Title: Expanding Alaska-Canada rail: visualizing mining revenue and CO2 impacts

Abstract:
Recent discussions in Alaska on transportation networks and mineral resources have included expanding the regional rail network to connect Alaska to the Lower 48 for the first time via a new Alaska-Canada Rail Link. Our team is developing a Desktop ArcGIS tool that visualizes the potential revenue from new mining efforts for areas within approximately 100km of proposed new rail routes. A web-based version of the tool is planned for release in early 2011. Users, including Alaska and Canada stakeholders, can select locations of known mineral occurrences near rail routes and based on mineral deposit models, gain an estimate of resource amount and their extractable value over time, plus multi-modal transportation volumes. The tool translates the revenue scenario into likely CO2 emissions based on transport of mineral concentrates to regional and international destinations. Users can select and visualize multi-modal transportation networks to understand and minimize carbon emissions as part of their scenarios.

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Introduction:

The proposed Alaska Canada Rail Link (ACRL) and other proposed rail extension projects in Alaska have significant implications for the development of mineral and other natural resources in the state and in the northwestern Canadian region of Yukon and British Columbia. These implications include revenue generation from a potentially multi-modal and intermodal infrastructure to support the logistics operations needed to take advantage of increased access to mineral resources. Phase I of the ACRL study (ALCAN RaiLink Inc., 2007) summarized the feasibility of the ACRL and its potential economic benefits, which were analyzed to have a net potential revenue of US $7.8 billion and net public benefits of $11.4 billion. This project is focused on economic impact on mineral extraction in the ACRL and extended corridor region, as co-author Dr. Metz recommended that further detail was needed after the Phase I study was completed. Part of that focus was accounting for the total volume of rail, truck, barge, and ocean-going vessel traffic and the carbon emissions from these transportation modes that might be generated as extraction of additional mineral resources became more economically feasible with a nearby railroad.

Methods:

To implement the goal of understanding potential revenue, traffic volumes, and carbon emissions, the Michigan Tech Research Institute (MTRI) team members were charged by Dr. Metz to develop a map-based visualization tool for the ACRL region. A key part of that charge was to take Dr. Metz's detailed Mineral Occurrence Database that he had developed for the Phase I study and link it to GIS layers of regional mineral occurrences for the Alaska, BC, and Yukon areas. The Metz Mineral Occurrence Database includes detailed information about mineral deposit type (after Cox and Singer, 1986), gross metal value based on tonnage and grade (originally using representative 2007 commodity prices) at 10th, 50th, and 90th percentile level of likely deposits, expected concentrate, and gross metal value (GMV) at the different percentile deposit levels (see Figure 1 for an example of Dr. Metz's database). For Alaska, we linked it to the Alaska Resource Data File (ARDF - http://mrdata.usgs.gov/mineral-resources/mrds-ak.html - see figure 2). For Yukon and BC, Dr. Metz shared the recent Major Mine File GIS layers for the Yukon Territory and BC Province.

Quad./ Map No.	Name	Mineral Deposit Type (after Cox & Singer, 1986)	Land Status	Gross Metal Value Based on Tonnage/ grade of the 10th percentile deposit of this deposit type (after Cox & Singer, 1986)	Gross Metal Value Based on Tonnage/ grade of the 50th percentile deposit of this deposit type (after Cox & Singer, 1986)	Gross Metal Value Based on Tonnage/ grade of the 90th percentile deposit of this deposit type (after Cox & Singer, 1986)
Wiseman	**Quadrangle**					
Wiseman WI003	John River	Simple Sb deposit (27d)?	National Park	$2,260	$118,078	$6,220,075
Wiseman WI005	Unnamed (east of VABM Allen)	Polymetallic replacement deposit Cu, Mo (19a)?	State Land	$13,435,330	$473,974,011	$17,265,436,650
Wiseman WI011	Unnamed (between Sirr Creek and Wild Lake)	Polymetallic vein Ag, Au, Cu, Sb (22c)?	State Land	$28,175	$4,323,695	$606,385,705
Wiseman WI012	Unnamed (south of Pet Lake)	Polymetallic vein Ag, Au, Cu (22c)?	State Land	$28,175	$4,323,695	$606,385,705
Wiseman	Unnamed	Polymetallic	State	$13,435,330	$473,974,011	$17,265,436,650

Expected Concentrate Tonnage at 10 Percentile					Expected Concentrate Tonnage at 50 Percentile					Expected Concentrate Tonnage at 90 Percentile					Expected GMV 10 Percentile	Expected GMV 50 Percentile	Expected GMV 90 Percentile
Probability of Develop.	Mine Recovery	Mill Recovery	Conc Fac	**Tonnes Conc**	Probability of Develop.	Mine Recovery	Mill Recovery	Conc Fac	**Tonnes Conc**	Probability of Develop.	Mine Recovery	Mill Recovery	Conc Fac	**Tonnes Conc**			
0.001	0.9	0.85	1.3	**0**	0.001	0.9	0.85	1.3	**0**	0.0005	0.9	0.85	1.3	**2**	$2	$118	$3,110
0.001	0.9	0.85	1.3	**5**	0.001	0.9	0.85	1.3	**165**	0.0005	0.9	0.85	1.3	**2,845**	$13,435	$473,974	$8,632,718
0.001	0.7	0.95	2.89	**0**	0.001	0.7	0.95	2.89	**2**	0.0005	0.7	0.95	2.89	**64**	$28	$4,324	$303,193
0.001	0.7	0.95	2.89	**0**	0.001	0.7	0.95	2.89	**2**	0.0005	0.7	0.95	2.89	**64**	$28	$4,324	$303,193
0.001	0.9	0.85	1.3	**5**	0.001	0.9	0.85	1.3	**165**	0.0005	0.9	0.85	1.3	**2,845**	$13,435	$473,974	$8,632,718

Figure 1: A sample of records from the Mineral Occurrence Database shared by Dr. Metz for linking with spatial mineral occurrence data for Alaska.

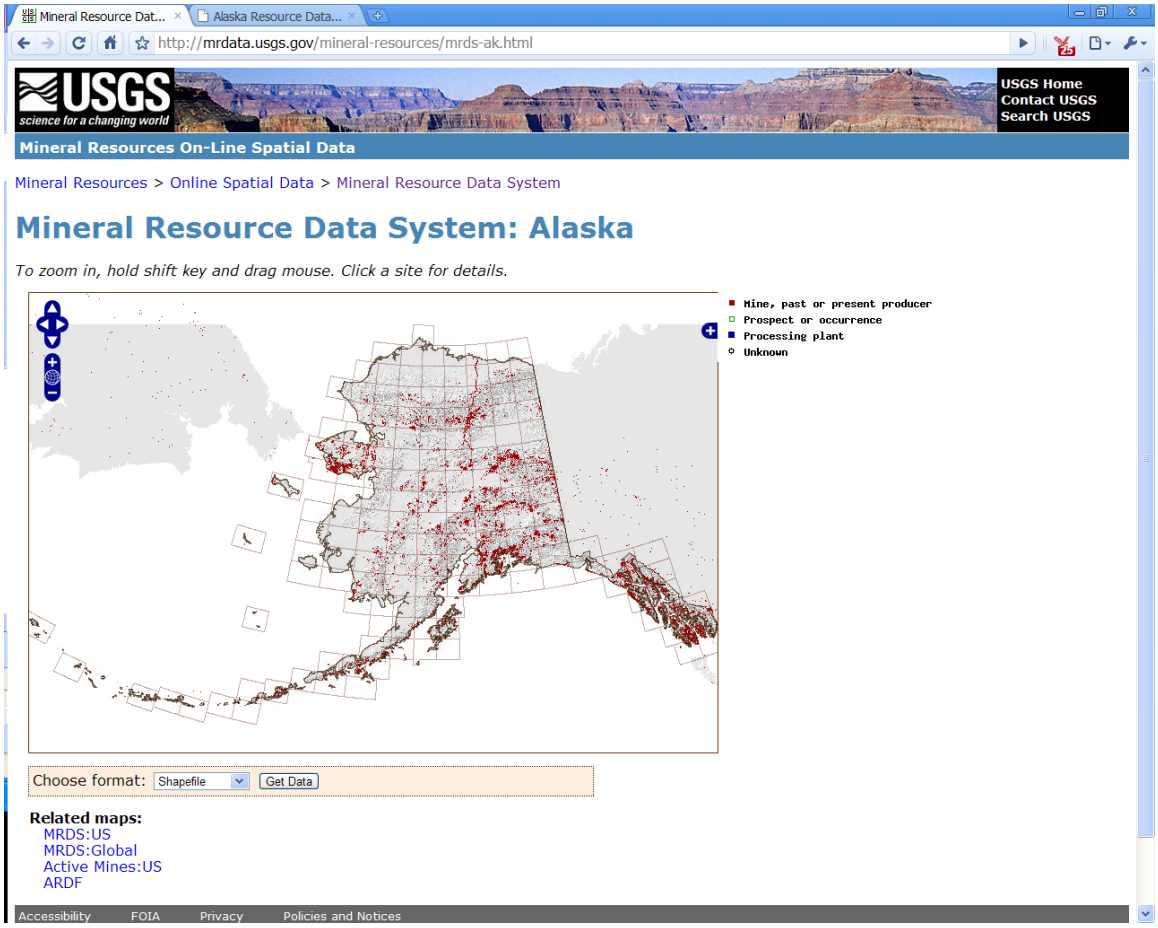


Figure 2: A map showing the Alaska Resource Data File as available for download from the USGS at http://mrdata.usgs.gov/mineral-resources/mrds-ak.html

In addition to linking to GIS layers, we aimed to make Dr. Metz's detailed data set available to more users and to explore scenarios for mineral resources and transportation networks. Specifically, based on input from Dr. Metz, UAF colleague Mark Taylor, and other stakeholder input, we wanted to:

- Calculate expected revenue from occurrences within 100-km (60 mile) corridor of a proposed transport link
- Visualize proximity to existing infrastructure, historic mines, and nearby deposits
- Visualize land use patterns, watersheds,and political boundaries
- Track CO2 in transportation segment for a proposed mine
- Calculate and visualize most efficient multi-modal transportation network.

To meet these goals, we are creating the flexible and geospatially-based Mineral occurrence Revenue Estimation and Visualization (MOREV) tool (http://www.mtri.org/mineraloccurrence.html), using Desktop ArcGIS 9.3.1 as the tool platform with VB.NET as the application language. A web-based version of the tool for users to investigate the capabilities of the MOREV tool is under development using ArcGIS Server 9.3.1. For the desktop MOREV tool, we are ensuring that sensitivity

analysis can be performed, such as looking at transportation costs for new mine development with and without a new rail link. Assumptions in the tool are transparent, through the use of interactive help links explaining economic, carbon, and other details. The mineral occurrence data, such as the ARDF, has been integrated in a way that is easily updateable, as new versions are being planned for release by the State of Alaska. Most critically, we have made inputs modifiable by the user, so that users can use their own expertise and explore what happens with economic and carbon impacts when tonnages, costs per ton-mile, commodity prices, mine recovery rates, and other variables are changed.

We are anticipating a wide variety of potential users of the tool based on Dr. Metz's experience, advice from project consultant Leon Van Wyhe, and a recent demonstration of the tool at the March 2010 conference of the Alaska Miners Association held in Fairbanks, Alaska (http://www.arcticminers.org/2010conf/). These users include:

- Small to midsized exploration interests in pre-feasibility stages of project planning for new mining projects
- Transportation & infrastructure planners
- State & Local Government
- Potential for helping parties in permitting process
- Example: Preparation of NI 43-101 mineral project disclosures in Canada
- Government agencies and resource database maintainers
- Investment community and lenders
- Researchers (geological, transportation, economic, etc.)

The MOREV tool focuses on explaining and sharing the Gross Metal Value of documented occurrences, in part because of the importance of the multiplier effect in the local economy from developments of mineral resources. For example, a 1998 study by Information Insights for the Fairbanks North Star Borough estimated the annual economic impact of the Fort Knox Gold Mine at $104 million per year during the anticipated 12 year mine life (since updated to $181.7 million per year in 2004, see http://findarticles.com/p/articles/mi_hb5261/is_11_21/ai_n29238592/). The estimated GMV at the time was $1.2 billion, serving as an example of how the value to local communities of developing a mineral resource can be equal to the sizeable GMV of a mineral deposit.

The tool is being developed to help users visualize and understand the GMV for each of the approximately 22,000 mineral occurrences in the geospatial data for the Alaska, Yukon, and BC, of which almost 16,000 are within 100km of the various proposed and existing rail routes that the MOREV tool is currently capable of modeling. Figure 3 uses the tool's ArcGIS background to show both the 22,000 mineral occurrences (light gray dots) and those within the 100km "rail corridor" (black dots); the corridor area is displayed in the yellow outline. Figure 4 shows the same area, but with only the rail corridor and 22,000 mineral occurrences. We also use ArcGIS to help users understand the locations of different kinds of mineral resources, such as gold, copper, gold, iron, and nickel (see Figure 5). Coal GIS data are also displayed where available as Alaska has one operating coal mine (Usibelli) and significant coal resources (Flores et al. 2004).

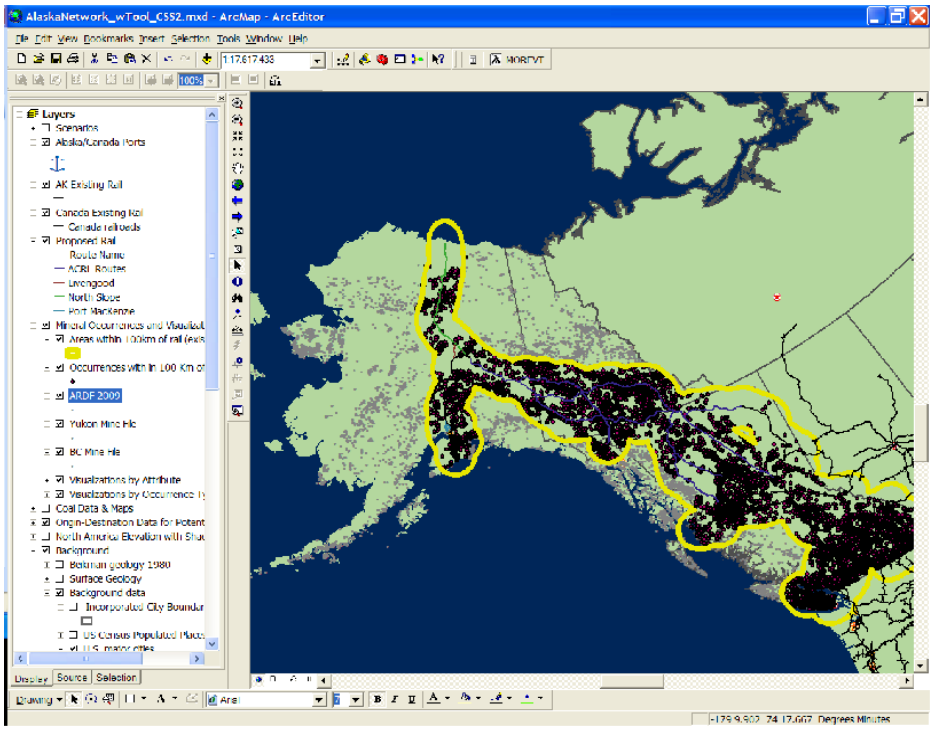


Figure 3: The MOREV ArcGIS desktop with the mineral occurrences within 100km of existing and potential rail highlighted in black dots; 16,000 of the 22,000 regional mineral occurrences are located within this corridor.

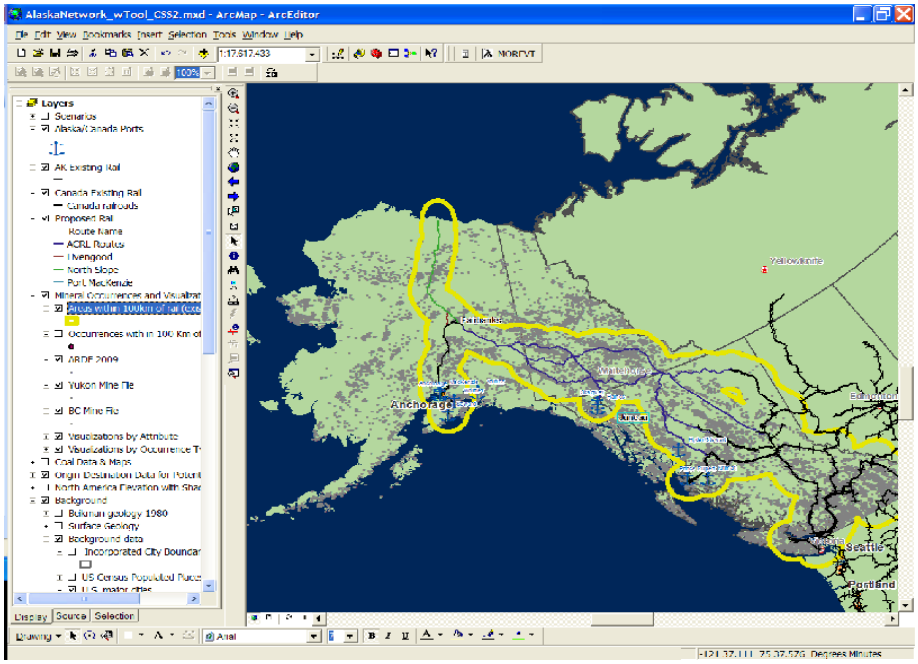


Figure 4: The same corridor, highlighting existing rail (black rail lines) and potential rail (purple – ACRL; green – North Slope route; Livengood and Port Mackenzie extensions are also included in the model).

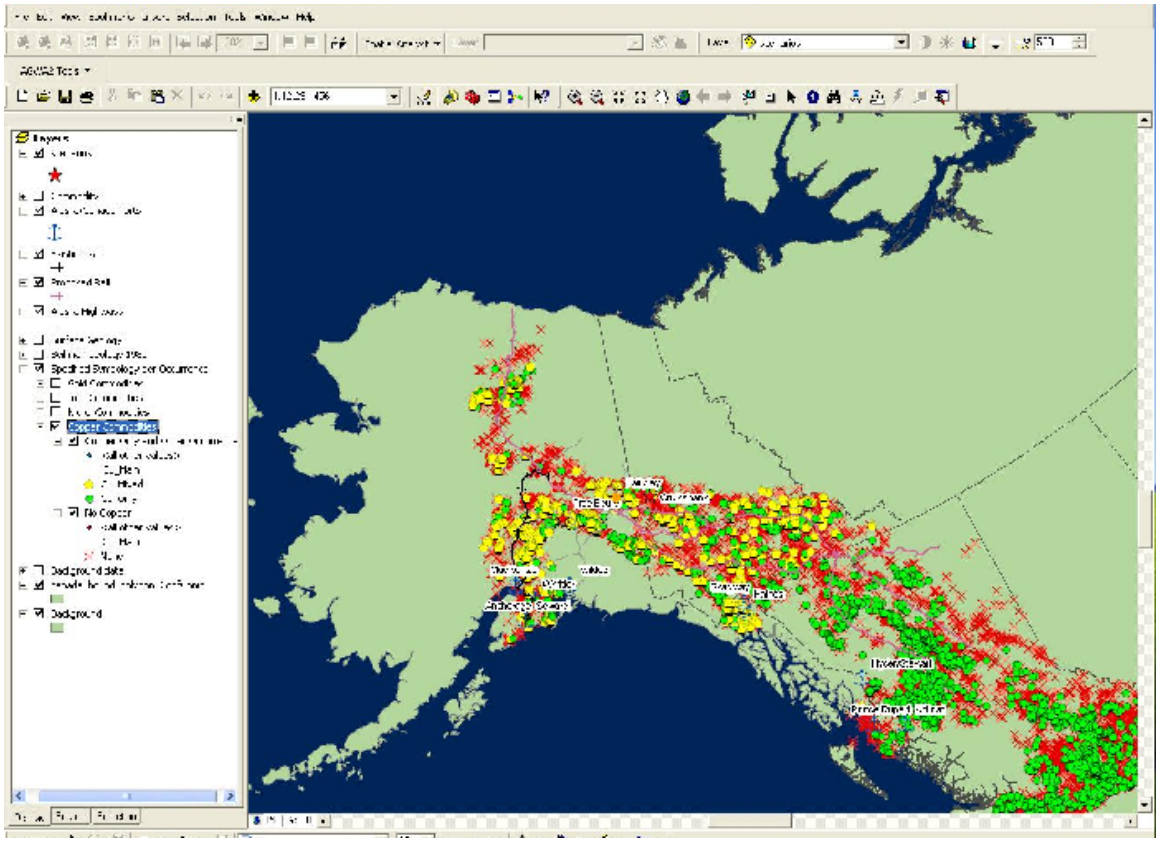


Figure 5: An example of the mineral occurrences within the rail corridor listed as having only copper (green circles) and copper with other minerals (yellow pentagons); red crosses are non-copper mapped occurrences.

In addition to calculating GMV with updated and historical mineral prices, we are also developing cost estimation methodologies to help with assessments of economic viability of developing particular occurrences. As an initial, simplified method for rapid user access, we are using a factored model approach based on Camm 1991 as published by the USGS. Camm's work empirically relates tonnage and depth to capacity, capital cost, and operating cost, given a user-selected mining and milling method, which the MOREV tool makes available. We are currently exploring the methods necessary to implement a more detailed cost accounting, using the itemized U.S. Bureau of Mines Cost Estimating System (1987) with advanced cash-flow analysis capabilities. Planned inclusions are updating cost functions (such as using Producer Price Index to account for inflation) and discounted cash flow for rate of return estimates, with a user-selected discount rate to obtain net present value of potential revenue.

For transportation costs, we are currently using the values from the ALCAN 2007 Phase I report for rail haul, and Ballou (1998) for waterborne freight with updated input from project collaborator Mark Taylor of UAF. Truck and ocean-going vessel (OGV) transportation costs are based on current US Bureau of Transportation statistics. We are developing methods of accounting for multi-modal transportation connection costs as well. Transportation costs are reported based on shippable tonnage times distance times

dollar per tonne-km costs. Table 1 shows the transportation costs the MOREV tool is currently using, which can be adjusted by the tool user.

Table 1: Transportation costs in dollars per tonne-km used as default user-adjustable values in the MOREV tool.

Mode	Source	Default value $/tonne-km
Truck	Transportation Statistics Annual Report (RITA 2008)	**$0.0940**
Rail	National Transportation Statistics (BTS 2009)	**$0.0177**
Domestic Water	National Transportation Statistics (BTS 2009)	**$0.032**
Ocean Freight	AXSMARINE Dry Bulk Shipping Indices (2009)	**-8.62E-8x + 0.003216 where x = route distance (km)**
Intermodal Transition	**Source**	**$/tonne**
Land <> Water	Mark Taylor (UAF) / publicly available data	**$3.00**
Truck <> Rail	Bob Rieck, expert opinion (Agrico Sales)	**$4.50**

An important component of cost accounting in our current methodology is calculating mining capacity for a mineral occurrence based on reserve tonnage, using methods recently updated by Long (2009) based on the work of Taylor (1977). The main model is represented by the equation $C=bT^a$, where T is the shippable tons in metric tons, C is the capacity in metric tons per day, ^{a} is the point elasticity of capacity (the proportionate change in capacity with respect to a given change in reserves), and b is the scaling coefficient determined by empirical fit (as updated by Long). Shippable tons are calculated as T = (ore tonnage) x (ore grade) x (mine recovery rate) x (mill recovery rate) x (mineral-to-metal weight factor).

Figure 6 shows the start of the MOREV tool being used to evaluate a particular occurrence that has been selected by a user. After choosing the example Fairplay mineral occurrence in Alaska, the starting tool form has loaded giving the user information on the deposit type, the ore commodity, the tonnage under different percentile estimates, the Gross Metal Value in US and Canadian dollars, the estimated mine life, the latitude/longitude, Alaska quadrangle name, the Cox and Singer deposit model type, the number of occurrences (deposits) within 20km, and the distance to existing and proposed rail. Figure 7 shows the same tool interface form in greater detail.

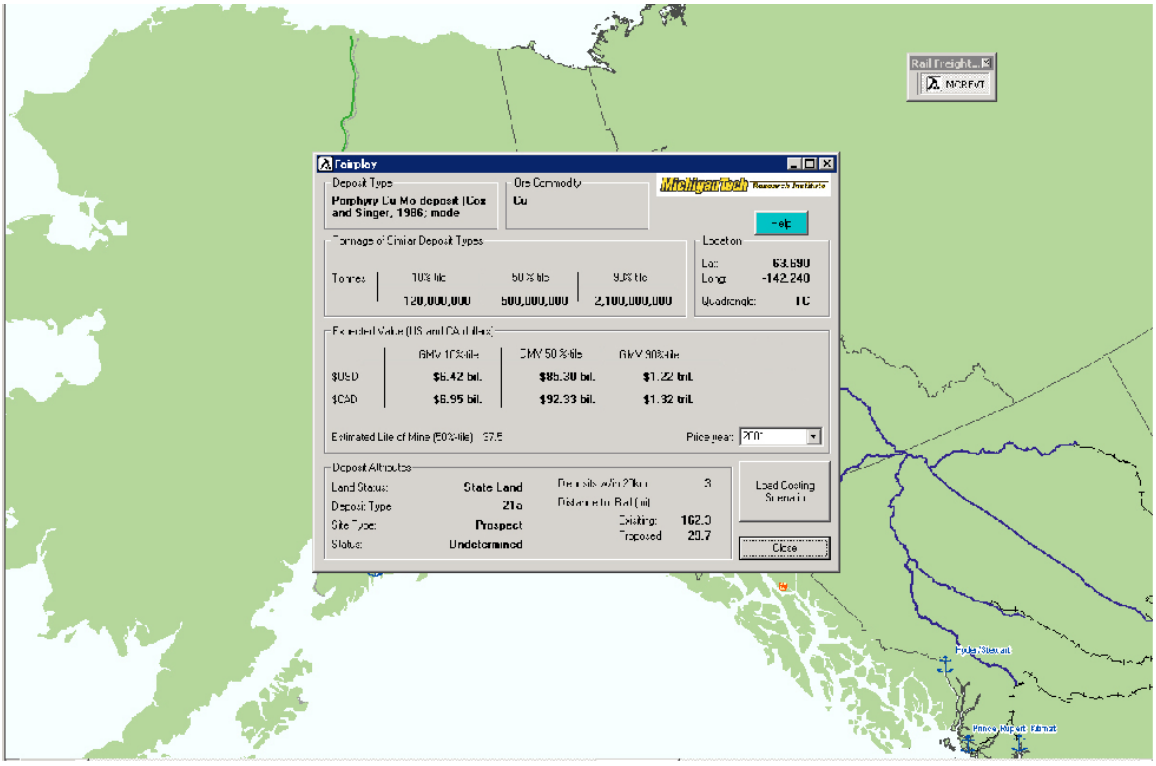


Figure 6: The starting interface for the MOREV tool after a particular mineral occurrence in Alaska has been selected for evaluation by a user. A wide variety of data is available to the user and Gross Metal Value can be adjusted to historical and current mineral values.

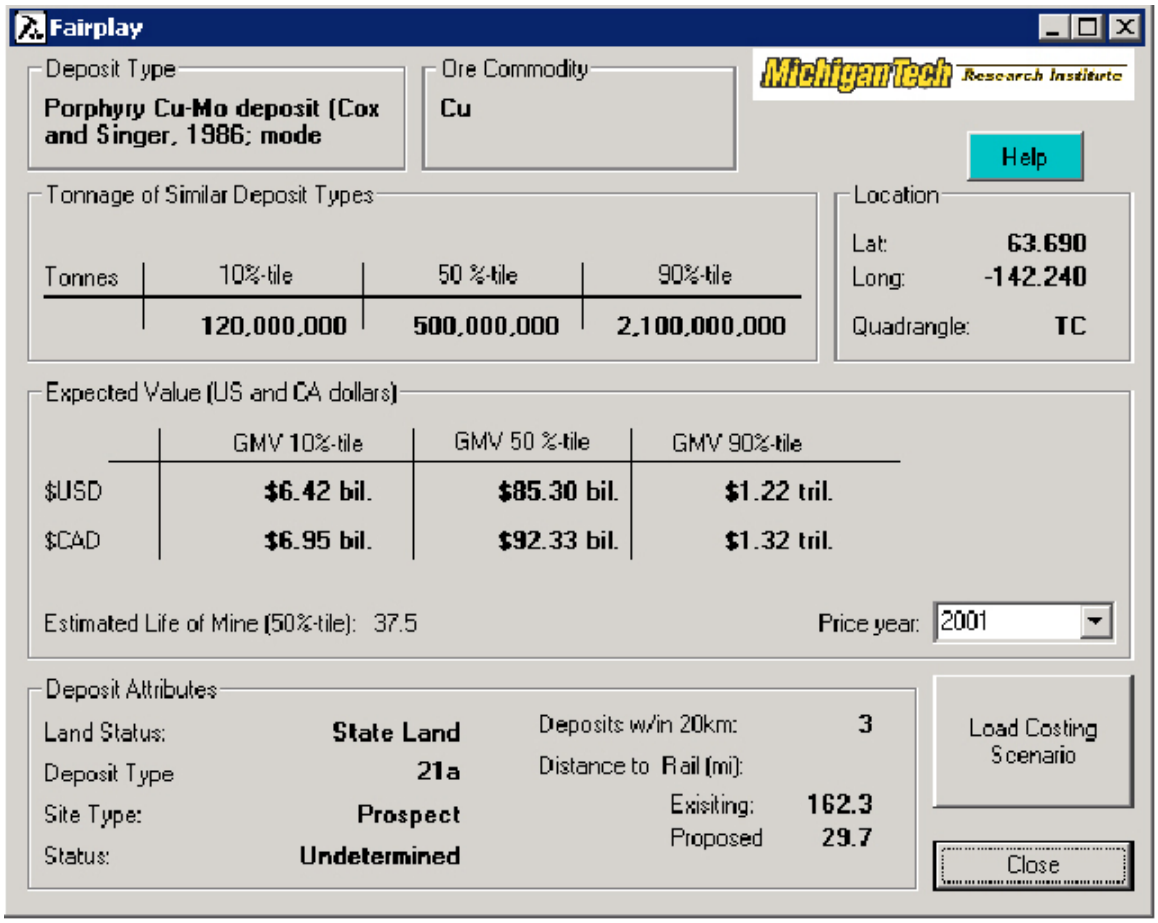


Figure 7: The starting MOREV tool interface showing detailed data for an Alaska mineral occurrence being evaluated by a user. The GMV values come from having linked geospatial mineral occurrence data to the Dr. Metz 2007 Mineral Occurrence Database, and are updateable using current and historical mineral values.

After reviewing the GMV data, the user can select the "Load Costing Scenario" button which loads the second part of the tool, showing pre-feasability-level costing scenarios, including transportation costs, and Camm-style operating and capital costs (see Figure 8). The user is able to select the percentile model for tonnage and GMV, the mine type, the mill recovery rate, capacity tonnage, and scenario length if they are trying to understand potential revenue over a time period shorter than the possible likely mine life. We are adding functionality to enable users to use metric or English (Imperial) units. The user can select the destination for the mineral concentrate freight, from regional ports, towns and cities that could have refining capacity, or East Asian locations (such as coastal China ports) that were analyzed as likely destinations in the ALCAN Phase I study. Figure 9 shows an example of the origin/destination tool interface, which includes the ability to select particular ports or cities that the freight should be shipped through.

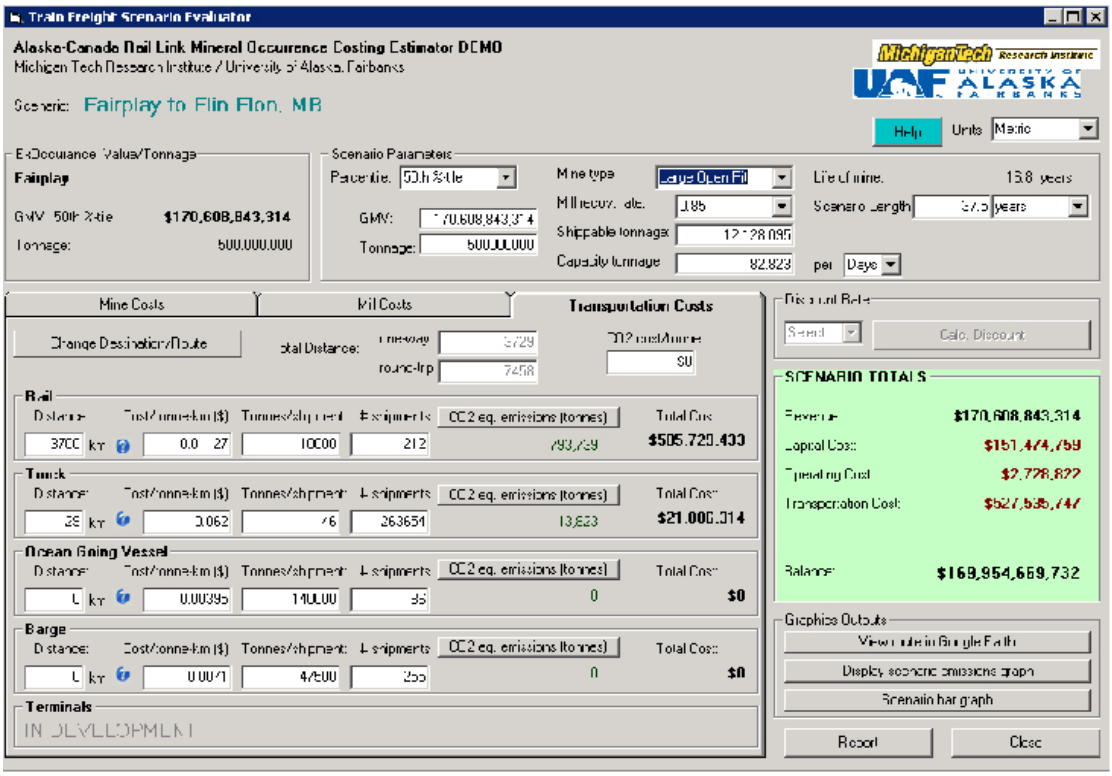


Figure 8: The mine costing and carbon emission summary interface in the MOREV tool showing revenue and total CO2 emissions for the scenario currently being evaluated by a tool user.

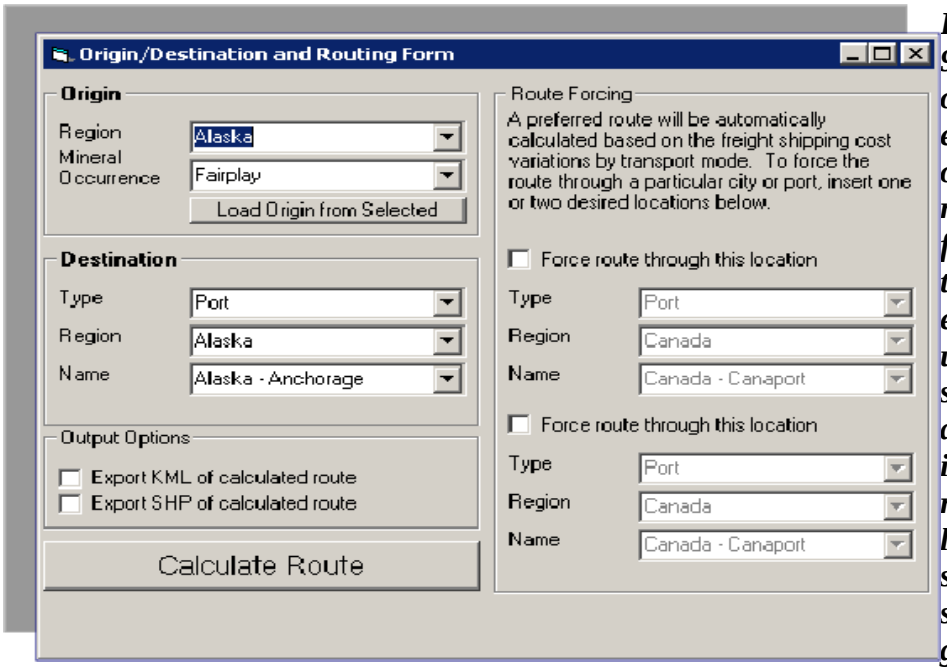
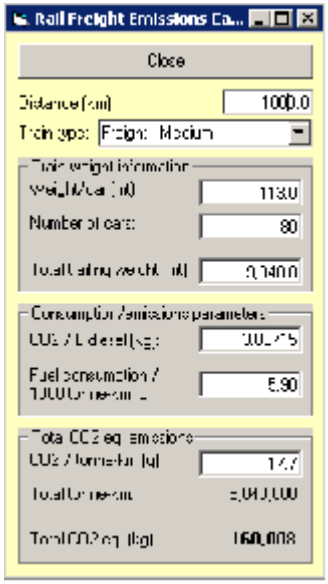
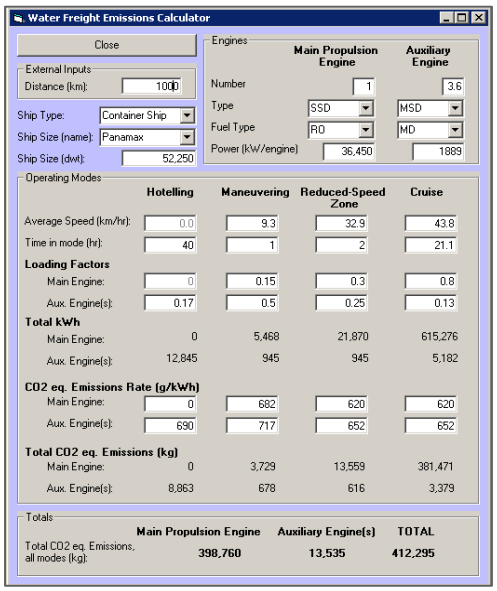


Figure 9: The origin/destination and routing form that enables users to select destination and routing locations for shipping mineral concentrates from an evaluated mineral occurrence.

A critical part of our tool is to enable users to evaluate the users to evaluate the potential CO2 emissions of a particular mineral occurrence becoming developed and

shipping resources to a user-selected destination. With recent national policy initiatives to potentially enact “cap-and-trade” and similar carbon legislation, this is an important consideration that has not traditionally been includes in cost equations. We are developing this functionality in a modular Transportation Carbon Accounting Module (TCAM), which can also add the CO2 emission costs in dollar per tonne to the total scenario costing. Our CO2 emissions are based on aggregate figures from US Environmental Protection Agency (EPA) and Iowa State for fuel consumption per tonne-km. The emission models are based on fuel usage estimates, and are divided into fine levels of detail available for user changing and analysis. Total emissions are based on CO2 equivalent, accounting for C02, CH4, and N2O emissions based on fuel type, ship type, truck type, train type, number and weight of cars, and other important factors. Figures 10a through 10c show this level of detail for rail, water, and truck freight as available through the TCAM part of the MOREV tool. Currently under development is the ability for users to select the most carbon efficient routing for shipments of developed resources.





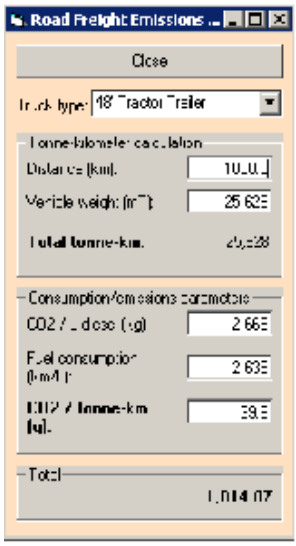


Figure 10a, 10b, and 10c: The Transportation Carbon Accounting Module's mode-specific carbon emissions calculators, as made available through the MOREV tool. Most input values are changeable by the user and are documented in the tool.

In addition, users can obtain summaries of the carbon emissions, integrated into the tool, a reporting function, and in graph format through the MOREV tool. Expansion of this reporting capability is under development through user testing with regional stakeholders. Summary data is also being made available in additional geospatial formats, such as KML link for the user-tuned scenario that enables the dynamic display in Google Earth (and other KML-reading mapping tools) of the route, with total distances, CO2 emissions, and transportation costs. Figure 11 shows an example of this visualization functionality in Google Earth for a scenario involving shipping of mineral concentrates to China.

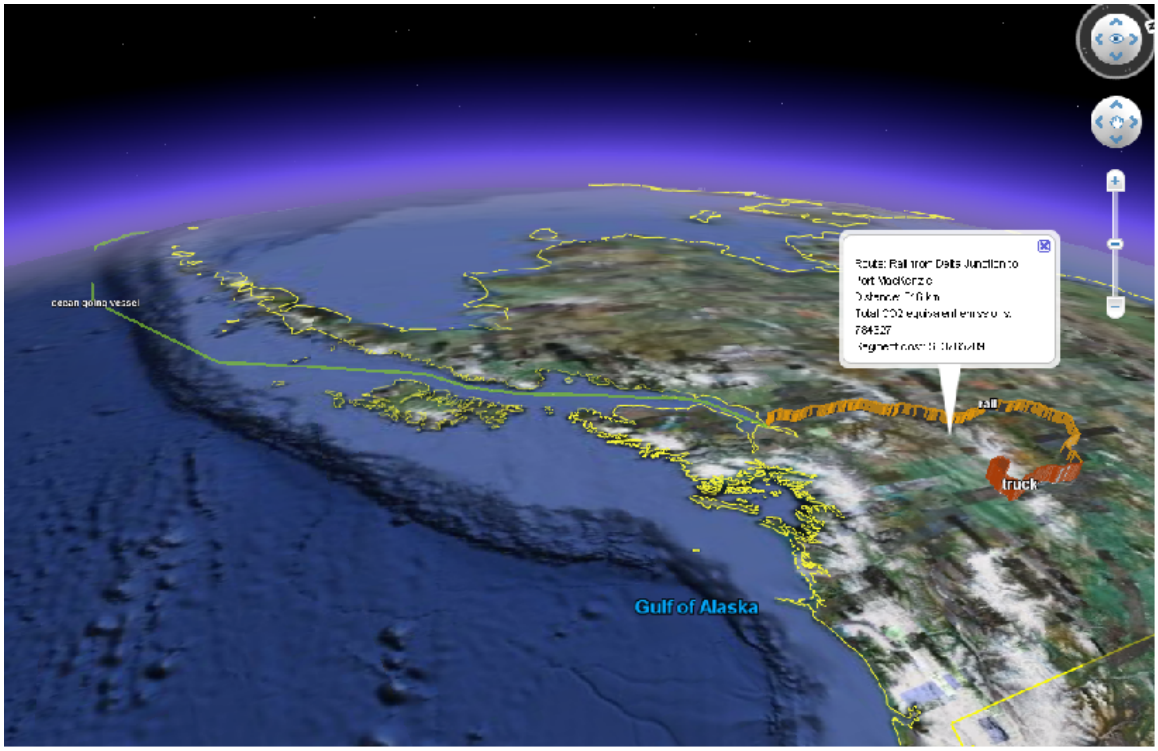


Figure 11: An example of visualizing a selected mineral occurrence and shipping scenario through the MOREV tool's KML/Google Earth functionality currently being developed.

Summary and Next Steps

The MOREV tool, currently under development and testing by our MTRI-UAF team, enables user-friendly map-based analysis and visualization for economic assessment of mineral resources in the Alaska-Yukon-British Columbia region that could be served by extension of rail networks that are currently undergoing assessment at the regional and national level. It includes many user-customizable parameters, with reasonable defaults based on the published literature and expert opinion. It is easily updated with new mineral occurrence, commodity price, and other critical information. Taking advantage of the power of ArcGIS and visualization tools such as Google Earth, users can investigate and map options such as commodity type, location information, proximity to infrastructure, natural features, and other geospatial data integrated into a single location by our MOREV tool. Carbon accounting is included to enable users to analyze the most carbon-efficient way of developing and shipping mineral resources; this is important in an increasingly carbon-aware political and economic environment.

A web-based version using ArcGIS Server is currently under development so that users can understand the desktop tool's detailed functionality, and is anticipated for release in early 2011. For site-specific, detailed, and in-depth analysis, we anticipate collaboration with our MTRI-UAF team by contacting the team leads of Colin Brooks, Dr. Paul Metz, and Dr. Robert Shuchman (see below). We are also developing functionality to help in modeling potential usage of an expanded rail system in future national security scenarios

and military usage where a trans-continental rail system may of increased value. Testing of current level of functionality is underway with regional stakeholders, and upcoming increased functionality will undergo similar testing. Enhanced help, user-entered commodity prices, net present value of gross mineral value for extractable concentrates, and more detailed mine and mill operating costs are also currently under development. Assessment of more detailed functionality to enable advanced cash flow and rate of return analysis is underway in collaboration with Dr. Metz. Integration of the tool into the larger cooperative international investigation linking Alaska and Canada rail systems involving the University of Alaska, Michigan Technological University, and the University of Calgary is also underway. A Fall 2010 workshop to help potential users understand and access the MOREV tool is being planned for the Alaska Miners Association and Yukon Geoscience Forum. A second paper is planned to detail how the tool can rapidly be adapted to other multi-modal shipping and logistics scenarios in North American and elsewhere.

For additional information on the MOREV tool and the carbon-accounting TCAM module, we encourage contacting Colin Brooks (colin.brooks@mtu.edu), Dr. Paul Metz (ffpam@mtu.edu), and Dr. Robert Shuchman (shuchman@mtu.edu). We anticipate that the ability to rapidly and easily explore and evaluate the economic impact of new mineral resource development in the region of the proposed Alaska-Canada Rail Link and shorter extensions using our flexible, modular ArcGIS-based tool will be of critical use in the region. By including carbon accounting, we have also made it possible to help ensure that any mineral resource development can be accomplished in the most environmentally efficient method possible over the life of new resource developments.

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