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Comparative Life Cycle Assessment of Road and Multimodal Transportation Options – A Case Study of Copperwood Mine Project

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Comparative Life Cycle Assessment of Road and Multimodal Transportation Options – A Case Study of Copperwood Mine Project

Introduction

Freight transportation of goods and commodities is a necessity and often accounts for a significant portion of the overall investment in the industrial development, especially in the natural resource industry. Further, the transportation industry is a major contributor to the global greenhouse gas (GHG) emissions. Although 'tailpipe' emissions represent a major share, several studies have indicated that the emissions from the construction and maintenance of infrastructure and equipment also play an important role. With almost all activities of transportation projects contributing to emissions, it is essential that the new freight transportation facilities and operations use alternatives that minimize energy consumption and emissions throughout the project life cycle.

The economic costs of developing an infrastructure have long been factored into the project costs, but environmental and/or social impacts have received less attention. In addition, alternative transportation modes are rarely compared from both economic and environmental perspectives. This project uses a case study to assess the environmental impacts (emissions) of different transportation options for transporting ore between a planned copper mine (Copperwood, MI) and a processing plant (White Pine, MI), and concentrate from the processing plant to an intermediate location (Escanaba, MI). The ore transportation options include a truck only option and two multimodal (truck-rail) options, while the concentrate transportation options include truck only, rail only and one multimodal (truck-rail) options.

This study uses a process called Life Cycle Assessment (LCA) to estimate the overall life cycle emissions for all different transportation alternatives considered for the Copperwood Project. This LCA is performed using SimaPro software covering construction, operations, maintenance, and end of life phases of the infrastructure and equipment involved. The results are obtained in terms of kilogram equivalents of CO2 (kg CO2eq) and represent the 100 year Global Warming Potential (GWP) of the greenhouse gas emissions. In an attempt to facilitate incorporation of these results into economic studies like Life Cycle Cost Analysis (LCCA), they are converted into cost factors (US dollars) using the "social carbon unit costs" published by U.S. Environmental Protection Agency.

The final part of this study focuses on understanding three different aspects of economic evaluation of alternatives. Firstly, State agency (MDOT) decision making perspective, by discussing the general objectives of the MDOT when determining support for transportation alternatives, and reviewing two specific DOT programs available to support projects similar to Copperwood, namely Transportation

Economic Development Fund (TEDF) – Category-A, and Freight Economic Development Program (FEDP). Secondly, reviewing the currently available software for conducting economic analysis of transportation projects in the U.S. The final section includes a brief discussion on the economic analysis considerations for Copperwood project, including MDOT support mechanisms.

Case Study

Copperwood project is a proposed Copper mine in Gogebic County, which is located in the western upper peninsula of Michigan. The mine is expected to produce about 2.7 million tons of ore annually (7,000 tons per day). The ore is to be transported to a processing plant in White Pine where it would be converted to concentrate. The quantity of concentrate produced after processing is 10% of the ore volume or approximately 270,000 tons annually. The concentrate is transported from White Pine to a currently unidentified location for further processing. It is expected that the concentrate transportation will travel through Escanaba, which is a regional transportation hub with good ship and rail connectivity.

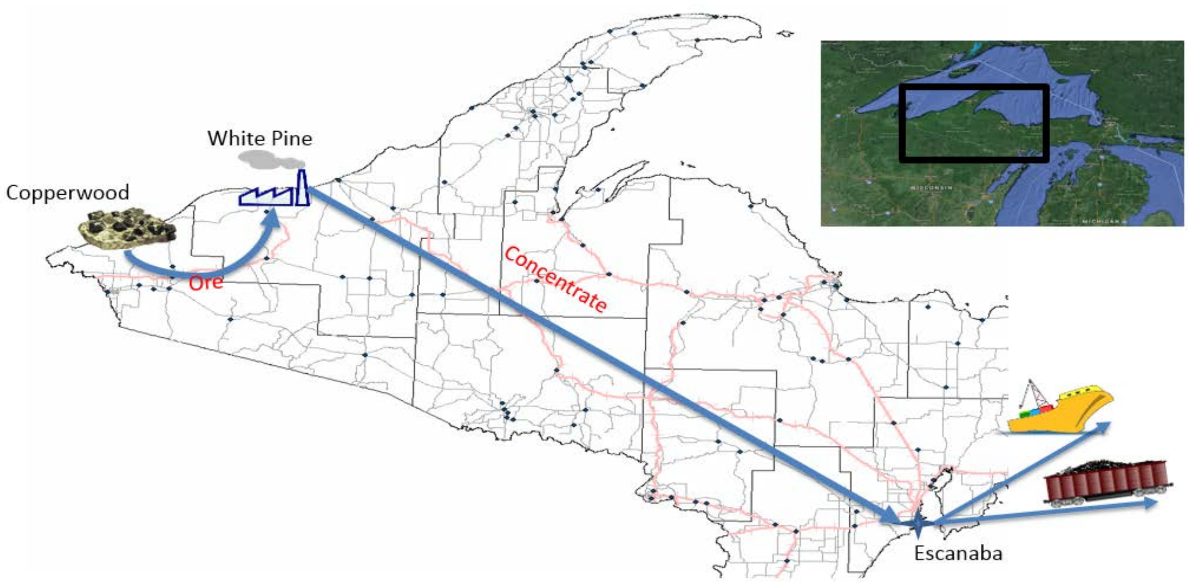

Figure 1: Location Map of Copperwood, White Pine and Escanaba

The scope of this study is to evaluate alternatives for transportation of Ore between the mine (Copperwood) and processing plant (white pine) and concentrate up to Escanaba. Figure 1 gives the details of various locations involved.

Three different route alternatives for each of the two stages of transportation were selected. Ore transportation options include a truck only option (option A) and two multimodal (truck-rail) options (B&C), while the concentrate transportation options (D-F) include truck only, multimodal (truck-rail) and rail only options. Figures 2 and 3 provide the highlights of each alternative. LCA is performed on these alternatives to estimate GHG emissions over several possible mine lives (10, 20, 25, 30 years).

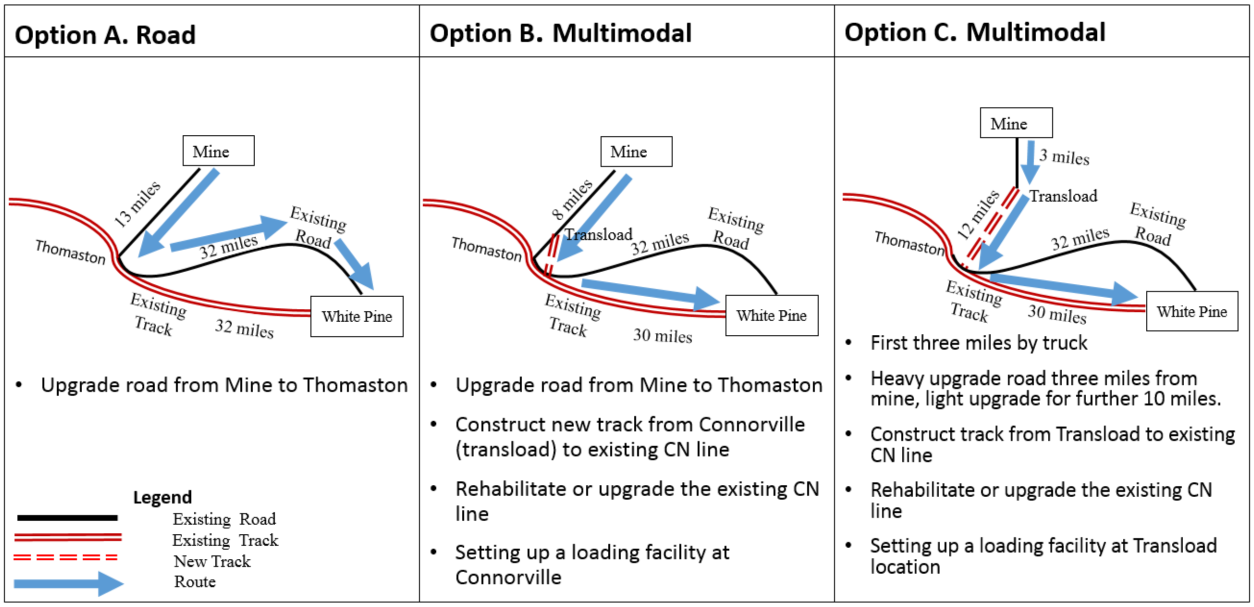

Figure 2: Infrastructure and Route Comparison of Ore Transportation options between the Mine and White Pine

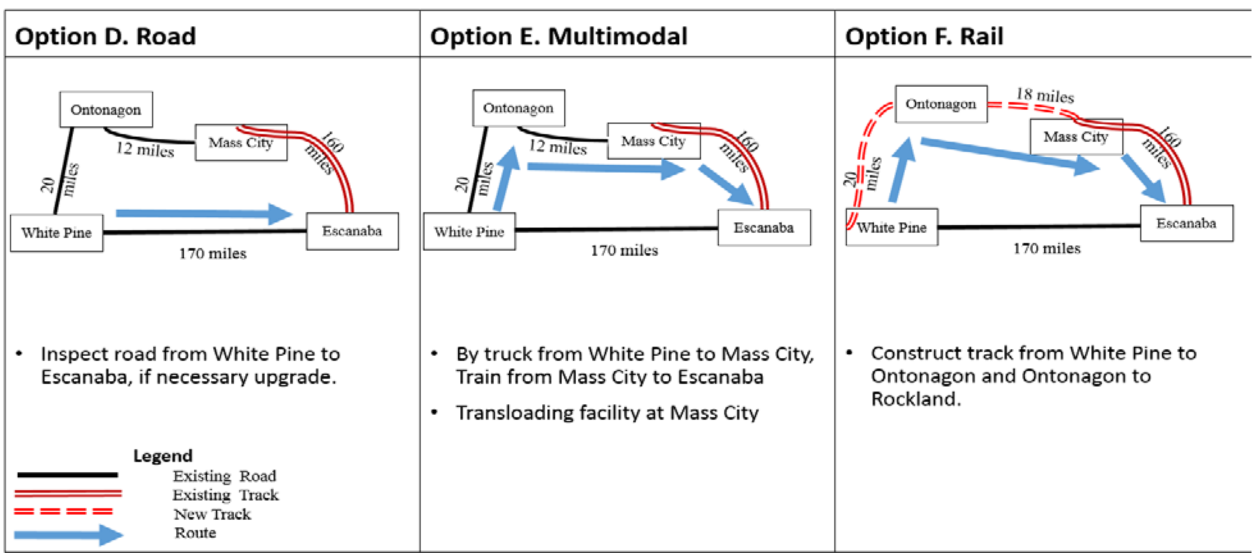

Figure 3: Infrastructure and Route Comparison of Concentrate Transportation Options between White Pine and Escanaba

Life Cycle Assessment

The LCA in this project was performed in accordance with the framework prescribed by the international organization for standardization in ISO 14040:2006. It was performed for construction, operations and maintenance phases of Infrastructure (roads, railroad tracks, transload facility) and Equipment (Trucks, Railcars, Locomotives, Loader). LCA process involves the following four main steps-

- ***Goal and scope definition:*** This step involves defining the goal, System boundary and functional unit for the analysis. The goal of the project is to conduct a LCA for the three different transportation options available for ore and concentrate transportation and compare the final LCA results to identify the option that releases the least amount of greenhouse gases to the environment. The functional unit of the study is either one ton of ore or concentrate moved from origin to destination. The system boundaries for the LCA are from the point of loading to the point of unloading, excluding the initial loading at the origin and final unloading at the destination. The LCA study is performed for mine life periods of 10, 20, 25, and 30 years, which causes differences between the number of new rolling stock and maintenance cycles, as new equipment will replace the old equipment at the end of life of the rolling stock.

- ***Inventory analysis:*** The inventory analysis phase describes the data used for the LCA, including all the quantities of material use and energy consumption during the stages of construction/manufacturing, operations and maintenance. Version 8 of SimaPro (SimaPro8) was used in this study, along with the datasets from Ecoinvent, which is a European based database with extensive datasets for many infrastructure and transportation related processes. Regional data obtained from local industry experts was used when available. For the LCA processes that were not available from Ecoinvent, custom datasets were developed based on locally collected data. In addition, the fuel consumption of locomotives in the options involving rail was calculated through Rail traffic Controller (RTC) simulations. Figure 4 presents a Screen shot of an RTC Simulation for one of the cases.

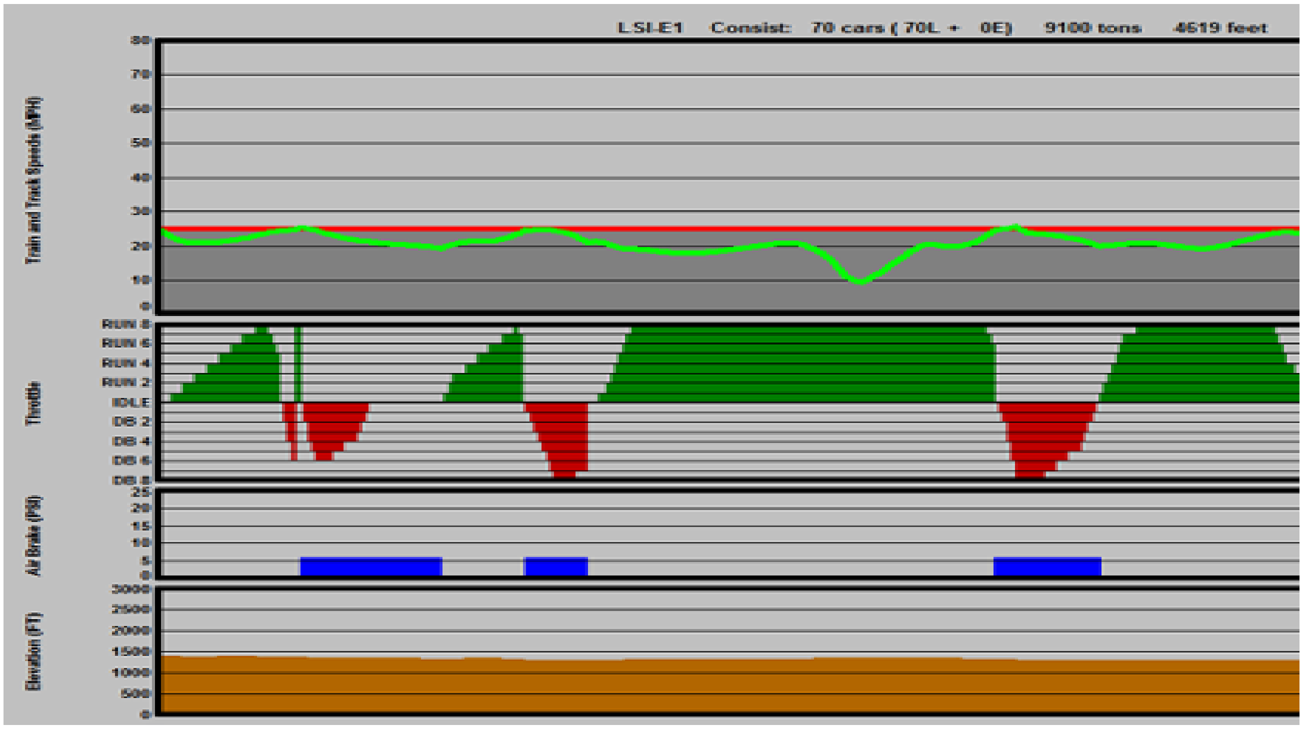

Figure 4: Screen shot of RTC Simulation including the Train Speed, Throttle, Braking and the Track Elevation from Top to Bottom

- ***Impact assessment:*** SimaPro has numerous impact assessment methods to select based on the needs of the project. This project uses the IPCC 2013 100a method for calculating Global Warming Potential (GWP), which calculates the amount of greenhouse gases released during the complete life cycle process in terms of equivalents of carbon dioxide (kg CO2eq). The output of the LCA will be in 100 year GWP equivalent measures of kg CO2eq, which can be normalized based on our functional unit for comparison of different transportation options.

- ***Interpretation***: In this phase, impact assessment results are analyzed based on the desired output of the LCA. Sensitivity analysis and uncertainty analysis for the parameters are also done in this phase. Based on the outcomes, recommendations can be made to revise the data inputs and/or the system boundary to perform the LCA iteratively.

LCA Results

After performing the analysis, results were obtained in terms of kilogram equivalents of carbon dioxide (kg CO2eq). Figure 5 shows the results of ore transportation scenario over different selected mine lives. From the results, it can be seen that GWP due to construction and maintenance of infrastructure and rolling stock have minor contributions to the overall emissions and their role (when normalized to ore production) diminishes as the life of mine is extended. However, as the life of the mine passes 20 years, a new fleet of trucks is needed to replace the initial trucks, adding to the total construction burden and offsetting the decrease in infrastructure emissions.

The percentage of total emissions from maintenance increases only slightly with the increase in mine life. This is because maintenance activity occurs on a regular time interval and mileage intervals for infrastructure and rolling stock, so they remain similar per ton of ore/concentrate. Since no consideration was placed on switching to new equipment with fewer emissions in the middle of mine operations, the burden of operation activities is also constant in each option regardless of the mine life. Across all time horizons, Option C results in the lowest overall GWP emissions, ranging from 2.51 to 3.65 kg CO2eq/ton ore, depending on mine life.

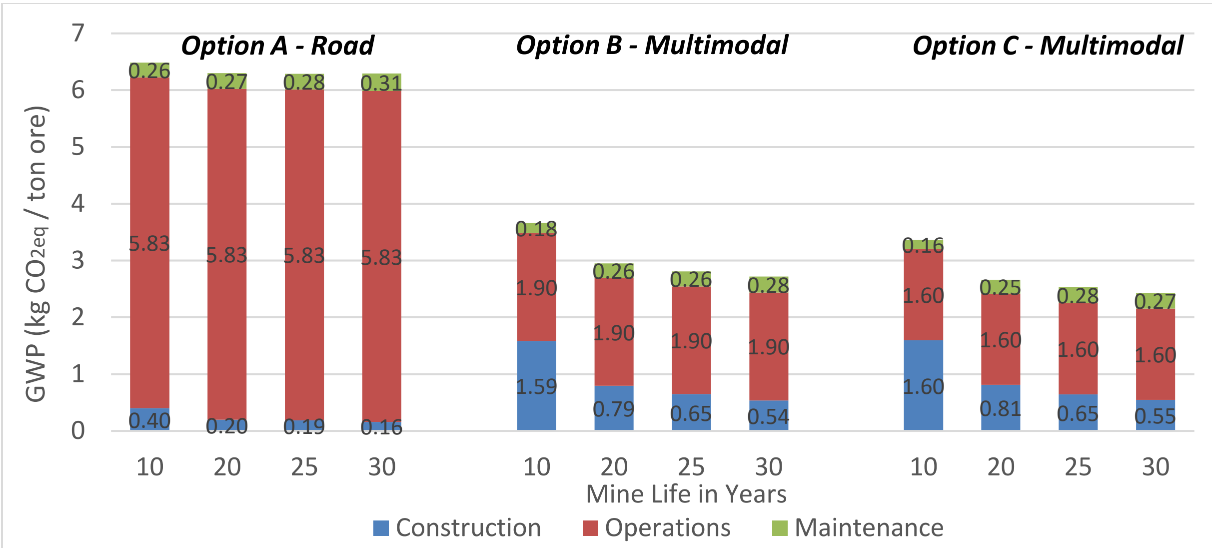

Figure 5: Kg of CO2eq per ton of Ore Transported for Different Options and Mine Life Times

The emissions from concentrate transportation show a similar pattern (Figure 6), but the per ton emission values are higher for concentrate due to longer overall transport distance. In Option F, the construction emissions are high, as new tracks have to be constructed from Mass City to White Pine in this option. The only construction activity in Option D is trucks, as there is no road construction in concentrate transportation scenario. Overall, in this case Option E provides lowest emissions, ranging from 10.96 to 14.23 kg CO2eq/ton concentrate. If only the operational emissions are compared, the rail only option has the least emissions.

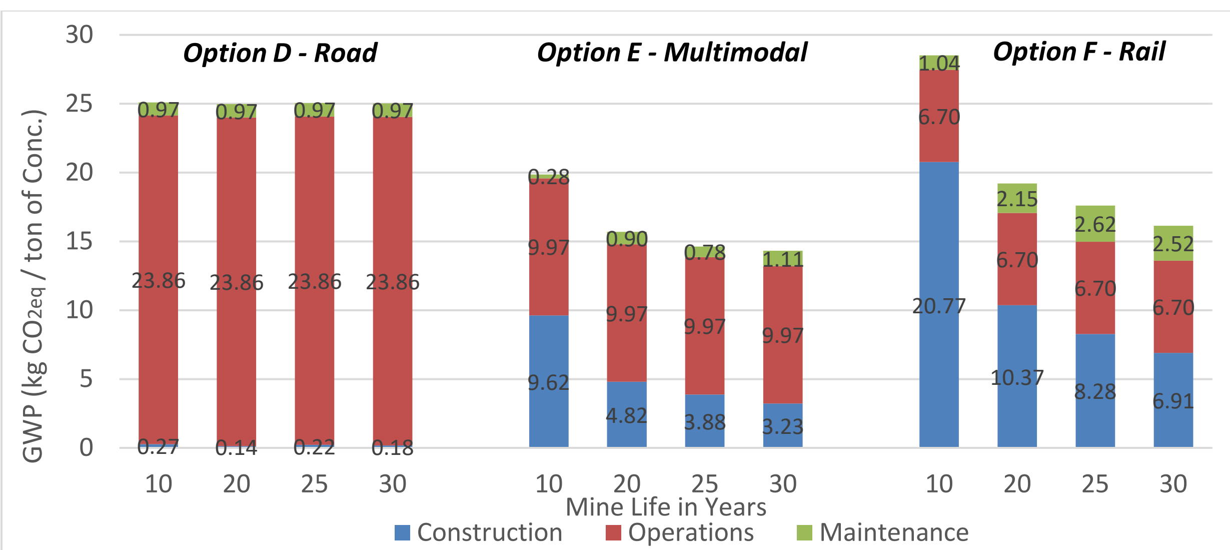

Figure 6: Kg of CO2eq per ton of Concentrate Transported for Different Options and Mine Life Times

Integrating LCA results in Economic Studies

Calculating the social costs of carbon emissions allows agencies to estimate the carbon dioxide reduction benefits and include them in their cost analysis in terms of economic, social and complete environmental impacts. The carbon emissions from different sources have various short term and long term impacts and in general have an adverse effect on the public health, wildlife, natural resources, forests and the environment. Since we performed LCA for the stages of construction/manufacturing, operations and maintenance, performing LCCA for the similar scope could identify all the costs along all the stages. Conducting full LCCA for the project was out of scope for this study, but the LCA emissions were converted into costs in terms of NPV for demonstration purposes. The major items for the conversion included identifying the cost of kg of CO2, selecting a discount rate for calculating the NPV's, and the breakdown of emissions to annual contributions over the different mine lives. There are several options for quantifying the social costs of carbon. The source of social carbon unit costs used in this study is the U.S. Environmental Protection Agency (EPA) published costs.

The quantity of emissions from all processes under each life cycle stage was calculated by multiplying the emissions in kg of CO2 per ton of material transported with the total quantity transported over the mine lives and the emissions for each process were assigned to the year they occurred. Then, the average annual emissions for each option of ore and concentrate transportation were calculated. Finally, the cost of CO2 emissions per ton of ore or concentrate transported were calculated. Figure 7 shows the cost of emissions per ton of ore transported for the three alternatives.

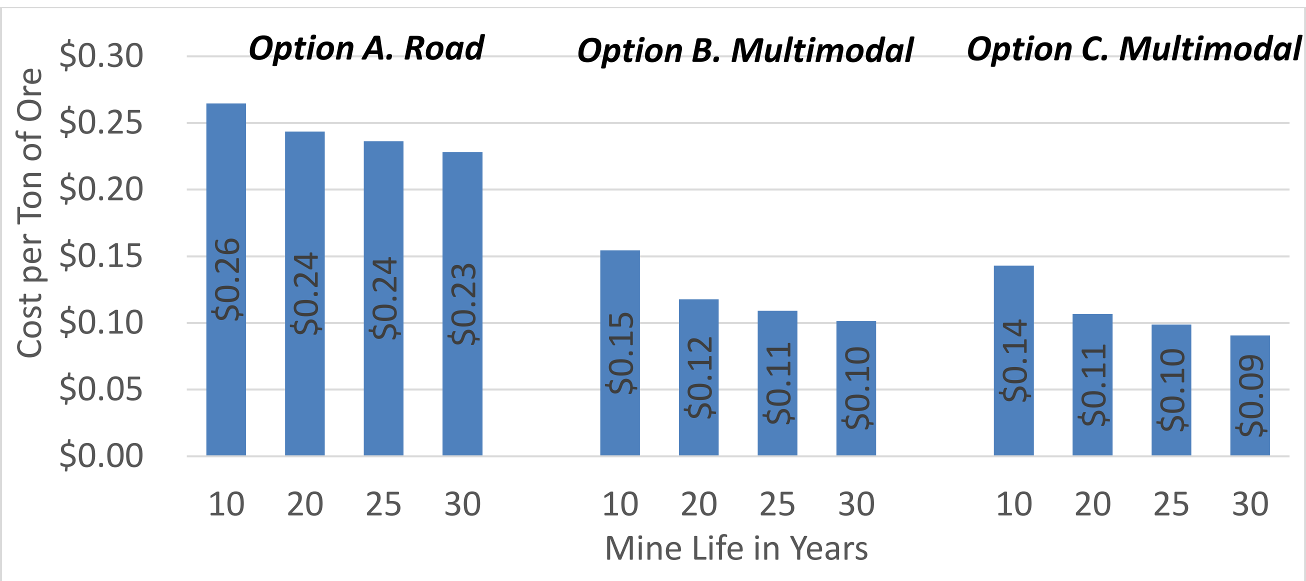

Figure 7: Emission Costs per ton of Ore Transported

Economic Analysis

As part of the study, three different aspects of economic evaluation of alternatives were studied. The mode/route selection for a freight project can be influenced by various economic and social factors, especially if it involves infrastructure investments. In many cases, these investments are supported in part or whole by state agencies. In case of Copperwood project, the available state support from MDOT plays a significant role. The preferred alternative for a specific freight transportation project may not be the same from every stakeholder's perspective. Hence, the decision-making perspectives of the state agency (MDOT) and the mining company (Highland Copper) were reviewed and compared. Table 1 provides a brief summary of the primary objectives and criteria of both entities.

Table 1: Mode selection criteria for Highland Copper and MDOT in Copperwood Project

Mode Selection Criteria		
	Highland Copper	**MDOT**
Main Objective	• To minimize life cycle costs	• To provide the highest quality integrated transportation services for economic benefit and improved quality of life
Criteria	• Capital/Operational/Maintenance Cost • Available capital • Available State Support (MDOT)	• Project Cost • Economic Impacts • Environmental Impacts • Societal Impacts

In this case, there are two completely independent MDOT programs, namely TEDF (category-A) and FEDP from which, funding can be obtained. TEDF provides funds road infrastructure development and FEDP does so for rail. The evaluation criteria and procedures of both programs were reviewed and summarized.

Subsequently, the software currently available for conducting economic analysis of transportation projects were reviewed in order to identify the most suitable tool that can be used in case of small, regional scale projects involving rail and multimodal options, like Copperwood. After the initial review, it was observed that most tools are oriented towards road projects and a few supported evaluation of passenger rail and transit. While none of the reviewed tools seemed directly applicable to projects similar to Copperwood, it was determined that TREDIS offers the greatest potential to evaluate specific freight transportation projects, mainly due to its ability to analyze rail and multimodal options. However, from the reviewed tools, TREDIS is explained in more detail, as it seemed to be most applicable for multimodal freight development projects. However, even TREDIS seemed oriented toward larger scale projects with macro level effects, and as such may not be directly applicable to analysis of smaller individual projects like Copperwood. Finally, the study briefly discusses the economic analysis considerations for Copperwood project, including MDOT support mechanisms.

Conclusions

This project introduced the concept of LCA, reviewed its past applications in transportation and applied these concepts to the case study of Copperwood project to analyze emissions from ore and concentrate transportation. The analyses used SimaPro tool to perform LCA for calculating the global warming potential over the life of the mine in terms of kg of CO2 equivalents per ton of ore / concentrate transported. The analysis was performed for 10, 20, 25 and 30 year mine lives to compare the impact of lifespan on the mode of transportation. The study also outlined the concepts of economic analysis for comparing transportation system alternatives and investigated the integration of emission costs in the LCCA analysis. The social costs of carbon or emission costs per ton of ore/concentrate transported were calculated. The main conclusions of this study include:

- Performing LCA requires very extensive data and datasets that include all the parameters to perform LCA for transportation systems are not available or are case specific. The case study used data available in Ecoinvent database and complimented it with custom data sets that were collected from local sources and then formatted to match the requirements of SimaPro.
- LCA was performed for the ore and concentrate transportation option of Copperwood Project. The impact assessment results indicate the following:
  - Significantly lower GWP emissions are observed from multimodal transportation options (options B,C &E)
  - Operations of truck and trains (fuel usage) account for the majority of emissions in most alternatives, across mine lives.
  - For short mine lives, new track construction emissions contribute significantly. (option-F)
  - Maintenance and transloading emissions have minor effect in all the options.
- As expected, the emission costs calculated from the LCA results identified that the road only options have higher prices per ton of freight transported. These costs can be included in the LCCA results to include them in the overall economic analysis. Since the scope did not include complete LCCA analysis, the significance of emissions costs in the overall project selection could not be quantified.

Publications

- Kalluri, S. (2016). Comparative Life Cycle Assessment of Road and Multimodal Transportation Options-A Case Study of Copperwood Project. Available at https://digitalcommons.mtu.edu/cgi/viewcontent.cgi?article=1179&context=etdr
- Kalluri, S., Lautala, P., Handler, R., Comparative Life Cycle Assessment Of Road And Multimodal Transportation Options – A Case Study Of Copperwood Mine, Transportation Research Board 95th Annual Meeting of the National Academies, Washington, DC, January 12-16, 2016
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- Lautala P, Nelson D, Kalluri S, Oduru S. (2017). "SECTION 2: Addendum to Copperwood Project – State Support Mechanisms for Transportation Projects and Available Tools for Economic Analysis". National University Rail Transportation Center (NURail) Tier 1 – Final Report. Office of Research and Best Practices, Michigan Department of Transportation" https://www.michigan.gov/documents/mdot/MDOT_NURail_Tier_1_final_2-24-17_553656_7.pdf

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