck variations, see Biomass Transportation Equipment Tables in Appendix F.

Figure 3-3- Tractor-trailer combination with self-loader capability (Green et al. 2005)

Figure 3-4- Crib style trailer (Green et al. 2005)

<u>3-1-2- Chips and Biomass Residue</u>

Chips and loose forest residue are commonly hauled by tractor-trailers (Figure 3-5 and Figure 3-6) that consist of a tractor and large chip truck trailer (42 to 48 ft. in length) (Jeuck, 2009). For these types of biomass, it is common for trailers to reach their capacity before weight limits. Trailers come with different axle configurations and loading/unloading capabilities (Figure 3-5 and Figure 3-7). Chips can be either hauled in an open top or rear loading chip trailer while for residue, loading can only be done with open top trailers. Chip trucks without live floors are less versatile because they need a tipping platform and machinery to help them in unloading process (Figure 3-8) (Schroeder et al, 2007).

Figure 3-5- Truck with dual chip bin trailers loaded with chips [2]

Figure 3-6- Tractor-trailer chip truck [3]

2 : Forestencyclopedia website, http://www.forestencyclopedia.net/p/p2/p1136/p1296/p1313

3 : Safe and Efficient Practices for Trucking Unmanufactured Forest- Virginia Tech., http://pubs.ext.vt.edu/420/420-310/420-310.html

Figure 3-7- Open top chip/biomass trailer [4]

Besides the type of road vehicles and their technical specifications, the storage yard capability and current facilities typically determine what type of chip truck should be used. For instance, larger facilities usually use truck-tippers (Figure 3-8) to empty feedstock from almost any type of chip truck, while smaller facilities may not have such equipment, requiring use of trucks with self-unloading capabilities (Jeuck, 2009).

Figure 3-8- A type of chip truck tipper at a woody biomass facility (Jeuck, 2009)

An example of a truck with self-unloading capability for loose residue and chips is a live floor (walking floor) (Figure 3-9). Walking floor provides operational flexibility, but the high purchase cost and inefficient unloading process when compared to tipping can be considered disadvantages.

4 : Pitts Trailers, http://pittstrailers.com/app/inventoryapp/logging_trailers/inventory_view/94-95-66-1.html

Figure 3-9- Left: walking floor truck during unloading; Right: inside of walking floor truck [5]

3-1-3- New Technologies for Biomass Road Transportation

Due to an increased interest in biomass, especially in Scandinavian countries, new technologies and equipment have been developed and applied into service. Figure 3-10 shows a stump collection truck developed in Finland. These trucks are typically equipped with self-loaders and they have been designed to maximize the cargo space volume through high side walls. In addition, the trailer has a hydraulic system that can compress the load to increase its density and thus overall load capacity.

Figure 3-10- Truck-trailer for loose residue and chips transportation by UPM Kymmene Group-Finland (Maertens, 2009)

5 : http://www.trucker.com/TrailerDetail.aspx?TrailerID=1006498&CompanyID=32292

In the past few years, the use of roll-off pallet racks has been investigated as a way to find a cheaper woody biomass collection system. These systems can decrease transportation and handling costs under particular conditions, such as in small markets that require less than 50 green tons/day (Rummer, Klepac, 2004.) In this collection system, a forwarder is equipped with a roll-off or hook lift unit that can carry either residue bins or log rack into the woods. Once the forwarder has filled the bin, it returns to the landing and quickly transfers to a new bin. At the landing, can then pick up the bin or rack and haul it to the mill (Figure 3-11). The method allows for less down time and eliminates double handing of the material. It has been estimated that a roll on/off forwarder can eliminate one to two hours of total work from the conventional method of woods-to-roadside cycle. (Atkins, et al, 2007) However, in research done by Rawlings et al, it was concluded that a roll on/off container system is not competitive with a regular highway chip truck, unless loading site is inaccessible to the chip truck (Rawlings, et al, 2004).

Figure 3-11- Two types of Roll 0n/Off trucks (Wynsma, et al, 2007)

3-1-4- Road Transportation Equipment Available in the State of Michigan

The Secretary of State office is the prime source for inventory of available trucks within the state of Michigan. Even though detailed analyses of current truck inventory wasn't completed, as access to data required special arrangements, the research team was able to obtain total numbers for stake bed and tractor trailer trucks that are registered with log farm plates (codes L09 and L10) as of November,2010. Vehicles registered with these log plates can only haul non-processed wood products (logs, chips and forestry residue). Processed wood products (wood pellets, lumber and strand board/plywood) should be hauled only by vehicles registered with commercial plates. On the other hand, trucks with commercial plates can also haul non-processed wood materials.

The SOS data revealed there were 1,190 log plate registered vehicles within Michigan. The number was compared to a Log Truck Study II report produced by Michigan Technological University in 2005 (Green et al. 2005) which used SOS and insurance company data along with field surveys to determine that there was an approximately 1,050 log trucks within the state. In 2005, the SOS registration data indicated that there was about a 2:1 split between the Upper Peninsula and Lower Peninsula respectively. Using the same ratio, the team determined that approximately 800 trucks reside within the Upper Peninsula region while 400 reside in the Lower Peninsula.

<u>3-1-5-Equipment Manufacturer Interviews</u>

The transportation team conducted interviews with equipment manufacturers and dealers to determine equipment specifications, trends and markets for biomass transportation equipment within the state of Michigan. The list of the companies contacted is provided in Appendix G. The companies ranged from manufactures to new and used equipment dealers and equipment refurbishing. It was decided to also collect data from Northern Wisconsin, as several equipment manufacturers and dealers located in Green bay, Appleton and Oshkosh area service the UP The key findings of the interviews include:

- **Equipment and Cost**
    - 75% of dealers cover both new and used equipment and the majority of the inventory includes trucks that are less than 10 years old. Approximately 25% of dealers have 164,000 lbs. Michigan log trucks in their inventory but almost all dealers carry “Michigan Special” tractors which are versatile and have high horsepower (550 to 600 hp).
    - Most large biomass trucks are available based on demand. Dealers are facing limited interest for biomass trucks, but more inquiries for small, versatile trucks.
    - Since 2009 the base price on a chassis has increased $30,000 due to new government regulations on emissions and safety standards.
    - Table 3-2 shows price ranges for each type of equipment surveyed.

Table 3-2- Road transportation equipment cost ranges

Equipment Type	Cost – (New)	Cost – (Used) (Typically 5 years or older)
6 to 7 Axle Log Truck (Just Truck)	$130,000 to $250,000	$30,000 to $80,000
6 to 7 Axle Log Truck (Truck and Pup Trailer)	$240,000 to $300,000	
Tractors (Tandem Axle)	$110,000 to $175,000	$8,000 to $70,000
Trailers (Log/ Pulp and Chip trailers)	$30,000 to $130,000	$2,500 to $30,000

- **Current market:**
    - All dealers mentioned that sales for 2010 were down drastically (compared to 2004-2007) but higher than 2009 numbers. Many companies were upgrading and buying trucks before 2008 when the new emission regulation engines came into production.
    - The inquiry for biomass equipment has declined due to the industry being unstable, rising transportation/maintenance costs and dwindling markets.
    - Increased amount of refurbishing old trucks now being done

- **Services and Maintenance:**
    - Approximately 90% of the dealers mentioned that they own a truck service shop, but only 60% use facilities for commercial maintenance and service centers.
    - Truck serviceability depends on the region. Northern Wisconsin and the Southern Lower Peninsula locations offer very limited service. Upper Peninsula locations see several hundred biomass trucks a year where as the Lower Peninsula sees mainly smaller, Class 8 trucks.
    - Since the 2008 emission regulations, there has been an increasing trend by operators to delay maintenance as a way to cut costs.
    - Most companies didn't want to deal with the new engines (based on emission regulations) due to the fear of problems and added expense on both base prices and maintenance costs.

3-1-6-Logger Surveys

In addition to equipment manufacturers, forest product operators in the state of Michigan were surveyed about their use of truck and rail transportation. Two different survey campaigns conducted in 2009 and 2010 covered the trucking equipment and key operational features (Table 3-3 and Table 3-4 and Figure 3-12). Truck data was analyzed with all units aggregated together, but separate analyses for the larger 10-11 axle log trucks and chip vans were also conducted.

Table 3-3- State of MI trucking equipment summary

Truck Type	**Responses**	**Year** (avg / stdev[b])	**Fuel Use** (avg / stdev)	**Miles/year** (avg / stdev)
All log trucks reported in surveys	146 – 168[a]	2000 / 8	4.48 / 1.78	55,707 / 60,052
Large log trucks (10-11 axles)	66 – 78	2003 / 5	3.69 / 0.72	63,896 / 39,093
Smaller log trucks (2-9 axles)	74 – 84	1997 / 8	5.28 / 1.94	46,914 / 73,277
Chip vans	15 – 21	1998 / 7	4.19 / 0.99	42,800 / 28,357

a- numbers indicate number of survey responses. 'Large log trucks' and 'Smaller log trucks' are subsets of the category 'All log trucks'. In some cases, the sum of responses in the 'Large log truck' and 'Smaller log truck' categories do not equal the responses for 'All log trucks' due to additional entries where no axle number was recorded being omitted in the data breakdown by axle number.
b- numbers reported are the averages and standard deviations of survey responses

Table 3-4- Percentage of round wood transported by self-loading trucks

Responses	180
Average %	**86.0**
Standard deviation (%)	30.5
Responses that indicated 100%	128
Responses that indicated 0%	18

As expected, large log trucks had lower average fuel economy and higher annual mileage than other trucks represented in the survey. Overall, the distribution of annual mileage data for trucks varied considerably, as seen in Figure 3-12. The survey also revealed that most of the log trucks in the state of MI are equipped with self-loaders, as over 70% of respondents (128 / 180) had 100% of their round wood production transported with self-loading trucks.

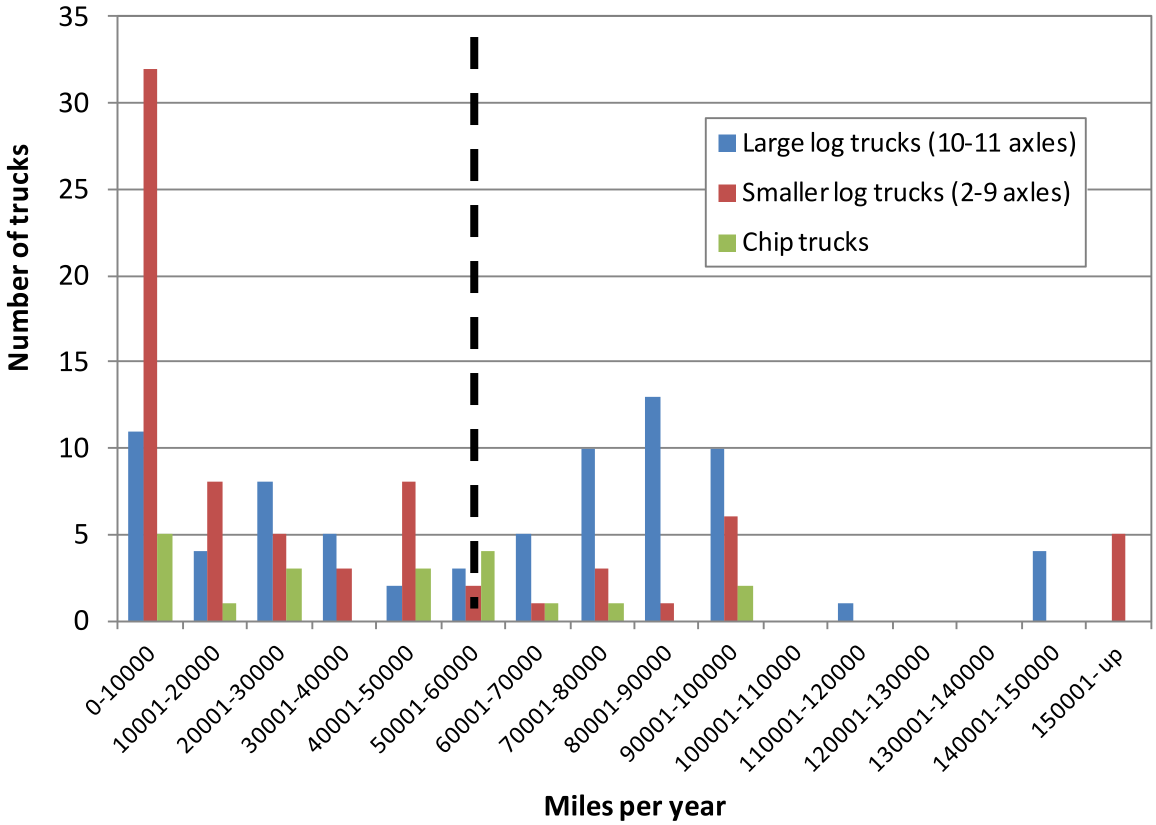

Figure 3-12- Histogram of reported yearly mileage data for all log trucks

3-2. Railroad Equipment

Several different types of rail cars are capable for hauling woody biomass, but certain cars are typically preferred. Bulkhead flat cars and log cars are mainly used for logs and gondolas and in some cases hoppers are used for chips. All rail cars require separate loading/unloading equipment.

Due to the interstate nature of rail assets, there are no dedicated rail cars that operate in the state of Michigan. However, industry representatives felt that they are capable of securing necessary rolling stock assets if the demand for woody biomass transportation emerges. According to rail car manufacturers, the demand for biomass cars (mainly for chip transportation) has been quite low for extended period of time which has also led to an aging fleet.

Table 3-5- List of common railroad cars for forest and wood material transportation (CN, 2010)

Type of Biomass	Transportation Equipment Type	Load Capacity	Length	Material Used For and Notes
pulp/logs/biomass bundles	bulk head flat car	75-110 tons	50-66 ft.	used for metals and minerals/ aluminum and steel products
pulp/logs/biomass bundles	bulk head flat car	80-97 tons	52-66 ft.	forest products/lumber and panels
pulp/logs/biomass bundles	log car	75-85 tons	46-52 ft.	forest products/logs
chips/forest residue	wood chip hopper	75-83 tons	53-66 ft.	forest products/ wood chips, has bottom gates or no doors

3-2-1- Pulp, Log, and Biomass Bundles

The railroad designates two different types of cars to pulp/logs/biomass bundles. The first type of car is a simple bulkhead car (Figure 3-13). Table 3-5 contains two columns for these types of cars due to commodity usage and structural reinforcement/ durability between cars. These cars are designed with sturdy end-walls to prevent loads from shifting longitudinally and logs are typically loaded perpendicular to movement. Most railroads tend to shy away from using these cars due to the safety risk of the load shifting laterally, or logs sticking out from the side of the car into the railroad right-of-way.

Figure 3-13. Bulkhead car-Kansas City Southern Railway [6]

The second, more commonly used rail car is a log car (Figure 3-14). In contrast to a bulkhead car, these cars have stakes on the sides and they carry the load longitudinally, like a crib style trailer. This secures the load and eliminates the concern for lateral shifting. Typically these cars can hold about 35 cords (~80 tons) of 8 foot cut-to-length logs.

6 : http://www.answers.com/topic/flatcar

Figure 3-14. Log car-BFPX [7]

3-2-2- Chips and Forestry Residue Cars

For chips/forest residue or waste, a “wood chip gondola” is often used. They typically have interior space/area of approximately 9,200-10,000 cubic feet with higher than normal side walls (8-9 ft. in height) to increase the volume. In comparison, standard gondolas typically have interior space of about 2,000-2,500 cubic feet with side walls of about 4-5 feet in height. (Figure 3-15 and Figure 3-16). Typically, these cars have to be mechanically loaded and unloaded which places restrictions on efficiency. However, models with rotary dump capabilities or with tipping mechanisms have also been used.

Figure 3-15. Woodchip gondola with front and rear gates, Great Northern [8]

7 : http://www.rrpicturearchives.net/showPicture.aspx?id=467176

8 : http://www.rrpicturearchives.net/showPicture.aspx?id=1423672

Figure 3-16 presents another type of car that can be used, an open top hopper. These cars are typically equipped with a bottom dump unloading system. To use this system, the mill would have to have appropriate facilities available for bottom dump.

Figure 3-16- Open top hopper with bottom discharge, GPSX [9]

3-2-3- Estimated Costs of Rail Cars

Similar to trucks, the rail car cost is very dependent on the type of the cars, features, manufacturer and age. Due to the longer life cycle of rail cars in comparison to the trucks (between 30 to 40 years), many industries prefer to buy second hand or used rail cars rather than purchasing new ones. The research team contacted twenty rail car manufacturers and dealers throughout North America to obtain more information on new and used rail car prices. Based on the information from four companies who responded to the inquiry (complete list is provided in Appendix H), the team summarized the prices of new and used rail cars commonly used for log/biomass transportation (Table 3-6). The cost of used cars varies broadly, since it is dependent on the condition of car, its accessories, age and capacity/size of the car.

Table 3-6- Price estimation for new and used car types used for biomass transportation

Biomass Type	Rail Type	Cost	
		New car	Used car
pulp/logs/biomass bundles	bulk head flat Car	\$80,000- \$90,000	\$15,000- \$50,000
pulp/logs/biomass bundles	log car	\$80,000- \$90,000	\$15,000 - \$50,000
chips/forest residue	wood chip hopper	\$80,000- \$90,000	\$15,000 - \$50,000
chips, waste wood products	standard gondola	\$70,000	\$15,000 - \$45,000

9 : http://www.rrpicturearchives.net/showPicture.aspx?id=2119435

Besides buying new and used cars, leasing or sharing (pooling) are two other procurement options for rail cars. Typically a rail car lease is in the range of $450-$650 per car per month. The benefits and drawbacks of these options are discussed in more detail in Chapter 4.

3-3. Marine Equipment

This section reviews major physical requirements and specifications for barges and vessels and presents an inventory of barges with their respective features. In addition, it reviews the legal requirements and operational limitations placed by the U.S. on marine transportation.

3-3-1-Legal requirements

Cargo that is transported between two U.S. ports without leaving country is governed by the Jones Act. The Jones act requires that any vessel transporting cargo for hire in the domestic trade be:

- Registered in the U.S.
- Built in the U.S.
- Owned/managed by a U.S. company
- Crewed by U.S. citizens

The legal requirements limit the pool of available vessels for transporting biomass between Michigan ports or with other states to U.S. flag vessels. This means that all Canadian flag or foreign flag vessels will not be able to engage in the movement of biomass that takes place within the state of Michigan. U.S. flag vessels may also be limited in their geographic range by the U.S. Coast Guard. The decision is based on the design of the vessel. A vessel designed for use on rivers or bays may not be safe to operate on the open waters of Lake Superior. Each vessel will have a Certificate of Documentation that defines the allowed area of operation. Vessels can be certified for additional bodies of water if the equipment meets the operational requirements for the new area of operation.

3-3-2- Physical requirements

In addition to being able to operate on the proposed route, the vessel needs to be capable of safely carrying the biomass cargo, including the loading and unloading operations. A large number of U.S. flag Great Lakes vessels are designed for specific trades such as aggregate, coal, taconite or liquids. The design of the vessel’s holds or available cargo gear may make the vessels unsuitable for carrying logs. While a self-unloader may be capable of carrying wood chips, the vessels were designed for dense cargo rather than light bulky cargo. The capacity of the vessel is also an issue as the larger lake vessels with 20,000 ton and upward capacity would require a very large stockpile of wood chips before they could carry a full load. The self-unloaders are designed for quick loading and unloading and will not accept a long period in port. This would require a loading system in the port of origin for wood chips. While the use of a large size self-unloading vessel is not impossible, it is unrealistic.

A more likely vessel would be a barge that is propelled by a tug, (Figure 3-17). The barges have relatively low operating costs, have a smaller capacity (1,000-10,000 ton range), and costs are economical enough for a dedicated trade. With a suitable dock that allows the use of a ramp between shore and barge, forklifts can be used to move the logs, reducing equipment costs. Wood chips may require specialized loading and unloading equipment for barges.

Figure 3-17- Tug W.N. Twolan and barge McAllister 132, in Duluth/Superior Harbor
(Photo: Courtesy of Kenneth Newhams)

3-3-3- Barge Inventory

Only U.S. flag vessels could be used on the proposed routes. Table 3-7 presents current U.S. flag tug barges (as of October 2010) in the Great Lakes, with notations on size and suitability for the movement of biomass (Harbor House Publishing, 2009). This list does not include barges designed to handle liquid cargo. The deadweight tonnage of the barges ranges from 300 to 9,000 short tons. These barges may not be able to travel on all potential routes, as some of them may be engaged in long term contracts that render them effectively unavailable. In addition to current barges, a barge could be repositioned from an ocean coast or newly built, if a suitable market with an acceptable return on investment existed.

Table 3-7- U.S. Flag Great Lake Barges

Owner	Vessel/Barge	Type	LOA[1]	Beam[2]	Comp.[3]	Deadweight	Equipment
Basic Marine, Inc. Escanaba, MI	BMI-FDD-1		160'	65'	0	not listed	
	BMI-192		220'	55'	0	not listed	
	Greenstone		81'	24'	0	not listed	
Busch Marine, Inc. Carrolton, MI	STC 2004		250'	50'	flush deck	2,500	100 ton crane, clam, grapple, ro/ro, front end loader
Durocher Marine Cheboygan, MI	141		140'	9'	flush deck	800	75 ton excavator
	142		140'	9'	flush deck	800	150 ton crane
	D-2002		195'	12'	15	1,700	deck barge
	D-2003		195'	12'	15	1,700	deck barge
	D-2006		195'	12'	12	1,700	deck barge
	D-2007		195'	12'	12	1,700	deck barge
Geo. Gradel Co. Toledo, OH	Barge 717		128'	32'	flush deck	500	deck barge
	Clyde		134' 6"	41'	flush deck	800	deck barge
	Crow		110'	42'	flush deck	600	deck barge - 150 ton crane
	GL 170		120'	36'	flush deck	600	deck barge
	MCC 528		115'	27'	4	not listed	350 yard dump barge
	MCC 529		115'	27'	4	not listed	350 yard dump barge
	MOBRO 2000		180'	52'	flush deck	2,400	derrick barge
	MOBRO 2001		180'	52'	flush deck	2,400	derrick barge
	Moby Dick		121'	33' 2"	flush deck	835	deck barge
	Relief		160'	40'	flush deck	900	derrick barge
	Scow #32		128'	33'	4	not listed	550 yard dump barge
	Scow #33		128'	33'	4	not listed	550 yard dump barge
Great Lakes Towing Co. Cleveland, OH	Milwaukee		172'	40'	5	1,170	deck barge
Laken Shipping Cleveland, OH	Cleveland Rocks	dry cargo	390'	71'	18	9,000	boom
Malcolm Marine St. Clair, MI	504		120'	33'	0	not listed	50 ton crane
Marine Tech, LLC Duluth, MN	Dean R. Smith	crane	120'	48'	0	500	crane
	Alton Andrew	crane	70'	50'	0	300	crane
	MTI-H1	hopper	195'	35'	1	1,800	
	MTI-H2	hopper	195'	35'	1	1,800	
Pere Marquette Shipping Co. Ludington, MI	Pere Marquette 41	deck	403'	58'	flush deck	5,500	material handler, hooks, buckets, magnets
Ryba Marine Construction Co. Cheboygan, MI	CT150		150'	50'	12	1,600	crane barge
	CT251		197.9	43.1	7	not listed	dump scow
	CT252		197.9	43.1	7	not listed	dump scow
	Harbor Master		70'	27	11	not listed	spud crane barge
	Jarco 1402		140' 1"	39' 1"	7	700	spud crane barge
	No. 4		120	42	8	not listed	spud derrick barge
	No. 18		140'	36' 7"	10	600	dump scow
	OB 185		180' 1"	54'	16	1,200	deck barge
	Tonawanda		120'	45	6	600	spud crane barge
	Vulcan		100	34	2	not listed	deck barge

[1]: Length overall, [2]: Width of ship, [3]: Compartments: Number of cargo compartments,

4.0 Modal and Multimodal Transportation Operations

Tasks covered in the chapter include:

Task	Description
B1.8	Interview selected transportation providers to define potential service capacity
B1.9	Identify key operational challenges for biomass transportation
B1.11	Industry inquiry to collect rate information for biomass transportation
B1.12	Synthesis on challenges and synergies between alternative modes
B1.13	Summary of transportation operations and available equipment

Transportation operations utilize the infrastructure and equipment to provide transportation services requested by the shipper community. The following sections review key operational features and considerations for biomass transportation, both from single and multimodal perspectives. The specific topics covered include:

- Biomass transportation supply chain alternatives
- Modal considerations and challenges (road, rail and marine mode)
- Biomass transportation capacity
- Transportation economic considerations
- Transportation outcomes of logger survey and biomass transportation case studies

4-1- Alternative Supply Chains for Biomass Transportation

Figure 4-1 represents the alternative supply chains for woody biomass transportation. 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). However, supply chains can also take advantage of multimodal transportation opportunities (Scenario 2), or it can break the chain by using intermediate storage (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.

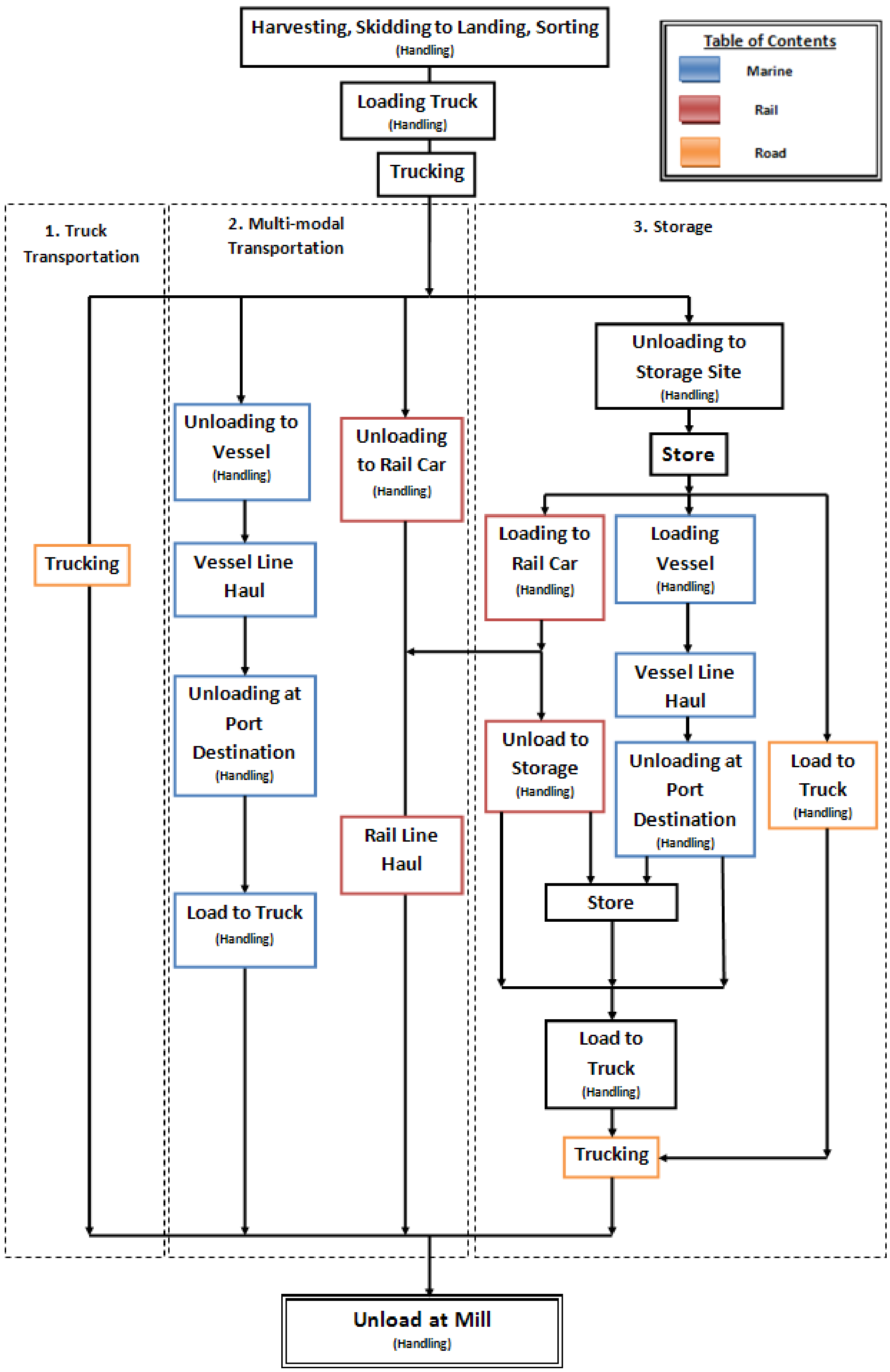

Figure 4-1. Alternative supply chains for biomass transportation

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.

4-2- Biomass Transportation Distances

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. The transportation research team 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 Technological University 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).

Another source for average transportation distances was the logger survey conducted as part of the project. 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 woody biomass are transported within a ninety mile radius from the landing with pulp logs traveling slightly longer distances than chips and saw logs (Figure 4-2).

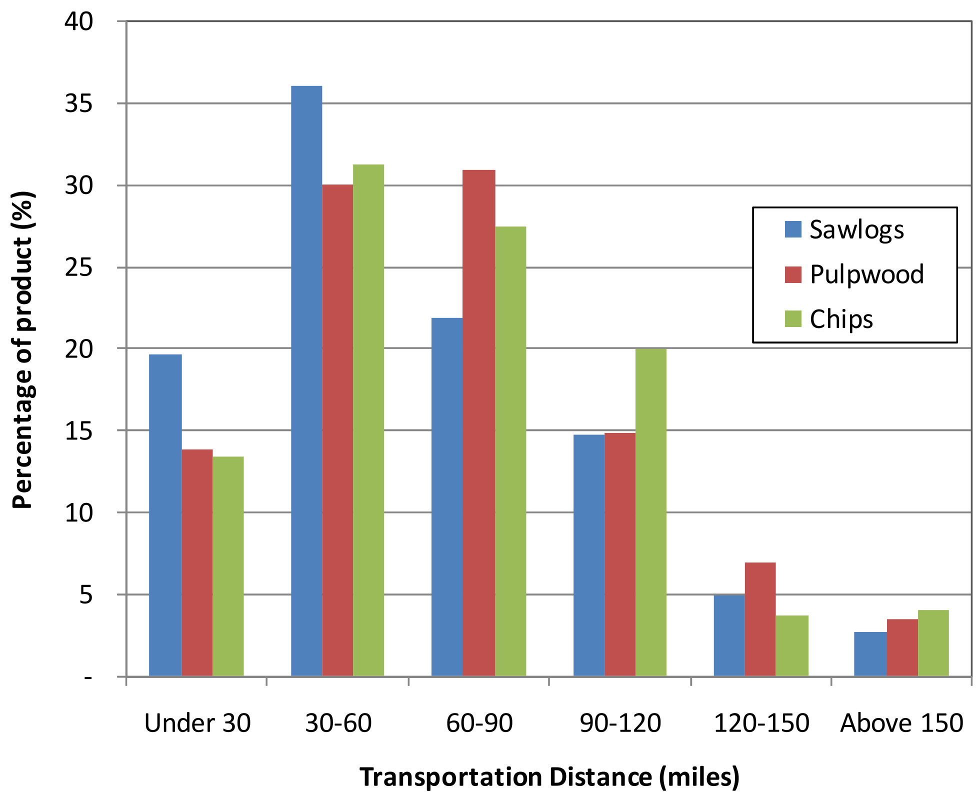

Figure 4-2- Biomass transportation haul lengths based on loggers' survey

In 2009, Hicks analyzed more than 100,000 trip datasets of log trucks through the Michigan, Wisconsin and Minnesota regions. Based on the collected data, a histogram was constructed to show the relationship between tons of logs and transportation distances (Figure 4-3). The average distance of Hicks' sample was under 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 while the majority of trips were less than 100 miles, there were numerous trips between 100 and 200 miles and some even beyond 200 miles. (Hicks, 2009)

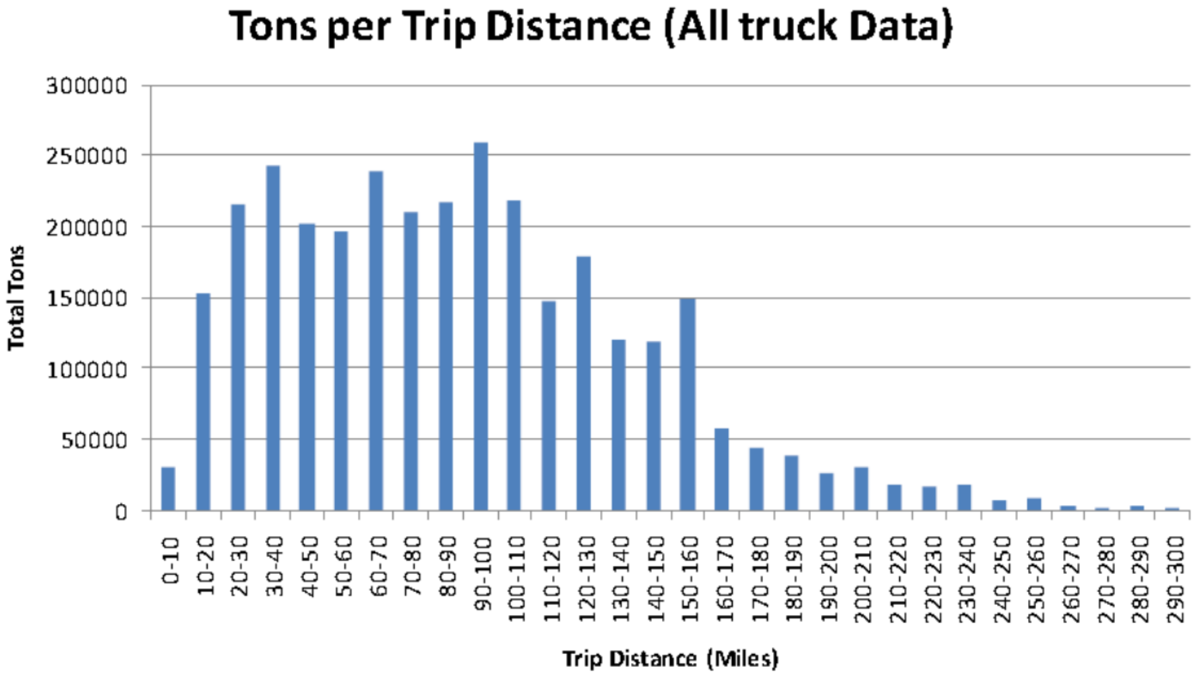

Figure 4-3- Log truck hauling distances in Michigan, Wisconsin and Minnesota (Hicks, 2009)

The data from all three references mentioned above suggests that the average hauling distance between 75 up to 100 miles is an accurate range for a typical biomass transportation movement. It also suggests that the 100 mile hauling radius used by the FBSCC modeling team seems justified. 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.

4-3. Road (Highway) Transportation

With its extensive network covering the entire state, road offers the most flexible alternative for biomass transportation. Available road infrastructure and equipment form the backbone to the system, but there are also several operational aspects that should be considered.

4-3-1- Truck Transportation of Log/Wood Products in Michigan

Trucks play a significant role in Michigan transporting approximately 84% of total weight for in-state movements. Table 4-1 provides total volumes for log and wood products in Michigan 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. Unfortunately, it could not be defined whether chips were covered under log or wood product category.

Table 4-1- Log and wood product transportation by truck between Michigan and neighboring States in 2009 (FHWA, 2011)

ORIGIN	DESTINATION	Commodity	Total Tons (in thousands)	Total M$
Michigan	**Michigan**	Logs	12323	450.82
Michigan	**Michigan**	Wood prods.	3065	1372.50
Michigan	Illinois	Logs	27	17.67
Michigan	Illinois	Wood prods.	142	91.78
Michigan	Indiana	Logs	143	23.92
Michigan	Indiana	Wood prods.	280	193.37
Michigan	Ohio	Logs	44	7.30
Michigan	Ohio	Wood prods.	147	96.05
Michigan	Wisconsin	Logs	88	50.87
Michigan	Wisconsin	Wood prods.	216	85.15
Illinois	**Michigan**	Logs	0.1	0.01
Illinois	**Michigan**	Wood prods.	123	81.57
Indiana	**Michigan**	Logs	3	4.96
Indiana	**Michigan**	Wood prods.	48	81.44
Ohio	**Michigan**	Logs	1	0.07
Ohio	**Michigan**	Wood prods.	78	90.31
Wisconsin	**Michigan**	Logs	3	1.01
Wisconsin	**Michigan**	Wood prods.	191	230.68

4-3-2- Truck Performance and its Operations Requirements

Operating trucks to transport log and biomass material is a low-profit business and the majority of truck transportation in Michigan is handled by independent owner-operators who often own only a single truck. The following section reviews operational aspects that should be considered when defining the capacity potential provided by the trucks.

According to movement data collected with GPS, log and chip trucks in the UP typically operate **8-12 hours per day and five days per week** (Figure 4-4). Saturday operations seem to depend on the season, as during the fall collection period, few trucks had any operations on Saturdays, while during the winter, Saturday operations were more common.

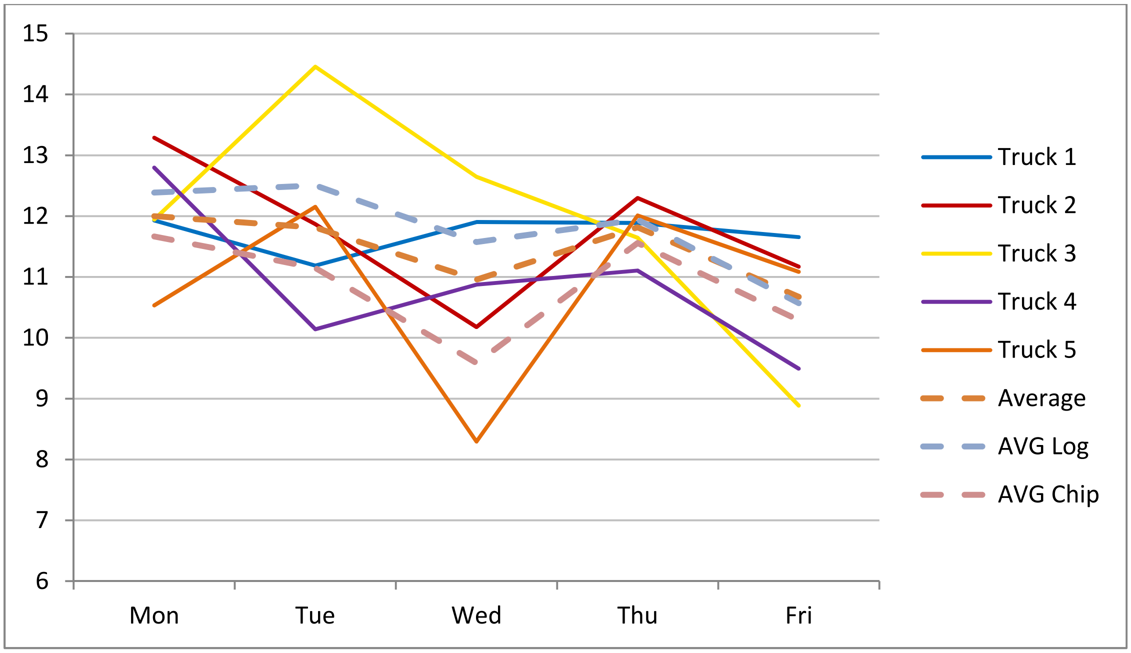

Figure 4-4- Average operating hours per day for three log and two chip trucks (derived from GPS study, 2011)

In the same study, the average daily distance traveled by log/chip trucks was approximately 270 miles and they conducted **two to three daily round trips** between harvesting/log yard facilities (origins) and destinations (paper mill or pulp mills, power plants, or private landings/yards). The trucks are typically equipped with radio and cell phone systems for logistics coordination, but GPS technology commonly used by on-road trucking is largely absent.

Trucks **move with a payload for only 30 percent of the operational time,** unless backhaul opportunities can be identified. Various types of stops can take almost 50 percent of the time, mainly due to loading and unloading activities (Figure 4-5). Unloading processes should be considered by a proposed biomass facility, as they have potential to speed up the overall supply chain. Even though unloading accounts for a smaller overall portion of stoppage time, it has larger variability, based on equipment available at the facility and the required waiting due to other unloading trucks.

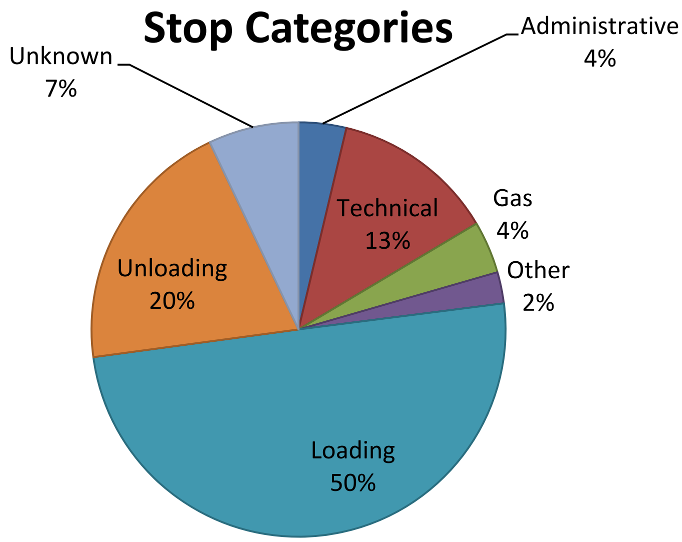

Figure 4-5- Stop categories share for log/biomass trucks (derived from GPS-CFIRE project, 2011)

4-3-3- Operational Challenges for Truck Biomass Transportation

Even though truck transportation is the main alternative for biomass transportation in Michigan, there are some challenging aspects for the operations. Some of the specific challenges are provided below, followed by a short discussion of each challenge:

- Optimized supply chain management
- Limited opportunities for backhaul movements
- Loading/unloading inefficiencies
- Bridge tolls and restrictions (Mackinaw Bridge)
- Spring weight restrictions

4-3-3-1- Optimized Supply Chain Management

Chapter 1 provided an interesting case study from Finland, where central dispatching systems based on the mobile network and real time data communications between mills, loggers and truckers were used to optimize the log harvesting and transportation. Accurate GPS devices, together with continuous updates on the levels of inventory at harvesting sites and unmet demand at the mills could be used collaboratively by truckers to identify the most productive loading sites and routes. While the recent studies in Michigan suggest that loggers and truckers coordinate effectively in transportation planning, a more technology-based approach might offer potential to improve the larger scale coordination within the industry. The main challenge for implementing systems such as the one in Finland is the shortage of mobile network coverage, the implementation cost and the potential anti-trust considerations, if a larger group was to collaborate.

4-3-3-2- Limited Opportunities for Backhaul Movements

One of the key priorities for optimizing the transportation chain is to minimize the empty miles and maximize percentage of movements with a payload. Backhauling is a common process in on-road trucking, but biomass transportation provides three challenges for such opportunities. First, the short overall trip lengths limit the potential origins for backhauls. Second, the equipment for woody biomass transportation is specialized and operates often under special registration, limiting its suitability to transport alternative materials. Finally, facility locations don't support backhaul opportunities, as harvesting areas tend to be in north and facilities in south. However, there are some success stories, such as the one mentioned by Dan Glawe on forest product movements over the Mackinac Bridge to the UP with backhaul to the LP Overall, backhauling offers some of the most promising productivity improvements available and should always be maintained under consideration.

4-3-3-3- Loading/Unloading Inefficiencies

Since most of the trucks are equipped with self-loading systems on the truck or trailers, they can load or unload material in mills, landings, plants, rail sidings and refineries. In comparison to the fixed and mechanized loading and unloading systems in the mill or plants, the self-loading/unloading is more time consuming, sometimes up to three times. Providing mechanized and modern loading and unloading systems can help to save loading/unloading times which can increase the availability of trucks. However, a tradeoff exists in the capital and operations costs of such equipment. In addition, in some cases the waiting time by trucks at mills due to congestion may pose even bigger delay for truck movements than the actual unloading procedure.

4-3-3-4- Mackinac Bridge

The Mackinac Bridge is a major restrictor of movements between the UP and LP, mainly due to weight restrictions and crossing fees. Some of the main challenges of the Mackinac Bridge include:

- Proper axle configuration requirement for trucks and trailers
- Waiting time due to reconfiguration of the heavy truck and trailers
- The total cost of $4.50 per axle ($2-$2.25/cord) to ship over the bridge (no volume or "frequent user" discounts available)
- Potential future requirement to split heavy trailers such as B-train trailers into two single trailers, if the total allowed weight is decreased from 144,000 lbs. to 100,000 lbs.

Based on the trucker interviews, woody biomass movements between the peninsulas are difficult to justify economically, unless a backhaul movement can be identified to reduce the empty miles traveled. Potential further reduction in allowable weights would make the situation even more difficult.

4-3-3-5- Spring Weight Restrictions

Temporary weight restrictions during spring break-up are a well-known challenge for any truck movement, as reduced loads decrease the productivity of the system. These restrictions form one justification for a development of a multimodal transportation system, as rail and marine transportation are not affected by the restrictions.

4-4. Railroad Operations

Railroads offer perhaps the most promising alternative for trucks in biomass transportation, even though the more limited reach of physical infrastructure, and in some cases equipment, pose challenges to its use. The following section discusses how railroads' operational features affect the overall usability of rail service to biomass transportation. A special focus is placed on shortline rail operators in the Lower Peninsula, as they are the only potential direct service providers to the nine plants proposed as part of the project.

4-4-1- Freight Rail Transportation 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. Furthermore, the majority of exported lumber and wood products originated in the Upper Peninsula and was moved by E&LS and CN railroads to Wisconsin (HNTB, 2011)

More detailed information on the role of rail transportation in woody biomass movements was obtained as part of the Logger Survey. 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 UP 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 LP

4-4-2- Rail Performance and Operations Requirements

In railroads, freight moves in trains that consist of a locomotive or locomotives and typically several cars. The main train types are unit trains, intermodal trains and manifest trains (or carload trains). Since the origins for forest biomass are dispersed, they normally move in manifest trains that transport various types of freight. However, if sufficient volume was generated within a small area, a unit train carrying only forest biomass could be considered.

Even though Michigan has almost 30 operational railroads, few of them offer high potential for woody biomass transportation services. The main opportunities for in-state movements exist in the northern part of the LP and in the UP, which eliminates a majority of rail providers. If out-of-state movements were also considered, the number of potential rail service providers would be significantly higher.

4-4-2-1- Shortline Railroad Operations

Since most of the potential woody biomass harvesting locations and all nine proposed facilities are located in the Lower Peninsula, the shortline railroads operating in the vicinity of selected locations were the main interest for rail transportation analysis. The infrastructure data obtained through a shortline questionnaire was discussed in Chapter 2 (Table 2-5) and the summary of the operational data collected in the same questionnaire is summarized in Table 4-2. The following discussion incorporates data from the questionnaire with data collected through interviews with two rail companies – Lake State Railway (LSR) and Great Lakes Central Railroad (GLC).

Table 4-2- Operational features of Michigan shortline rail operators

Rail Operator	**Operation**			
Railroad	**Number of interchange points**	**Percent of moves interchanged**	**Average Delivery Time to interchange points (In Days)**	**Average Haul Length (Miles)**
Grand Elk Railroad	4	99%	1	50
Great Lakes Central Railroad	4	98%	2	220
Lake State Railway (including Saginaw Bay Southern Rail Way)	4	Majority	1	25-90
Michigan Southern Railroad	2	100%	1.5	14
West Michigan Railroad	1	100%	1.5	2
Marquette Railway	2	100%	1-2	50-118

Some of the key findings include:

- Most public sidings available through rail providers are capable of loading/unloading biomass.
- There was a correlation with the size of the railroad and the number of interchange locations with other railroads (some interchange locations included switches with more than one railroad). It was also noticeable that almost 100% of the moves require at least one interchange from one railroad to another.
- Most railroads haul a wide variety of commodities including respondents interested in the opportunities for woody biomass hauling, but woody biomass movements seem to be non-existent.
- Railroads currently do not possess the equipment needed to move woody biomass, but they believe that equipment could be obtained, if sufficient demand existed to justify the business interaction. Railroads would be in a position to lease/purchase the cars, but they would also recommend shippers to consider obtaining their own cars.
- There is no simple or single formula for rail rates. Pricing mainly depends on quantity being shipped and distance traveled, but none of the railroads had specific rate tables for biomass moves. All interviewed companies would be interested in providing rate quotes on a case by case basis. In general, for year-round transportation, contract rates could be expected, unless the volume would be really low (a few cars per month). Tariff rates, if available, would only be used for random moves.

- Railroads can typically move a carload within one to two days from loading. If shipment requires an interchange, cars can be moved to interchange locations within a day or two, but the overall transit time depends on the other carrier's interchange schedule.
- Most shortline railroads operate seven days a week, but some shut down for the weekends.

4-4-2-2- Rail Operations in the Upper Peninsula

In addition to the shortline rail companies, CN Railroad has a history in woody biomass transportation in the Upper Peninsula. CN is currently hauling logs within the Upper Peninsula and Northern Wisconsin for various paper mills, such as Verso in Quinnesec. The log volumes transported by rail used to be higher, which has led to closure of several sidings on the network. CN is interested in increasing the biomass transportation in the area and closed sidings could easily be brought back into operation if consistent demand existed. Escanaba and Lake Superior Railroad (E&LS) has also transported woody biomass, but interchange requirements with CN to access any of the main mills are a major hindrance for economic operations.

4-4-3- Key Operational Challenges for Rail Biomass Transportation

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 4-3). 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 4-3- 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

In addition to the factors identified by loggers, additional challenges to transporting woody biomass by rail include the following:

- Transportation distances, dispersed origins and numerous rail rates
- Rail car availability and transportation time/service reliability
- Providing rail access to final destination

4-4-3-1- Transportation distances, dispersed origins and numerous rail rates

As mentioned earlier, rail transportation tends to excel in longer distance, high volume movements. In addition, the optimized operations are most easily achieved on routes where trains move consistently between a limited number of defined origin(s) and destination(s), both equipped with proper facilities. As the average distance for in-state biomass movements used in the study is expected to be less than 100 miles, efficient rail transportation would be difficult to achieve. The fact that harvesting will take place in limited quantities at numerous geographically dispersed locations further complicates the situation. It is not practical and reasonable to have direct rail access to each individual harvesting site, so trucks are used to move wood material from harvesting to the rail siding. Typical distances for such truck movements from forest landings to rail sidings range between 20-30 miles (Hicks, 2009, Lahdevaara, 2010).

According to railroad interviews and questionnaires, the majority of public sidings are capable of handling woody biomass, but some rail operators like CN don't allow for log/biomass storage in their right-of-way for liability reasons. In such locations, shippers would either conduct all loading of rail cars directly from log/biomass trucks, or make inquiries to lease the specific siding for private use. As leases tend to be for multiple years and may include maintenance costs in addition to leasing costs, this approach would only be beneficial at locations with sustainable flows and storage needs.

Another source of complication is rail rates. Rail transportation rates are rarely readily available, as they don’t typically follow simple tonnage/distance formulas. Instead, they tend to be determined for each case separately in a confidential contract agreement between shipper and rail provider, especially when larger quantities are considered. Rates are also tied to certain other requirements, such as the number of required interchanges between railroads. More detailed discussion on the importance of transportation distance and rail rates is provided as part of the transportation cost discussions.

4-4-3-2- Rail Car Availability and Transportation Time/Service Reliability

Rail car availability and interchange requirements are the two main parameters affecting the transportation time/reliability of shipments by rail. Rail car availability depends on multiple factors. Most rail cars are not dedicated to one specific rail operator or line segment, but rather operate across the whole U.S. rail system, based on demand. If shippers want to use cars that are in a general pool, the availability must be confirmed in advance by shipper and rail operator. As railroads have made a push for improved rail car utilization, they have reduced the size of these fleets by retiring old cars and tightened the rules for loading and unloading activities by customers. Today, a company is typically allowed 48 hours to load or unload a rail car, before railroads will start charging a fee (demurrage), to cover the cost of idling equipment (Cheaney, 2009).

If a shipper desires greater control of equipment to improve its availability, leasing, renting, and car-sharing are alternatives worth consideration. In addition to greater availability, there is also a smaller risk of contamination of the car, since it only carries the freight determined by the shipper. Car sharing is a suitable option for companies who have common sections of their desired route and whose shipments can share the same type of car. The actual lease arrangements range between 1-10 years and the shippers involved often need to negotiate and make an alliance or agreement with each other, including particular conditions and specifications based on their own requirements. There are several alternative types of leases, such as net lease, full service lease, per diem lease, etc. Prior to making leasing decisions, shippers should educate themselves on the alternatives to identify the best one for their situation. “How to Ship by Rail”, a publication by Cheaney, can be a useful tool in this process. It is also in the interest of railroads to have their shippers select the best equipment alternatives, so their input is essential during the decision making process.

The main disadvantages of leased cars include the following:

- Leased cars are usually more expensive than railroad-owned pool cars due to leasing cost (monthly or semiannually) or mileage credits (loaded mileages during leasing). Lack of backhaul can also increase the “relative” rail rate since most of the log and biomass cars may come back empty to the origin, reducing the loaded car miles.
- Some types of leased cars (especially tank cars) should be taken out of service every year or two for tests and inspections mandated by federal law (the car may be unavailable 2-12 weeks, depending on the location of railcar's shop and the market zone).

Rail cars can be handled from origin to destination by a single railroad, or by two or more railroads. Transfer of rail cars between companies is called an interchange and they take place if rail service at the origin is provided by a different railroad than the final destination. Typical interchange locations are rail yards, where both companies have access. Interchanges tend to increase the travel time and transportation rate for the movement. There are numerous switching/interchange points between different Michigan railroads. The majority of them are located in the Lower Peninsula, especially in the southern part of the state, in the vicinity of Detroit and Lansing. There are limited opportunities for interchanges in the northern part of the Lower Peninsula where all nine proposed biomass facility sites are located, reducing the potential for cost effective rail service that requires interchange. Thus, the most cost efficient rail movements would be those that originate in the vicinity of landings provided by the two main railroads serving the region, Lake States Railway (LS) and Great Lake Central Railroad (GLC).

4-4-3-3- Providing rail access to final destination

Rail access to the final destination can be considered a requirement for efficient biomass movements, as additional handling from rail cars back to trucks at destination would negate any potential savings gained from rail movements. Typically, industry spur tracks provide such access, branching from the closest existing mainline track. If no current rail access exists, new construction must be considered. The construction cost of the new access freight track and relevant switches is dependent on the topographic conditions of the designated area, but typically ranges between 1-4 million dollars per mile. In addition, proper storage track arrangements and sufficient space for car maneuvering should be provided within the facility. Unless there are possibilities for extensive rail freight revenues, the capital and maintenance costs for track construction fall on the facility.

4-5. Marine Operations

This section reviews the main features and requirements of marine operations related to transportation of woody biomass. It represents the main attributes of marine biomass supply chain in addition to the operations characteristics of barging on the Great Lakes.

4-5-1- Marine Transportation Records and History in the Study Area

Marine transport has a long history of serving the wood products industry in the study region. In the past, logs were moved from forest to mill using log rafts (booms and headworks) pulled by tugs and timber schooners (hookers). The log booms were capable of economically moving significant quantities of logs (Figure 4-6). The last time a log boom was in used was in 1972 when boomed logs were moved across Lake Superior from Grand Marias, MN to Ashland, WI. The increased use of trucking, inexpensive energy, and the closure of many mills located on the Great Lakes shoreline eliminated this method of log transportation. Due to concerns about the environment and liability issues with logs going adrift, it is highly unlikely that log booms would ever be used again in the study region.

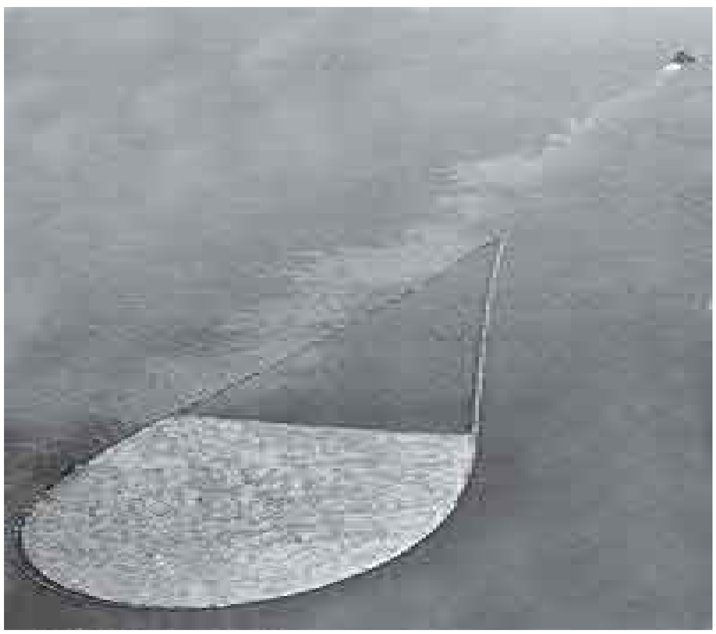

Figure 4-6- 4,000 Cord log boom on the Great Lake (Photo: Courtesy of the Lake Superior Marine Museum Association Maritime Archives at the University of Wisconsin-Superior

Research indicated that logs were transported across Lake Michigan during the 1990s by tug and barge, but the operation failed due a combination of having only short term contracts and liability issues. There have been a few more trials over the past decade, as highlighted below:

- Summer 2005 – three trip trial with Buchanan Lumber (Thunder Bay) and Sappi (Cloquet), MN, started through an already established relationship between Buchanan and Sappi, and the movement of wood chips from Thunder Bay via truck. Sappi used hardwood and Buchanan used softwood so it was an "exchange" and the barge (handled by Hallet) was loaded in both directions.

Birch logs were brought IN and pine, spruce, and balsam OUT. The operation had relatively simple requirements; approximately 300’ dock, unload/load equipment carried on the barge and forklifts as the shore side equipment. Trucks drayed product to and from the mill in Cloquet a distance of about 30 miles (Figure 4-7).

- Summer 2006 – Load to Elevator M in Superior with Buchanan and a local paper company, still with Hallett handling. Birch was brought IN and pine OUT. The last shipment Hallett handled was one to Elevator M in Superior, Wisconsin in 2006. The shipments stopped because materials were available closer, e.g. Sappi received wood from a WI mill that was shutting down. (Duluth Port Authority, 2010)

Figure 4-7- Tug W.N. Twolan and barge McAllister 132, in Duluth/Superior Harbor (Photo: Courtesy of Kenneth Newhams)

4-5-2- Marine Operations Features and Requirements

Marine transportation is a capital intensive industry with financial and regulatory barriers to entry. A new U.S. built Great Lakes commercial vessel can cost from a few million to $200 million depending on its size, (Singer, 2007). The Jones Act limits access to cargoes between U.S. ports to only U.S. built, U.S. flag, and U.S. owned vessels. Commercial traffic in the Great Lakes/St. Lawrence system is dominated by iron ore, coal, and stone with, roughly 81% of all tonnage generated by these three commodity groups, (USACE, 2010). U.S. Great Lakes marine transportation markets in break bulk cargoes, such as logs, have declined over the past decade due to low energy costs, government subsidies for road building, and the ability of railroads to operate year round.

While surplus vessels exist on the Great Lakes, they are usually designed for a specific trade. A self-propelled vessel built to haul ore, aggregate, or liquids would require extensive rebuilding to be able to efficiently and economically transport biomass in the form of logs. Analyses indicated that barges with a tug providing propulsion is the most likely vessel combination that could be used to move log biomass. The tug and barges would need to be able to cross the open lake so they will need to be certified by the U.S. Coast Guard that they are capable of sailing on the intended routes. The number of U.S. flag barges that are capable of operating on cross lake trade is limited and the number of U.S. tugs that can engage in cross lake trade is also limited. The costs of acquisition and operations compel owners to seek long term contracts and this keeps the supply of cargo and demand for tugs and barges nearly at a balance. This means that existing vessels, if available, will take voyage charters only when it does not adversely impact service for their long term customers.

Marine transportation by vessel benefits from economy of scale. The capacity of vessels is measured in the thousands of tons, exceeding the capacity of unit trains. To justify marine transportation, there needs to be a large supply of wood within a reasonable distance of the port. Operators will want to have volume to justify their use of the high capital cost vessels. Most operators will make single voyage contracts but the best rates will be for long term contracts that ensure the best asset utilization for the operator. The high volume shipments require space to store the buffer stocks on either end of the supply chain. Navigation on the lakes, and certainly the locks, is closed due to ice in winter creating the need for buffer stocks to carry the mills through a 2-3 month period unless biomass is brought in by rail during the time period. The seasonal nature further increases inventory and storage costs unless addressed by wood brought in by other modes.

Frequently, shippers use marine transportation as leverage to prevent dominance by another mode. A wood products shipper that uses rail as their principal mode of transportation may move loads by water to ensure that the option is available and also to let the rail operator know that a viable alternative is available, thus putting pressure on pricing by the railroad. Like rail, use of the marine mode will increase the handling of the logs, leading to additional costs. As presented in Figure 4-1 earlier, handling could occur as often as five times compared to two times with a direct truck run or 3-4 four times with a rail service. If the trucks are loaded directly onto the vessel, then handling will be equal to rail service. Facilities that have docks adjacent to their operations will reduce their handling to two or three times depending on storage.

Two additional items will be impacted with the use of marine transportation. Unless there is a truck scale on the loading dock, the weights will have to be estimated at the port of origin. The other impact will be that, like all modes, marine costs are most easily lowered by a backhaul cargo. Opportunities for such market should be explored in another study. An ideal use of marine transportation would be to move large quantities of biomass on routes that provide a savings in distance, energy consumption and with a landed price less expensive than truck or rail.

In summary, marine transportation of biomass material is an option where the following key attributes are met in the design of the biomass supply chain:

- Navigable waterways connecting the supply to the demand locations with a depth of at least 15 feet for barge and tug operations.
- Port infrastructure that can support the volume of traffic
- Landside access from the ports to biomass supply and demand locations
- Suitable vessels to carry the biomass in the desired quantity
- The total landed cost of using marine transportation as part of the supply chain is competitive.

4-5-2-1- Options for Optimizing Marine Transportation

To maximize the potential for marine transportation of log biomass the following criteria would have to be met:

- The biomass plant would prepare a total cost supply chain study including financial and external cost. If the result of the study found that marine transportation was a viable option for part of the biomass, then the supply chain would be configured to take long term advantage of marine transportation.
- Multiple voyage contracts would be available for qualified carriers. The longer the term (1-5 year duration) the more likely that there will be a lower marine line haul rate. Long term contracts would also allow operators to purchase or build vessels for the trade.
- Ports would have safe berths, cargo handling equipment, the ability to fuel the vessel at one of the ports, and infrastructure to move the logs from the woods or to the biomass plant. Mobile cranes would likely be suitable cargo handling equipment unless the volume justified fixed assets.
- If there were sufficient volume the marine transportation company may elect to use three sets of barges and one tug. This type of operation puts a barge(s) in each port and one underway. When the tug and barge arrive in port, the barges are switched. With this system, the tug is always moving, which is its best asset utilization, and there is always a barge to be loaded or unloaded. This system requires a dock with sufficient length to put both barges alongside.
- A marine transportation option that may reduce cargo handling costs would be to use a roll-on-roll-off (RORO) barging system. This would allow loaded log truck trailers to be driven onto the barge then secured without the tractors. Upon arriving at the destination port a yard hauler removes the loaded trailers and put them in storage or they are coupled to a tractor to be drayed to the facility. The logs would only have to be loaded once in the woods thus reducing handing costs and the need for dockside equipment. These savings would have to be high enough to offset the costs of reduced total volume on the marine line haul, additional storage area for the same volume of wood and the costs of additional trailers. RORO systems are in successful use on a number of routes.
- Storage would exist at key points in the supply chain to minimize buffer stocks required due to the seasonal nature of Great Lakes marine transportation.

- Future biomass energy plants would be built at or near underutilized ports to reduce drayage costs and maximize the economies of scale inherent in marine transportation. In this case Traverse City seems to be a logical location in terms of marine transportation.
- This study is not tasked with examining the physical distribution of the final product from the facility. There may be a viable option in shipping the ethanol by marine transportation from the tanker dock in Traverse Bay to destinations on the Great Lakes.

4-5-3 Barging Case Study on Lake Michigan

Mr. Dan Glawe from Northern Timberlands was interviewed as part of the investigations on biomass movements in the Great Lakes. The following is a synopsis of log transportation activity across Lake Michigan in the 1990's. Northern Timberlands had a three stage barge system where one barge would be loading while the second was being hauled across the lake and the third one unloading (each barge could carry about 1,200 tons of wood per load). All three duties were conducted simultaneously to minimize down time. Some wood was stock piled at the dock site to make sure there was enough wood to fill the barge at the time of loading. The company used a log loader with a 50 foot reach to load the barges and in some occasions, rocks were brought back as backhaul. When this was done, the barge would have to be cleaned in between to prevent contamination which would take about eight hours.

Northern Timberlands did find a tug and barges that they would have purchased, but the operation was halted when long term contracts could not be secured to justify the investment in the equipment. In addition, economy and market competition reduced the need for pulp wood and paper companies didn't feel comfortable committing to long term contracts. Today, similar operations would be difficult, as many of the capable harbors for these types of activities in the LP have been lost.

4-5-4- Key Operational Challenges for Marine Biomass Transportation

Since the origin and destinations of biomass transportation in the FBSCC project only moves within the state of Michigan, marine transportation is expected to play a minor role. Some of the main challenges of marine transportation include:

- Infrastructure capital costs
- Vessels: Capital and operational costs
- Marine haul business model challenges (risky business for operators)

4-5-4-1- Infrastructure Capital Costs

The decline in marine transportation has adversely impacted port infrastructure. Landside access to docks, loading equipment, water depth, and the docks themselves have not been maintained in operating condition. In some cases they have deteriorated to the point where extensive repairs or replacement would be necessary to operate at the location. Depending on which ports are used, the condition of the dock facilities may greatly increase the loading and unloading time and costs. If the proposed ports do not have shoreside loading equipment, the barge(s) will have to be fitted with cranes or front end loaders capable of loading and unloading the vessel. Barges can be fitted with this equipment but their placement increases cost, as the capacity of the barge is reduced, the equipment is subjected to the impact of spray and waves, vessel personnel need to be trained and certified in their operation, and if the barge is not in a dedicated biomass trade, the equipment will likely need to be removed and replaced for non-biomass voyages.

4-5-4-2- Vessels: Capital and operational costs

Additional vessels could be purchased or built for the biomass trade, but this will not be undertaken without a sound business plan that outlines markets, operational parameters, financials, and strategic planning. The acquisition of new or used vessels requires considerable capital that must be financed. Lending institutions are even more conservative than ship owners, especially when the overall market for marine transportation has been declining. This means that the financing providers will, in most cases, want the vessel owner to have a long term contract (charter) by a shipper before they will agree to the loan. The mortgager will also want experienced managers and preferably an existing marine transportation company with a proven track record.

The U.S. Maritime Administration (MARAD) is authorized to guarantee loans for shipbuilding thereby reducing rates and freeing up capital (MARAD, 2010). On January 16, 2009, the program made its first new commitment after almost four years of inactivity, and has approved a total of $330 million in new commitments through September 2010 (MARAD, 2010). MARAD requires a sound business plan to apply for these loans. Defaults on Title XI loans have raised the expectation that future loans from this program will have more intensive evaluations during the application process and greater oversight during the loan's term.

In addition to the usual fixed and variable operational costs, new market single voyage charters may also incur cleaning fees, barge configuration costs, and repositioning expenses. A tug and barge that is operating on a fixed route between ports, and must divert from that route to a new port, may travel hundreds of miles to reach the new port without cargo aboard (deadheading). The expenses for the deadhead voyage will have to be captured in the freight rates, making the rates for a single voyage in the new market relatively expensive. Multiple voyages on the new route allows the new market expenses to be spread over time, reducing the per ton rate.

4-5-4-3- Marine Haul Business Model Challenges

The factors and challenges discussed in the last sections compel a vessel owner to have a fiscally conservative business operation that is risk averse. This business model has resulted in the reluctance by vessel operators to provide single voyage quotes for the movement of biomass. Vessel owners interviewed also believe that single voyage charters were often offered to vessels as an inducement for rail and/or truck freight rates to remain low. Rather than seeking marine transportation as a viable option, some shippers would use the potential for low cost marine transportation as a threat to other modes.

Without exception, the owners' first response was to ask the interviewer how many years the contract would cover and the annual volume of cargo being moved between origin and destination. The second question was if there was a backhaul cargo. Without a backhaul cargo, the carrier must capture both loaded and deadhead voyage costs from one shipper. Another challenge faced by the owner is that most of their costs are largely fixed. In order to break even, the set of equipment must be fully utilized. Most of the vessel owners we contacted would not provide a single voyage price estimate as they felt a single voyage was an unrealistic proposal for a long term facility that will require millions of tons of biomass. The framework of this study did not provide volumes for O-D pairs.

The U.S. Army Corps of Engineers, in their Table 14 – Update of Fixed and Variable Vessel Costs from 2005 to 2008 Prices, provides daily cost estimates for bulk vessels operating on the Great Lakes. The smallest bulk vessel listed (class 2 Intra-Lake) had a daily operating cost in 2005 of $26,915 or $1,121 per hour, (USACE, 2010). These vessels typically carry 18,000 – 20,000 tons of cargo and travel at speeds of 15 miles per hour or 345 miles a day. The cost to deliver a cargo of 20,000 tons over a 250 mile voyage would be $.93 per ton.

While instructive of the economies of scale provided by marine transportation, this class of vessel would not be used for biomass delivery. A tug – barge combination would be most suitable for the marine transportation of biomass. During the interview process, one vessel operator provided voyage cost estimates, but with several caveats. The quoted prices do not include loading and unloading costs or voyage time because the origin and destination ports could not be guaranteed. The vessel would only call at a “safe harbor and berth” and depending on the energy market; there may be a fuel surcharge. The operator is from the Lake Superior region and their vessel is capable of biomass movements.

4-6. Transportation Service Capacity for Proposed Biomass Plants

Nine potential locations for cellulosic ethanol facilities were identified within the Lower Peninsula of Michigan as part of the FBSCC project. The capacity of each facility was estimated to be between 30-50 million gallons. Even though detailed analyses of transportation requirements for each specific plant were beyond the project scope, the research team developed preliminary estimates to quantify the number of loads and equipment required to provide woody biomass to the facilities. The team used plant operational conditions provided by researchers in Task B4, together with equipment load capacity and performance data to quantify the equipment needed. Some of the key assumptions in the analysis included:

- Plant sizes: 30, 40 and 50 million gallons and green tonnage requirements of 750,000 tons, 1,000,000 tons and 1,250,000 tons, respectively.
- Based on previous studies, trucks typically operate five days per week. However, analyses were developed for five, six and seven day weekly operations.
- Annual facility operates 50 weeks per year (two weeks for maintenance).
- All trucks hauling into the plant would be 10 or 11 axle trucks with a gross vehicle weight of 164,000 lbs. (with an empty weight of 55,000 lbs.). The trucks would be eligible to carry a total weight of 105,000 lbs. (52.5 tons) of woody biomass per truck. As a safety factor for truckers to not reach the overweight mark, 50 ton /truck are used.

- All material would be provided in the Lower Peninsula, so there would be no need for movements over Mackinac Bridge.
- Standard rail car holds between 75 and 85 tons of material. The analyses used 80 tons per car. Estimated at 1 delivery trip per week.
- For marine transportation, barges were identified to hold between 1,000 to 3,000 tons of material on deck. The analyses used three 1,000 ton capacity barge that serves the mill per week.
- Cord of wood would weigh 2.35 tons/cord (local forestry industry accepted factor)(Hicks 2009).
- Trucks can deliver two loads per day to the plant and to/from barge dock facilities and three loads per day to rail sidings. All material from origin to barge dock facilities and docks to final destinations are handled by trucks.
- Transportation of final products was not considered, even though potential backhauls of final products might provide economic benefits for rail and marine transportation. The analysis considered three different transportation scenarios for woody biomass:
- Scenario 1: 100% truck delivery
- Scenario 2: 80% by truck and 20% by rail
- Scenario 3: 60% by truck, 28% by rail and 12% by barge

Since rail cars and barges cannot pick loads up directly from the harvesting sites, trucks will have to deliver the biomass to the loading sites. The truck productivity for these deliveries is explained above and in Figure 4-8 and Figure 4-9. Additional requirements for these movements were included in the estimates.

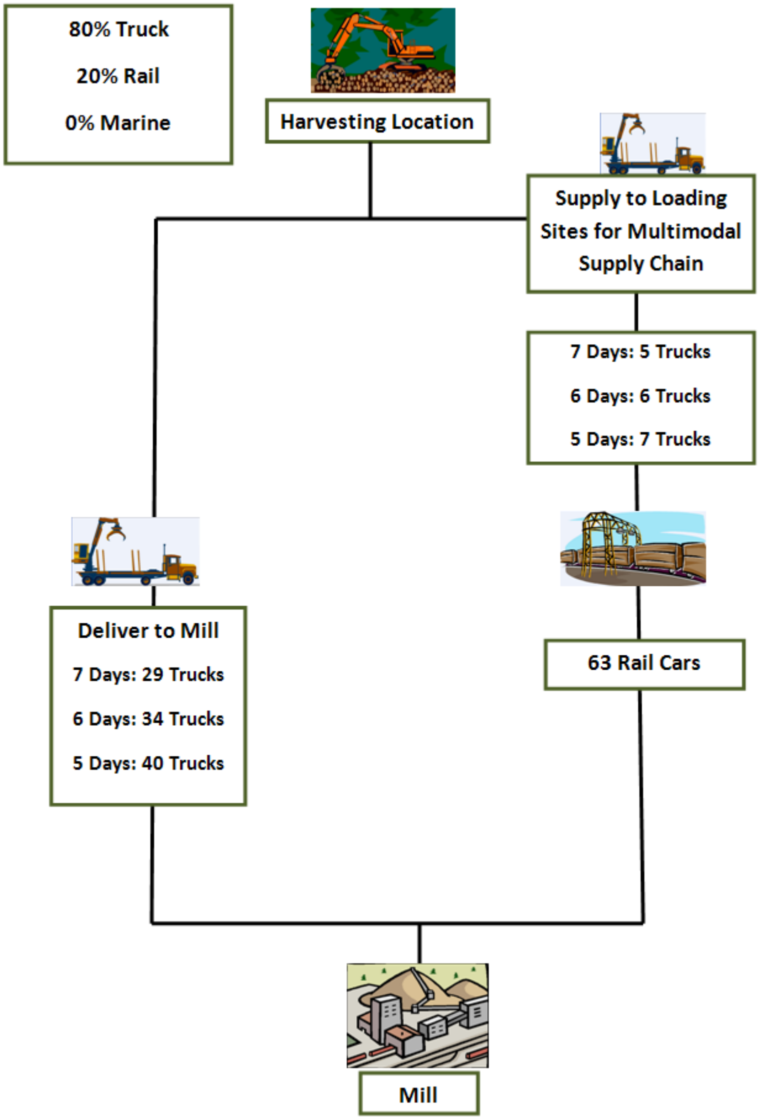

Figure 4-8- Scenario 2: Number of trucks needed to fulfill supply chain for 50 million gallon facility

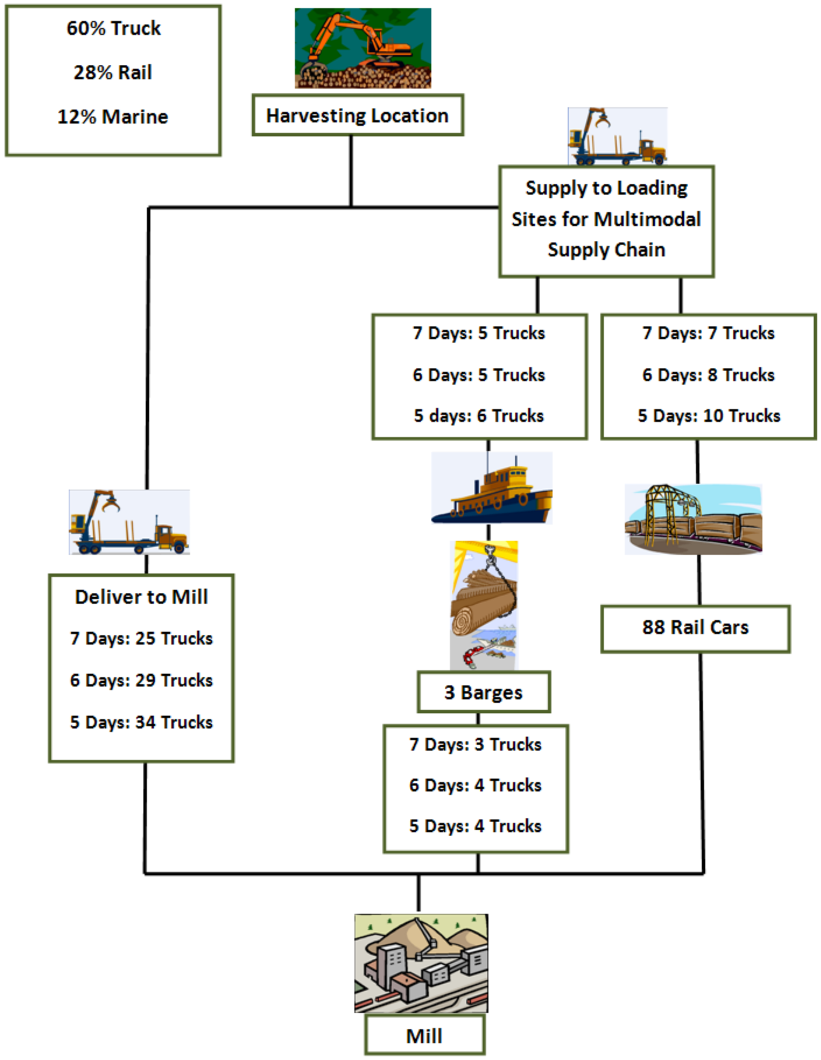

Figure 4-9- Scenario 3: Number of trucks needed to fulfill supply chain for 50 million gallon facility

Table 4-4 presents total volumes and load quantities for each alternative. 500 truck loads are necessary weekly to deliver needed material for 100% truck alternative. With 7 day service, the plant needs 36 trucks per day to support tonnage requirements, 42 trucks per day for 6 day service and 50 trucks per day for 5 day service (Table 4-5).

Transportation Mode	Percent of Tonnage Delivered by Mode					Tons/ Week Needed	Number of Truck Loads/ Week	Number of Rail Cars Loads/ Week	Number of Barge Loads/ Week	Delivery Mode from Marine shipment to Mill	
	Truck	Rail	Marine Transportation Delivery							# Trucks Loads to Mill (from barge delivery)	# Rail Cars to Loads mill (from barge delivery)
			Marine	Truck	Rail						
Truck	100	0	0	0	0	25,000	500	0	0	0	0
Truck and Rail	80	20	0	0	0	25,000	400	63	0	0	0
Truck, Rail and Marine	60	28	12	100	0	25,000	300	88	3	60	0

For 80% by truck and 20% by rail alternative, 400 truckloads and 63 rail cars are required to supply the necessary demand. Trucks needed to deliver material to rail sidings are 5, 6 and 7 (7, 6 and 5 day service); trucks needed to deliver to the mill are 29, 34 or 40 trucks to the plant (7, 6 and 5 day service). For 60% truck, 28% rail and 12% Marine alternative, there is a greater usage of multimodal transportation within the delivery process. Demands equal to 300 truckloads, 88 rail car loads and 3 barges (100% deliver by truck to plant location from barge). At 7 day service the plant needs 36 trucks per day to support tonnage requirements, 42 trucks per day for 6 day service and 50 trucks per day for 5 day service (seen in Table 4-5).

When truck and rail are used, there is a decline in the number of trucks needed due to shorter delivery distances (a single truck can make more trips, cutting down on the number of trucks needed). However, inclusion of marine transportation doesn't further decrease the number of trucks, as it was assumed that only two rounds trips can be made by truck to dock facilities. However, marine transportation would expand the radius of potential feedstock availability.

Table 4-4- Total Load Tonnages Needed by Mode

Transportation Mode	Percent of Tonnage Delivered by Mode					Tons/ Week Needed	Number of Truck Loads/ Week	Number of Rail Cars Loads/ Week	Number of Barge Loads/ Week	Delivery Mode from Marine shipment to Mill	
	Truck	Rail	Marine Transportation Delivery							# Trucks Loads to Mill (from barge delivery)	# Rail Cars to Loads mill (from barge delivery)
			Marine	Truck	Rail						
Truck	100	0	0	0	0	25,000	500	0	0	0	0
Truck and Rail	80	20	0	0	0	25,000	400	63	0	0	0
Truck, Rail and Marine	60	28	12	100	0	25,000	300	88	3	60	0

Table 4-5 - Truck Capacity Numbers Needed

Mode	Total Trucks to Deliver Multimodal Supply/ Days of Service			Total Trucks to Deliver to Mill/ Days of Service			Total Trucks Needed/ Days of Service		
	7	6	5	7	6	5	7	6	5
Truck	0.0	0.0	0.0	36.0	42.0	50.0	36.0	42.0	50.0
Truck, Rail	5.0	6.0	7.0	29.0	34.0	40.0	34.0	39.0	47.0
Truck, Rail &Marine	11.0	13.0	16.0	25.0	29.0	34.0	36.0	42.0	50.0

Based on the data collected on available trucks for biomass transportation in the Lower Peninsula, 50 trucks would account for more than 10% of the overall fleet, suggesting that necessary trucking capacity to support a single biomass plant exists in the Lower Peninsula. During the interviews, industry experts suggested that equipment in the Lower Peninsula is currently underutilized due to closure of several plants. However, if all nine proposed plants were established, they would need the whole LP truck fleet, putting pressure on new investment on trucking equipment. Similar analysis for rail equipment was not conducted due to interstate nature of the equipment but securing 60-80 cars for continuous should be manageable.

An analysis of Table 4-6 indicates that from a highway distance perspective, the ports of Charlevoix and Traverse City offer the shortest highway routes for biomass delivered by vessels to final destinations. Marine transportation of biomass to the potential facilities has the greatest potential when moving biomass from Lake Michigan ports on the Upper Peninsula of Michigan to Michigan ports on the east coast of Lake Michigan. Total distances needed to transport the biomass are, in some examples, reduced by more than two thirds. The potential cost savings may provide an opportunity to make the UP wood basket a viable source of biomass for the Lower Peninsula of Michigan. While the port of Bay City would serve Clare and West Branch with the shortest drayage, the longer water route from origin ports negates any potential savings.

Table 4-6- Distance between Origin and Destination Michigan Ports Comparative Analysis [10]

Michigan Origin –Destination Pairs via ports	Miles Marine mode – statue miles	Drayage	Combined miles	Direct Highway miles
Escanaba to Manton via Traverse City	91	37	128	267
Escanaba to Manton via Frankfort	91	64	156	267
Escanaba to Kalkaska via Traverse City	120	25	145	241
Escanaba to Kalkaska via Frankfort	91	44	135	241
Escanaba to Mancelona Via Charlevoix	91	31	122	227
Escanaba to Kingsley via Traverse City	120	17	137	264
Escanaba to Kingsley via Frankfort	91	38	129	264
Menominee to Kingsley via Traverse City	138	17	97	317
Escanaba to Clare Via Bay City	129 + 210	48	387	291
Escanaba to West Branch Via Bay City	129 + 210	52	391	272
Ontonagon to Kingsley via Traverse City	274 + 90 +97	38	499	410
Ontonagon to Mancelona Via Charlevoix	274 + 90 + 56	31	451	360
Ontonagon to Boyne City Via Charlevoix	274 + 90 + 56	32	452	331
Ontonagon to Clare Via Bay City	274 + 246	48	568	423

4-7. Biomass Transportation Costs

Supply chain cost analysis is a complex process with potential to provide a competitive advantage to a firm when properly done. No mode should be selected without a supply chain cost analysis. This section provides a review of the cost estimation methods for biomass transportation, considering both single mode and multimodal options. It reviews standard formulas for cost estimation, followed by more detailed discussion and a case study

10 : Distances Between US Ports, 10th Edition, National Oceanographic and Atmospheric Administration, Washington DC, 2009, Mapquest accessed 2011.

on specific modal rates for biomass transportation in the state of Michigan. It should be noticed that the variables in these formula will need to be calibrated and computed to determine the lowest landed cost for any proposed biomass supply chain.

4-7-1- Lowest Landed Cost Estimation

In transportation, landed cost refers to the final price of a product delivered to the final destination. The total cost components include transportation, handling, storage, ordering, and inventory. Businesses spend considerable resources to calculate landed cost of a product and are acutely aware that this cost is not static. The total cost can be impacted by a large number of factors outside the control of the industry. Just-in-Time business models may work when transportation costs are low and the product value is high, but increases in transportation costs such as fuel may cause industry to rethink their supply chain model and carry more inventories to reduce the transportation cost side of the equation.

To minimize their landed cost, industries use several calculations. Buffer and safety stock costs are calculated using the formulas provided in Figure 4-10. Economic Order Quantity and inventory costs are calculated using the formulas in Figure 4-11 and finally, the total landed cost can be calculated using a formula presented in Figure 4-12 (Coyle, 1996).

Computing Safety Stocks

$$S_{Dt} = \sqrt{(t)(S_D)^2 + (D)^2\,(S_t)^2}$$

Where:

- S_{Dt} = Units of Safety Stock required to satisfy 68 percent of sales levels during lead time
- t = Average delivery time
- S_t = Standard Deviation of delivery time
- D^2 = Average Demand
- S_D = Standard Deviation of Demand

Figure 4-10- An example of computing buffer and safety stocks

Total Cost = OC + CC

OC = Order Placement Cost = A(R/Q)

CC = Inventory Carrying Cost = 1/2(QVW)

Where:

- Q = Optimal Order Quantity (EOQ)
- A = Cost of placing an order
- R = Annual Rate of use
- V = Value per unit
- W = Carrying cost as a percentage of average value of inventory

$$EOQ = Q^* = \sqrt{\frac{2AR}{VW}}$$

Figure 4-11- Economic Order Quantity and inventory costs

Total Cost Analysis

Total Cost = OC + CC + Tr + PC + It + SS + Other

OC = A(R/Q)
CC = 1/2(QVW)
Tr = rRwt/100
PC = VR
It = iVRt/365
SS = BVW
Where:
Q, R, A, V, W = As previously defined
r = Transportation rate per 100 pounds (CWT)
wt = Weight per unit
i = Interest rate or cost of capital
t = Lead time in days
B = Buffer of inventory to prevent stockouts

Figure 4-12- Landed (total) cost calculation

4-7-2- General Equation for Transportation Cost Estimation

Figure 4-13 presents a simplified formula for determining the charge (or price) per ton of biomass shipment by any transportation mode.

Transportation Charge Formulas:

$$1: \quad \textbf{Rate per mile} = \frac{\textbf{Fixed costs} + \textbf{vehicle costs} + \textbf{profit margin}}{\textbf{Miles}}$$

$$2: \quad \textbf{Haul cost} = (\textbf{rate per mile}) \times (\textbf{distance})$$

$$3: \quad \textbf{Total Annual Haul cost} = (\textbf{Price per ton}) \times (\textbf{Total number of tons delivered})$$

Figure 4-13- Total cost formula for biomass transportation

It should be noted that additional “variable costs” may be added to the formula. Such costs may include interchange fees by railroads when shipments move from one carrier to another, clean up fees by barge operators and even increased mileage charge by truckers due to substandard access roads. There may also be surcharges, such as fuel surcharges, to protect carriers from fluctuations in operating expenses.

4-7-3- Cost Estimation for Truck Transportation

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 to assess transportation costs in the LP Several rates were obtained earlier for Upper Peninsula transportation. Movements that cross the Mackinac Bridge should receive $4 per cord additional fee to cover the crossing fees. The rates provided are for single-directional movements. Potential backhauls or circuitry routes that increase loaded miles have potential to reduce the rates.

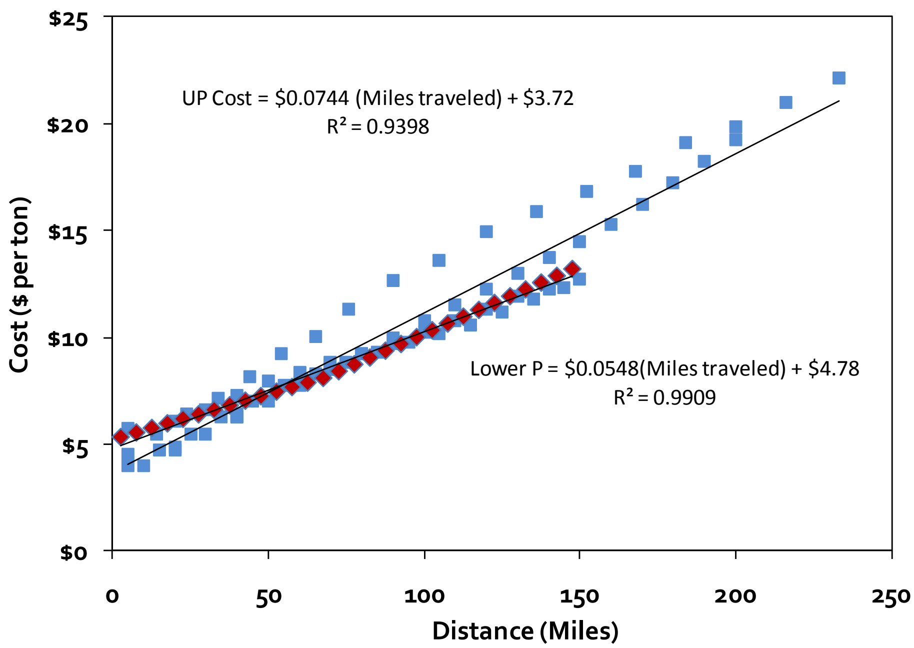

Figure 4-14- Lower Peninsula round wood transportation cost (red) as compared to aggregated costs for several Upper Peninsula trucking companies (blue).

4-7-4- Cost Estimation for Bimodal (Rail/Truck) Transportation

For rail transportation, rates are not as easy to determine as for trucks, since every rail service provider has a specific policy and rate to charge customers. 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 typically estimated case-by-case for each origin-destination pair. Typically, the rail transportation rates are formed based on following criteria (Cheaney, 2009):

- **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 for the study, as specific quantities and origin-destination pairs would have to be identified for the proposed facilities. However, as part of a recent study in the UP, a computer model was developed by a graduate student at Michigan Tech (Hicks, 2009) to combine knowledge of rail and truck rates with geographic information and further to attempt to optimize the transport of logs between a defined origin/destination pairs. The model was tested on 100,000 actual truck trips and has further been expanded to evaluate transportation cost to a specific destination in Kinross. The following section provides a short case study on the model and how it can be used for bimodal transportation rate estimations in Michigan.

As part of his study, Hicks was able to determine some of the tariff and contract rail rates offered by CN Railroad in the UP. These tariff rates were developed directly from the CN web site and contractual rates were derived from the Lake States Shippers Association (LSSA) data. Figure 4-15 presents the tariff rates and respective contract rates utilized in the analysis. 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 quantity being shipped. Figure 4-16 combines the rail cord truck rates to form the bimodal rates. The analysis of truck data revealed that logs move on average 20 miles before they 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 4-16 reveals that truck transportation in the UP is more cost efficient than the bimodal alternative with trips under 130 miles of total (combined truck and rail) distance. 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 (Lahdekorpi, 2010).

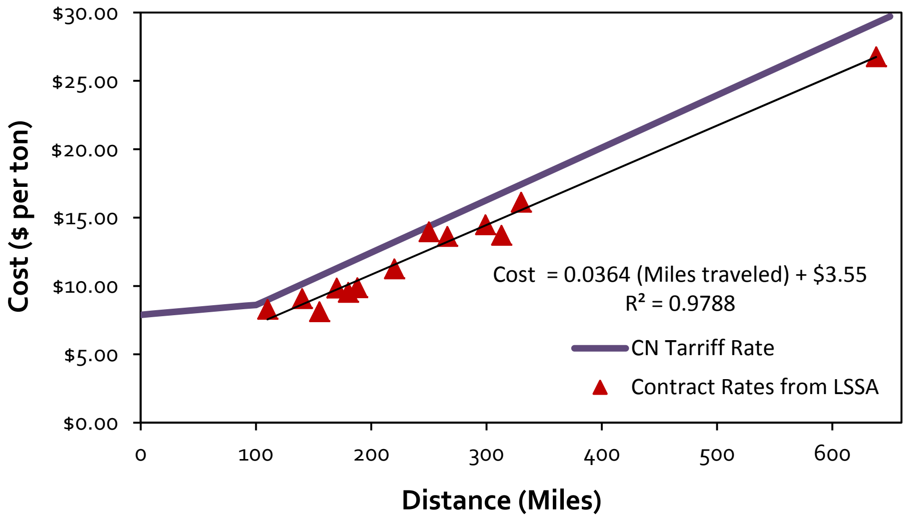

Figure 4-15- CN tariff and contract rail rates in the UP of Michigan

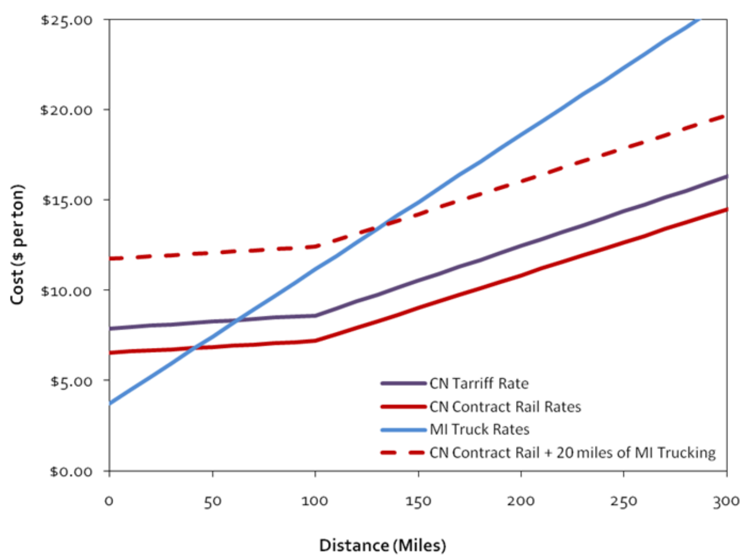

Figure 4-16- Comparison of trucking and bimodal transportation rates in the UP of Michigan

In addition to comparative rate calculations, "cost gradient maps", such as the one presented in Figure 4-16 can be developed for larger scale planning analysis to evaluate the general costs of transportation for a specific destination. Figure 4-17 demonstrates one example of such comparisons by presenting expected transportation rates to Kinross, when bimodal transportation alternative is or is not available. The figure shows how available rail lines and sidings expand the lower cost area of transportation origins along the rail corridors. In the example case, the entire UP was divided into 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.

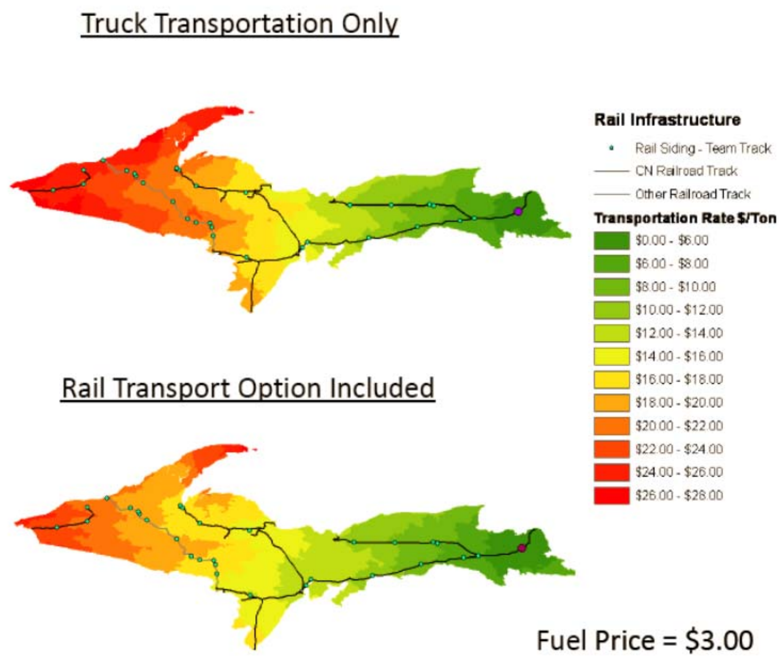

Figure 4-17- Transportation cost gradient maps of log shipments from the Upper Peninsula of Michigan to proposed facility in Kinross.

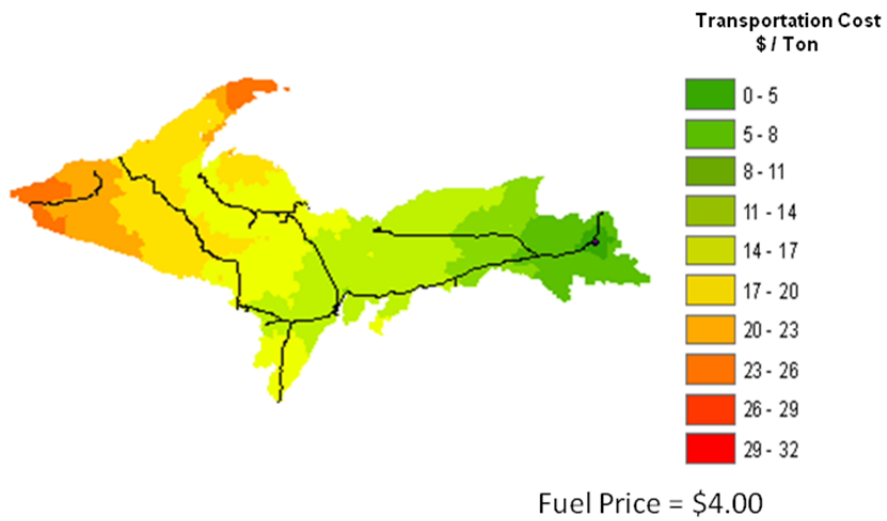

Figure 4-18- Cost gradient map for the UP of Michigan. Fuel price = $4.00.

A comparison of transportation costs per ton for single mode versus bimodal transportation is presented in Table 4-7 and Figure 4-19 in 30 miles increments and with different fuel price scenarios. The table reveals that increase in transportation distance causes a decrease in the percentage of trips that move by truck only. In order to demonstrate the cost savings from the price-optimized use of bimodal transportation options, the aggregated, optimized trip cost (using bimodal trips when cost-effective) can be compared to the single-mode truck cost, which uses truck transportation for every trip (Column "Single mode" in Table 4-7). In longer trips, the two prices begin to deviate and a greater portion of traffic should be moved by bimodal trips. The aggregated bimodal average price appears to be lower for trips above 90 miles in this scenario.

Table 4-7– Transportation cost summary for different transport scenarios, UP case study

	Cost of transport, $ per ton					
	Fuel price = $3/gal		Fuel price = $4/gal		Fuel price = $5/gal	
Transport Distance [a] (miles)	Single Mode	Bi-modal (Optimized [b])	Single Mode	Bi-modal (Optimized)	Single Mode	Bi-modal (Optimized)
0-30	5.26	5.26	5.48	5.48	5.71	5.71
30-60	7.17	7.17	7.67	7.67	8.17	8.17
60-90	9.69	9.69	10.55	10.55	11.42	11.40
90-120	11.95	11.69	13.14	12.46	14.34	13.01
120-150	14.25	12.36	15.77	12.82	17.30	13.28

a – mileage categories represent over-the-road trucking distances

b – optimized, 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.

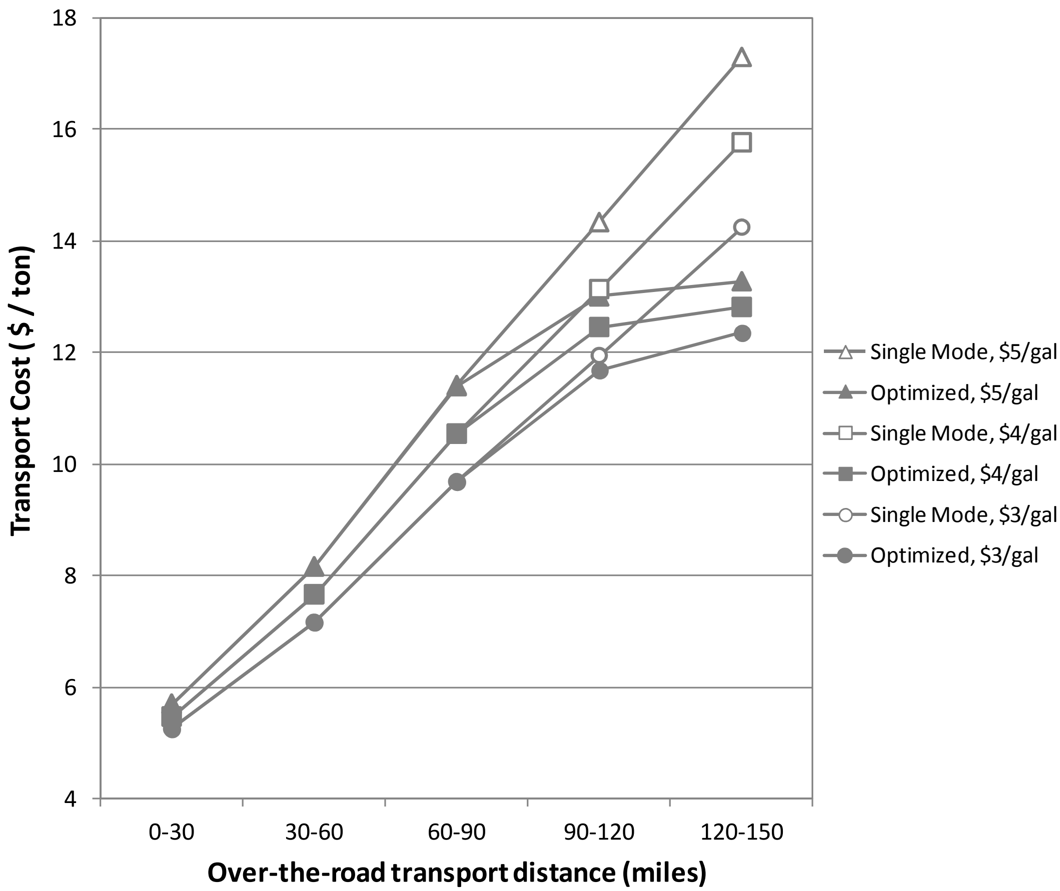

Figure 4-19- Summary of transportation costs for different fuel prices and transport scenarios for the Upper Peninsula case study.

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. This extra handling step represents an additional cost that will have to be considered in the bimodal transportation option (Figure 4-20). According to industry estimates, the estimated additional unloading/loading cost is $4.00-$6.00 per cord. 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 (data not shown).

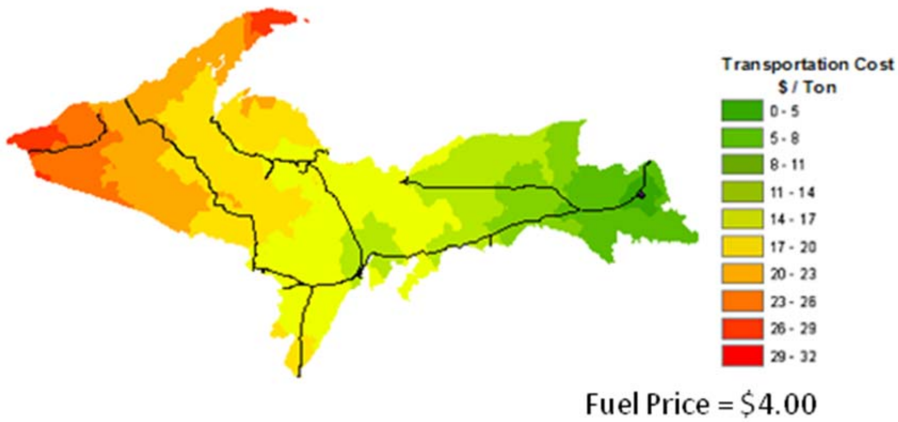

Figure 4-20- Cost gradient map with additional handling, Fuel price = $4.00.

Similar analysis was also conducted for material transported to Kinross from the Lower Peninsula. For these movements, the only transportation alternative is trucking, due to the requirement of crossing the Mackinac Bridge. Table 4-9 summarizes truck transportation costs from the Lower Peninsula, based on unit cost rates obtained from the LP, at a fuel price of $4.00.

Table 4-9- Trucking Costs from the Lower Peninsula

Trucking distance (miles)	Single Mode Only $ per ton (Fuel Price = $4.00)
0-30	--
30-60	10.72
60-90	12.25
90-120	14.38
120-150	16.38

A transportation cost gradient map that demonstrates the sensitivity of shipping costs to fuel prices within almost the entire project supply area is included in Figure 4-21. 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.

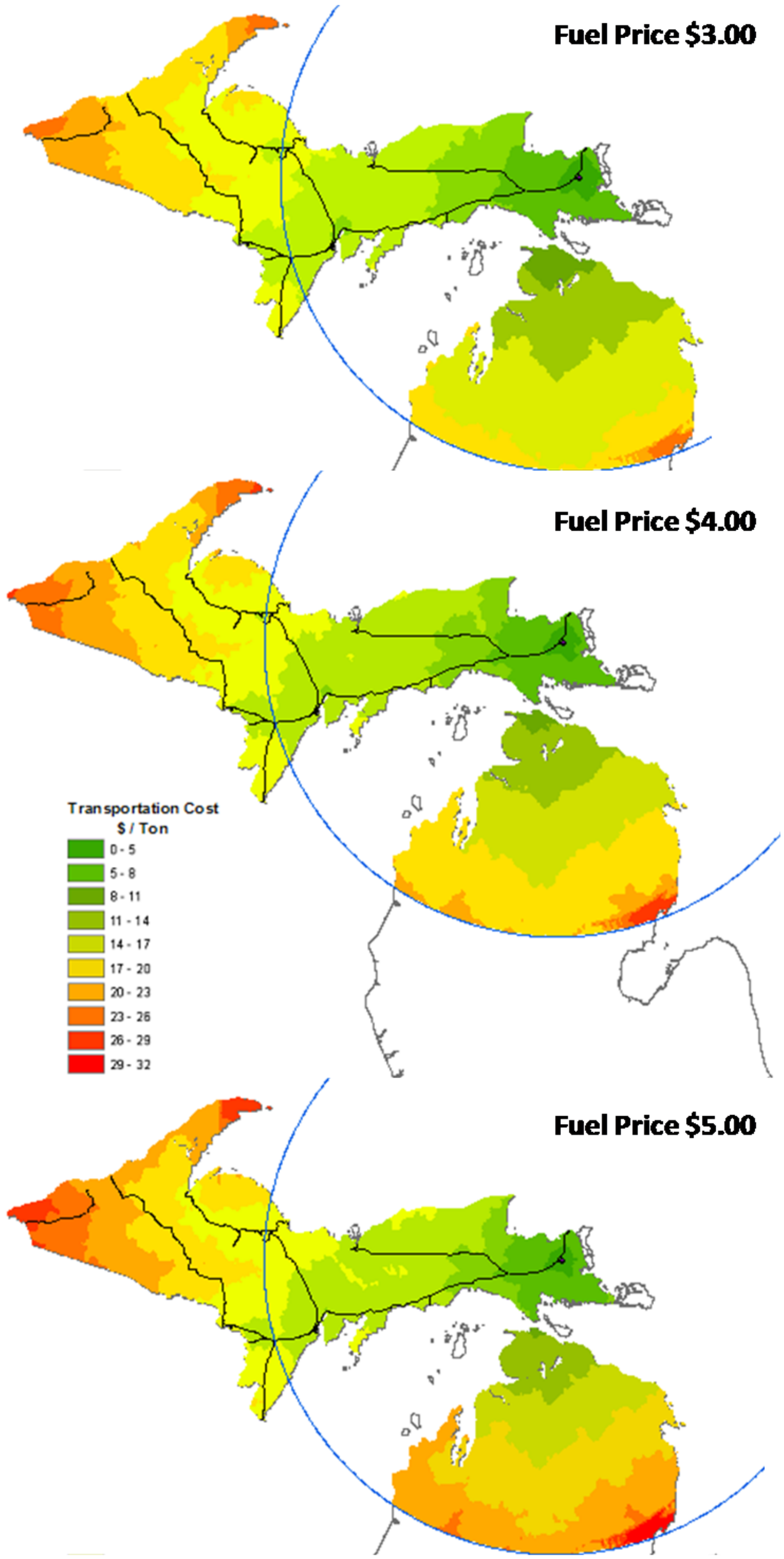

Figure 4-21- Transportation cost gradient maps with fuel prices of $3.00, $4.00, and $5.00. Blue circle indicates 150-mile distance from Kinross facility.

4-7-5- Marine Transportation Cost Estimation

Marine rates follow the transportation cost formulas explained earlier in the section. For biomass movements, tug and barges can transport logs at a quoted price of $120 per mile by a tug and barge with 1,000 tons load capacity. The following table (Table 4-8) provides a comparison between truck and marine on certain Lake Michigan ports and the potential facilities. The truck rates were calculated both using generic truck freight rates and specific rates provided by Michigan log truck service providers.

Table 4-8- Comparison between line haul truck and marine rates

Michigan Origin Destination Pairs	**Marine distance in statute miles**	**Quoted rate per mile**	**Distance x per mile rate = line haul cost**	**Total tons transported each voyage**	**line haul cost/total tons = price per ton***
Escanaba to Manton via Traverse City	120	$120.00[1]	**$14,400**	1000	$14,40
Truck - Escanaba to Manton (Generic freight rates)	***267***	***$2.27[2]***	***$606.90***	***25[3]***	***$24.25***
Truck - Escanaba to Manton (Michigan Log truck rates)	***267***	***Cost per ton = $3.72 + $0.074(mi) + $1.70 toll***			***$25.18***
Escanaba to Manton via Traverse City	**120**	**$120.00[1]**	**$14,400**	**2000[4]**	**$7.20**
Escanaba to Manton via Traverse City	**120**	**$120.00[1]**	**$14,400**	**3000**	**$3.60**
Escanaba to Kalkaska via Frankfort	**91**	**$120.00**	**$16,200**	**1000**	$16.20
Truck - Escanaba to Kalkaska (Generic freight rates)	***231***	***$2.27***	***$524.37***	***25***	***$20.97***
Truck - Escanaba to Kalkaska (Michigan Log truck rates)	***231***	***Cost per ton = $3.72 + $0.074(mi) + $1.70 toll***			***$22.51***
Escanaba to Kalkaska via Frankfort	**91**	**$120.00**	**$16,200**	**2000**	**$8.10**
Escanaba to Kalkaska via Frankfort	**91**	**$120.00**	**$16,200**	**3000**	**$5.40**

[1]This price does not include storage, loading and unloading expenses.

[2]Freight rate index cost-per-mile increased to $2.27 in December 2010, up from $2.24 in November 2010. *(This Cost Per Mile (CPM) indicator is comprised of 8 main and 65 total cost and cost influencing components, it considers completely, every cost related to freight transport by land)* *http://www.sgrc.us/Transportation/documents/LogisticsMarketSnapshotDEC2010.pdf* However, This cost does not include bridge tolls crossing the Mackinaw Bridge.

[3] The 25 ton payload assumes an 80,000 pound gross vehicle weight limit.

[4]The primary costs will be in the tug operation which will have some increases in variable costs. This assumes a single barge with at 1,000-3,000 ton capacity. The addition of more barges would likely raise this price.

The truck rates are calculated based on the obtained rates for Michigan log trucks, although it is questionable whether these rates would be valid for these longer trips, or if generic over the road trucking rates should be used instead of short haul log rates. Most log trucks stay within a 100 mile radius of a mill minimizing deadheading time. The marine line haul rate quoted does not include loading, unloading, drayage, and storage costs. Drayage will depend on the port and mill locations. These factors may raise the cost of the marine operation substantially and should be considered in the final supply chain analysis. The drayage from Traverse City to Manton is approximately 37 miles and will require 40 truck movements for each 1,000 ton marine cargo unit delivered. A truck will be able to move about 4 loads in a day on that route with favorable weather and traffic conditions. This means that a single truck will require 10 days to dray the marine load to Manton or 5 trucks will move the load in 2 days or less. At a $2.27 per loaded mile rate the extra cost of drayage would be:

40 truckloads x 37 miles x $2.27 loaded per mile rate = $3,359.60

The drayage cost from the woods to the origin port docks cannot be computed without exact wood supply location data, but assuming a like distance, origin drayage costs for a 1,000 ton wood movement would be $6,719.20. This would in effect increase the Escanaba-Traverse City-Manton marine per ton line haul rates for a 1,000 ton marine load to $21.12 per ton. This is a rate still below the truck rate.

$6,720 drayage + $14,400 line haul = $21,120 combined cost/1000 tons = $21.12 combined per ton rate

Economics of scale by using larger barges would not impact the combined drayage costs but would have the ability to diffuse the drayage cost when computing the final landed cost. For instance, the drayage costs for a 3,000 ton marine load would be $20,157. This would in effect increase the Escanaba-Manton marine per ton line haul rates for a 3,000 ton marine load to $11.59 per ton. This is a rate significantly lower than all truck rates.

$20,157 drayage + $14,400 line haul = $34,577 combined cost/3000 tons = $11.59 combined per ton rate

At the quoted marine line haul rates coupled with drayage costs there appears to be some saving on the cited routes in using marine transportation for loads of 1000 tons. However, when the marine loads are increased to 2000 and 3000 tons, then marine transportation can provide a significant value added proposition for line haul rates. This assumes that the tug barge combination could move 2000 tons at, or near the quoted per mile rate. Frequently tugs that can haul a 1000 ton barge can haul barge(s) of up to 3000 tons with minimal increase in variable costs for fuel. This also assumes that the capacity of the barge can be from 1-3,000 tons. For the economies of scale to work, the supply chain would have to be able to cost effectively, and efficiently deal with single cargos of that volume moving in the system.

This financial analysis clearly indicated the financial benefits that can accrue from making use of the economies of scale and routes that marine transportation can provide for appropriate cargoes and supply chains. However, this would require movements from the UP to the LP or vice versa.

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Appendix

Appendix can be found in separate included document