A MODEL FOR ENHANCING PRODUCTIVITY FOR TRUCK TRANSPORTATION OF MINERAL CONCENTRATES

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Seeking northern economic opportunities, the Aboriginal Economic Development Division of Indian and Northern Affairs Canada (AEDD) sponsored this project to enhance transport of mineral concentrates by road from mines to ports, railheads or processing destinations. The project focused on distances over 200 miles, and operations having severe physical, climatic or seasonal limitations.

The effort reviewed current relevant trucking sector best practices. Factors for special consideration include long hauling distance, lower quality of road infrastructure, special equipment needs, critical backhauling activity, options for loading, unloading or transfer, adverse seasonal restrictions and identifying break even volumes to warrant route upgrading.

Introduction

Remote mineral projects need economic transportation for moving products to customers and for securing inbound consumables. Frequently road transport is the best or only transportation option. At the same time, transportation is usually not the prime expertise of mine developers.

In this context, often trucking contractors design and plan the concentrate transportation system. These organizations lack large R & D budgets, so improvements to efficiency are generally piecemeal and implemented on a project by project basis. Notwithstanding these limitations, solutions devised need to be practical and responsive to market forces. Thus, they are competitive with other bidders and must be viable for project over-all economics.

Specific productivity factors that remote trucking systems must address include coping with low transportation volumes, adverse seasonal conditions that make hauling activity discontinuous, constraints in product handling (such as product freezing in containers or equipment hoppers), and maximizing payloads. Yet, with all the effort invested to overcome such constraints, mine associated transportation costs remain a significant determining factor in overall project viability.

In undertaking this project, we recognize the success of previous efforts to improve truck operational productivity for Canada's forest industry. The transportation unit at FERIC (Forestry Engineering Research Institute of Canada)[1] has contributed to this by developing and championing new technologies and then promoting changes to road regulations to accommodate the technologies. Success has been achieved with cooperation between industry and the public sector, and with opportunities and priorities explored using a computerized activity based operations management model to investigate and set priorities for needed change.

Project Approach

Our project began with a review of related prior information on concentrate hauling. This included:

- feasibility studies for a sample of remote minerals developments over the past thirty years,
- identification of firms that currently operate remote minerals projects involving longer distance truck hauls,
- a review of information available from the internet about projects, trucking firms that provide the services, and suppliers and manufacturers of equipment for road transport of minerals.

After we had assimilated this information, mining operations that use longer distance trucking were contacted and we enlisted their support to (1) tell us about their current operations (to fill gaps in publicly available knowledge), (2) agree to review our proposed minerals transportation model, as "calibrated" to their particular project, and (3) provide feedback as to whether our model was reasonably accurate, or needed further work. If changes were needed, we also hoped to identify how to better reflect currently used trucking technology and to investigate options to explore for enhancing efficiency.

To encapsulate what we learned from our consultations and to provide a useful framework for testing strategic options for productivity[2] enhancement, we then built a generic activity based hauling model for remote minerals concentrate sector trucking. As previously described, part of the "testing" phase for the model was to send calibrated copies of the model to each of the mining project interviewed, who had long distance mineral trucking operations or who were considering new NWT situated projects (and had undertaken some feasibility investigations already). Feedback after these organizations had reviewed our model was then integrated into how the model works.

Lastly, the project was documented in a formal report[3]. This gives project specifics about what was learned, describes and documents (for users) the activity based model of mineral trucking, and presents sample "case studies" for hypothetical minerals projects in NWT – applying the model. These are intended to demonstrate the capabilities of this model, for interested minerals development companies and for trucking firms that may be interested in employing the model to test and plan alternative truck operations strategies.

The project report did not publish the individual calibrated case studies for existing or proposed projects – as shared with individual mineral developers. By promising this treatment to our collaborators, we sought to distance our published research from having any direct commercial intervention that might impact transport carrier rate negotiations, affect project financing and feasibility considerations, or provide market intelligence to competitors of the firms sharing information with us.

Summary of Key Findings

Before presenting a model description and some sample generic case studies, it is useful to review some key factors considered and pertinent learnings from our review of industry practices.

Length of Haul: Although for longer distances, truck is generally viewed as a higher cost transportation mode, in comparison to (say) railway, we noted several mines that operated using very long distance truck hauls. These are apparently viable projects. A sampling of some interesting minerals trucking operations appears in Table 1. In the table, the two bottom rows are proposed projects (with hauling distances between 208 km and as far as 833 km). The other trucking operations appear to be economically sustained at truck hauling distances between 392 km and 1180 km one way. These are all in excess of 200 miles (320 km) one way.

Quality of Route Infrastructure: Though not tabulated herein, our review of the operating projects showed them to be on a variety of route standards and often, hauls would originate on a very primitive route (sometimes with seasonal restrictions, and usually with speed restrictions) and then progress through improving roadway segments – up through all weather gravel operations and even paved hauling. As a generalization, Table 2 shows some default average speeds for various qualities of route that we used when developing our productivity model. Note that speeds and route infrastructure quality are very "situation specific", so we recognize the need to customize hauling productivity analysis based on actual conditions "on the ground", if the model default values shown are found unrepresentative for a particular haul.

Table 1: Operations Summary For Existing and Proposed Mineral Development Hauls

Minerals Development	One-Way Haul (km)	Vehicle Payload	Annual Tonnes	Vehicle Configuration	Route Includes Public Roads?
Cyprus Anvil Mine, Later Curragh Resources, Near Faro, Yukon	545 km	51 Tonnes		10 Axle B Train Units: Containers on Chassis	Yes
McArthur River Mine (Australia) to Bing Bong Port	100 km	99 Tonnes		Australian Six Trailer Road Train (Side Dump)	Yes
Northgate Minerals Ltd., Kemess Mine	392 km	46 Tonnes	150000	7 Axle Tridem Tractor, Tridem Trailer End Dump Unit	Yes
Imperial Metals Corporation: Huckleberry Mine	514 km	46 Tonnes	100,000 tonnes of Copper Concentrate	B Train (End Dump)	Yes
Imperial Metals Corporation: Huckleberry Mine	1180 km	46 Tonnes	500 tonnes of Molybdenum	9 Axle B Train Unit (Side Dump)	Yes
Imperial Metals Corporation: Mount Polley Operations	631 km	46 Tonnes	100,000 tonnes	9 Axle B Train Unit (Side Dump)	Yes
Canadian Zinc Corporation: Prairie Creek Mine (Proposed)	460- 615 km, 470 - 625 km or 750 - 833 km (depending on route and railhead chosen)	46 Tonnes	100,000 tonnes	Open (Haul is Proposed)	Yes
Fortune Minerals: Nico Project (Proposed)	208 km	40 Tonnes	2200 tonnes of Concentrate in 17 tonne containers, 1200 tonnes in 15 tonne containers	20 foot ISO standard containers (Proposed) on chassis	Yes

Table 2: Standardized Average Travel Speeds (Model Default)

Route Type	Speed (km/hr)
Paved All Weather	80
Superior Gravel All Weather	75
All Weather (60 km/hr) Gravel	55
Winter Road (No Ice Bridges)	30
Winter Road (Ice Bridges)	20

<u>Trip Cycle Time and Basing of Drivers</u>: Distance and route quality, which translates into possible travel speed, combine to determine a

significant productivity factor for transportation from frontier locations such as remotely situated mines. This productivity factor is the trip cycle time expressed in hours.

Driving time is a result of distance traveled and feasible operating speeds, including provision for the return journey of the unit after making a delivery. Added to the driving time are other trip factors such as time for daily vehicle pre-trip inspection, awaiting loading and unloading operations, vehicle checks (tires and brakes), rest stops (mandated by hours of service regulations) and any other non-moving activities that take place during the haul. For some routes that were investigated, there are tractor "switches" where the same trailing equipment is pulled, successively, by a specially equipped off-road tractor and then followed by an on-highway unit that delivers to final destination. The trip cycle time must take account of all the foregoing needs.

The total of all the moving and stationary time factors amounts to the trip cycle time, expressed in hours. Basically, this cycle time can be viewed as the time in hours between when a vehicle will be available to start the next trip, having just finished the prior trip.

Ideally, to enhance productivity for the vehicle, the trip cycle should be as close as possible to an evenly divisible relationship to a full day's productivity, 24 hours. For example, a trip cycle of 8 hours enables 3 vehicle trips per day, 12 hours enables 2 trips per day, 4 hours enables 6 trips per day and so on. Sometimes, a value that is not evenly divisible can still be used efficiently if it has built in a regularly scheduled running maintenance program for the fleet. For example a 10 hour cycle time enables 2 productive trips and 4 hours for regularly scheduled inspection and running maintenance each day.

Note that for some trip cycle times, the total required time exceeds the hours that a single driver can drive or work in a day. There are then two options. One option is to consider whether drivers can be based at a mid point on the return journey, enabling a "slip seat" operation where the trip is started by one driver (who should have a realistically long enough shift length to make up a work day) and finished by a second driver, who both reside in the assumed "basing location". If there is no suitable community at the midpoint of the haul at which to base drivers and their families, one then needs to consider whether a "camp" or "bunkhouse" might be required at a strategic location on the route. The ideal key to productivity for manpower is to base drivers so that they are accessible to the haul in order to work it and so that each driver achieves a productive work shift of one, or possibly two (if the cycle distance is shorter) trips in an 8 to 12 hour period of time.

In this regard, we identified – as part of this research – the need to simulate the drivers' working day, and the equipment cycle, so as to be as productive as possible but within realistic safety (inspection intervals and other stops), daily hours of service regulations and equipment operating parameters.

Following Table 3 lists the trip cycle time and basing assumptions for some of the very long hauls from Table 1.

Table 3: Operations Summary For Existing Mineral Development Hauls

Minerals Development	One-Way Haul (km)	Round Trip Cycle Time (Hours)	Driver Basing	Hauling Route	Route Includes Public Roads?
Northgate Minerals Ltd., Kemess Mine	392 km	23.4 hr	Home: McKenzie: Camp for Layover at the Mine	Kemass Mine to McKenzie, B.C.	Open Access Forest Roads 192 km; Private 200 km
Imperial Metals Corporation: Huckleberry Mine	514 km	20.0 hr	Home Base is Midway at Houston, B.C. Driver 1 picks up load 8 hr; Driver 2 Delivers to Stewart 12 hr.	Huckleberry Mine to Stewart B.C.	Route is 70 km of Single Lane Forestry Road; 50 km of High Standard Forestry Road and 394 km of Paved All Weather Road
Imperial Metals Corporation: Huckleberry Mine	1180 km	21.0 hr	Home Base is Midway at Ashcroft, B.C. Driver 1 picks up load 9.2 hr; Driver 2 delivers to Vancouver 11.8 hr.	Mine via Ashcroft to Vancouver B.C.	Route is 12 km of High Standard Forestry Road, 76 km of Superior All Weather Gravel Road and 543 km of Paved All Weather Road

Note that for two of the hauls, the "basing" of trucks is roughly at a midpoint, allowing a slip seat operation for the drivers in their home city. Drivers can work up to 12 to 13 hours per day on a regular basis. Another of the hauls has trucks based at a trip destination, with no settlements at the mid point of the haul. In this case, there is a camp at the mine site, so that drivers can travel from home to position a truck, then lay over at the mine while a relay driver brings the loaded unit back to the home base location. This driver brought a previous unit up to the mine, before they had a layover at the camp. In this way, the trucks move continuously, while drivers are required to layover in the camp between their outbound trip to the mine and their loaded return to home base.

Because every hauling situation is a little different, our model needed to have the capability to enable the user to "plan" the hauling – and fairly quickly develop good alternatives for "solutions" that would account for all the driver time / trip cycle factors.

<u>Transportation Equipment:</u> In the course of our study, we encountered the use of a variety of truck configurations by some of the key players and manufacturers of trailing equipment. Much of the source information can be found at the various websites listed in following Table 4.

The final study report[3] describes equipment options in more detail. Such factors considered include a discussion of important materials handling considerations such as availability of different materials loading / unloading and transfer systems, susceptibility to freeze / thaw and issues related to product retention on equipment. Also, the study reviews equipment that permits backhauling of mine related products such as diesel fuel, reagents or grinding media.

All of these factors constrain what equipment types "work" for any given haul and what payload productivity and unit costs are applicable. The model needs to enable the user to compare a "menu" of equipment, currently used by other operators, and to be able to customize the analysis to consider new equipment options for a specific project.

Table 4: Carriers and Manufacturers Who Actively Service Concentrate Projects

Carriers	
Arrow Transportation	http://www.arrowtransportation.com/
Lomak Transportation	http://www.lomak.ca/equip_customized.html
Linden Transport	http://www.lynden.com/
Trimac Transportation	http://www.trimac.com
Manufacturers	
Beall Corporation	http://www.beallcorp.com/index2.html
Fort Garry Industries	http://www.fgiltd.com/
JMH Trailers	http://www.jmhtrailers.com

Hauling Seasonality: Generally, all weather routes permit truck operations 365 days per year whereas, depending on location, winter roads / ice bridges have tended to limit hauling to only 100 days between January and April. In recent years, warmer Arctic temperatures have reduced the season length for winter roads and ice bridges down to as few as 40 days, and with restricted weights and payloads over ice crossings for much of that time. It is now commonplace for planners to estimate truck operational costs based on using an 80 day, versus the traditional 100 day "winter road season" and one needs to be able to evaluate impacts for even shorter seasons in any productivity model.

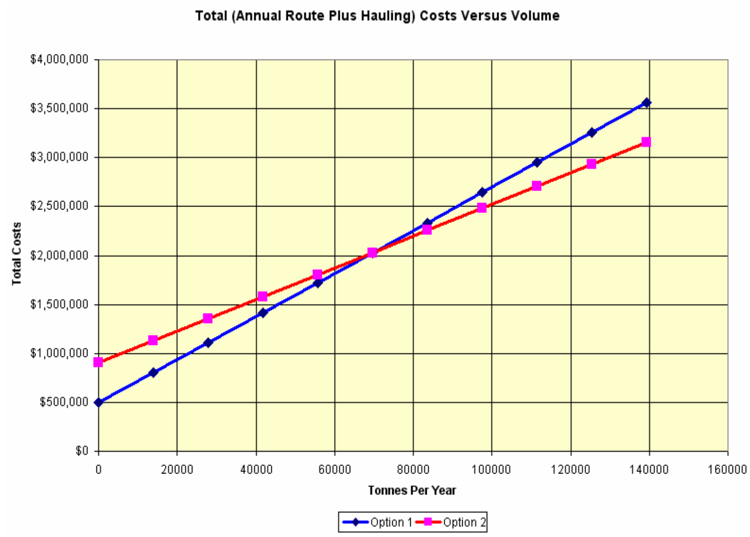
All weather routes with "seasonal crossings" (i.e. no permanent bridge has been provided for, due to very heavy capital costs) can operate approximately 300 days per year, usually with a ferry when the waterway is thawed and an "ice bridge" when it is frozen. Such routes cannot be used during freeze up and thaw periods; hence they do not operate 365 days per year. Again, such planning might reflect in only 250 days, if one accounts for a shorter winter access period.

In terms of “length of season”, from a truck productivity standpoint, to move the same annual volume of material requires more vehicles to be "chartered" for a shorter period of time, when hauling over a route with a shorter season -- hence the unit cost of owning or hiring trucks for the haul, rises. Per tonne transport costs increase accordingly.

Volume Thresholds: In response to route factors such as the foregoing, the economic justification for investing in an infrastructure upgrade makes use of a standard business break even analysis. For investing in infrastructure upgrades (or alternative modes), one needs to be able to identify the break even annual tonnage that will generate per trip operational savings to pay amortized annual costs for the required up front capital invested in the upgrade. The concept is illustrated in Figure 1 where lower annual production of concentrates only cost-justifies a Winter Road (Option 1) instead of All Weather Trucking (Option 2).

Note that as well as applying this concept to our truck productivity model, a similar cost break even analysis could be applied to considering use of more efficient unit operating cost modes such as a railway, or even an airship service (which is of interest in some quarters) to service the mine. The former has significant route construction expenses that need to be amortized over a business time horizon and the latter has significant research and development / design and prototyping hurdle costs associated with any implementation. Both are unlikely to be able to break even with likely transportation volumes of concentrates available from most currently considered operations.

Figure 1: Sample Break Even Analysis For Upgrading a Winter Road to All-Weather Truck Route



Modeling Activity Based Fleet Requirements and Costs

Following our review of prior projects and consideration of detailed system needs, the project findings were incorporated into an activity based fleet requirements and costing model.

The purpose of the model is to accurately project costs in a manner that aids users to maximize trucking productivity by identifying and comparing best options for the hauling activity.

The model we proposed was used by us to provide confidential "calibration" to various specific hauling projects. In addition, as documented in the project report, we demonstrated the model's application for a hypothetical concentrate haul in the NWT.

Such a model permits strategic comparison of the relative efficiency and scope for improvement derived from optional strategies for route infrastructure, where drivers are based, higher payload/GVW units, special 2-way hauling configurations, and stacking equipment for empty return.

Implementation of the model was in the form of a Microsoft Excel workbook containing a number of "pre-codes" for standard configurations and route characteristics, but permitting user "overrides" if these coefficients require customization to a specific haul.

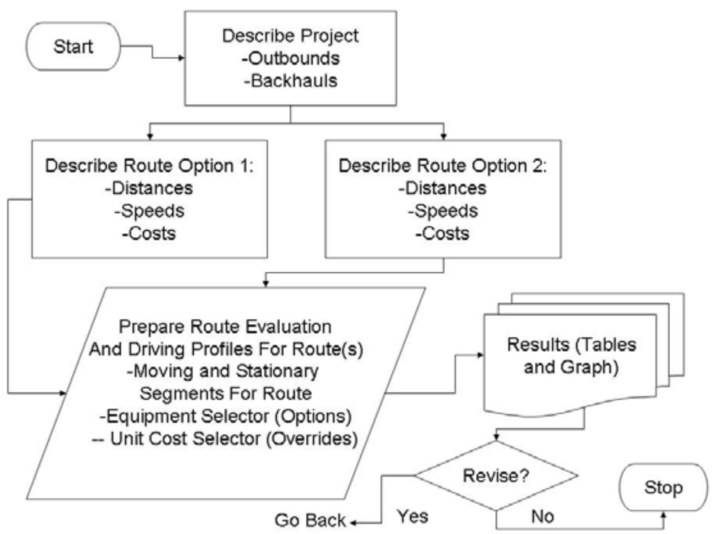
Figure 2 gives the activity sequence to be followed by a user of the model.

Note that the route evaluation process devised by us is not especially automated, however a user template is provided on the spreadsheet and the study report has step by step instructions to enable a user to devise realistic route evaluations that are used to drive the model's costing process.

Figure 3 illustrates the model's route planning template. In this scenario, the haul consists of 120 km of ice road having no ice bridges and 225 km of paved all weather highway.

The upper half of the template lists up to 10 user specified route segment types (each segment type has associated unit speeds, annualized capital and annual maintenance costs per km) and 9 possible stop segment categories. Elsewhere in the model, these parameters can be "adjusted" from base values researched in our study, if user customization is needed.

Figure 2: User Activity Sequence Using the Concentrate Trucking Model



In the lower segment of the template, the user describes the haul using a series of route codes -- specifying distances and times, as needed. While creating this route description is a manual procedure, the model's template and instructions "walk the user" through the process of developing a workable hauling scenario. If the user finds a problem with the planned hauling cycle, part way through, it is relatively simple to make changes and have the computer re-calculate times and distances for the trip segments and over-all.

In order to accommodate break even analysis (such as comparing winter road to a scenario where the mine may operate with an all weather road, albeit at increased capital expenditure), the model has two such route planning templates (called option 1 and option 2). This permits the user to make strategic comparisons of candidate hauling methods for a given development project (over-all results are summarized graphically in the model in the format of Figure 1, previously discussed.

Figure 3: Sample Route Planning Template From Model

MINERALS CONCENTRATE DELIVERY MODEL

Aboriginal Economic Development Division Indian and Northern Affairs Canada
System developed by Logistics Solution Builders Inc.

Route Code	Driving Segment Type	Total Length	Total Annual Construction $	Annual Road Mtce. $	Route Code	Stop Segment Type
1	Paved All Weather	450.0	$0	$0	11	Pre Trip Inspection
2	Superior Gravel All Weather	0.0	$0	$0	12	Tire / Vehicle / Brake Check
3	All Weather (60 km/hr) Gravel	0.0	$0	$0	13	Meal Stop
4	Winter Road (No Ice Bridges)	240.0	$15,000	$300,000	14	Slip Seat (Driver Change)
5	Winter Road (Ice Bridges)	0.0	$0	$0	15	Layover Stop
6	User Specified 1	0.0	$0	$0	16	Loading or Unloading Stop
7	User Specified 2	0.0	$0	$0	17	Balance to 8 Hour Shift
8	User Specified 3	0.0	$0	$0	18	User Specified 7
9	User Specified 4	0.0	$0	$0	19	User Specified 8
10	User Specified 5	0.0	$0	$0		

Transport Option 1: Route Evaluation and Driving Cycle

Code	Location / Segment	Distance	Time (Hr)	Remarks	Cum Hr	Cumulative Distance
All	***Total All Segments***	***690.0***	***17.38***		***17.38***	***690.0***
11	Pre-trip Inspection	0.0	0.25		0.25	0.0
4	Winter Road to Mine	80.0	2.67		2.92	80.0
12	Vehicle Check	0.0	0.25		3.17	80.0
4	Winter Road to Mine	80.0	2.67		5.83	160.0
16	Loading at Mine	0.0	0.50		6.33	160.0
13	Lunch Stop	0.0	0.50		6.83	160.0
4	Winter Road From Mine	80.0	2.67		9.50	240.0
12	Vehicle Check	0.0	0.25		9.75	240.0
4	Winter Road From Mine	0.0	0.00		9.75	240.0
14	Driver Change	0.0	0.25		10.00	240.0
1	Paved to Load Out	150.0	1.88		11.88	390.0
12	Vehicle Check	0.0	0.25		12.13	390.0
1	Paved to Load Out	150.0	1.88		14.00	540.0
16	Unloading	0.0	0.50		14.50	540.0
13	Lunch Stop	0.0	0.50		15.00	540.0
1	Paved From Load Out	150.0	1.88		16.88	690.0
12	Vehicle Check	0.0	0.25		17.13	690.0
1	Paved From Load Out	0.0	0.00		17.13	690.0
11	Post Trip Insp	0.0	0.25		17.38	690.0

For the 345 km haul outlined in Figure 3, and a project volume of 50,000 tonnes of concentrate annually and using a 46 tonne payload tridem tractor -- tridem end dump unit, delivery costs were estimated to be $53.86 per tonne based on $47.37 for the trucking operation and $6.48 per tonne for route maintenance (mostly winter road maintenance expenses). The required fleet to move the volume consists of 16 tractor trailer units. In this simplified scenario, no costs have been shared to move inbound mine supplies (such as backhauls of diesel fuel, grinding media, etc.), a factor that would improve the productivity of truck operations.

The full study report[3] presents comparative sample scenarios for:

- Break even analysis for using an all weather route standard
- Making use of various backhaul productivity options
- Use of a 200 tonne payload Australian road train type unit
- Application of "stackable technology" (the concept borrowed from the forest industry).

Project findings from our investigations are as follows:

- Longer distance truck transportation systems for supporting remote mineral developments are clearly viable undertakings.
- Activity based economic modeling for such applications would seem to shed light on methods to enhance productivity for particular projects and enable setting of priorities for further research toward best practices.

REFERENCES

1. Forest Engineering Research Institute of Canada (FERIC), http://www.feric.ca, Internet Search Performed February 2007, discusses OTTO 2000, a tool to Simulate your trucking operations and the performance of current or potential vehicles on your roads and compare the effects of different component choices, driving styles, and road layouts on vehicle performance.

2. William J. Stevenson and Mehran Hojati, Operations Management, 2nd Canadian Edition, McGraw-Hill Ryerson Press, 2004, ISBN 0-07-091189-4, define productivity as a measure of the effective use of resources, usually expressed as the ratio of output of a business process to inputs.

3. Logistics Solution Builders Inc., Productivity Of Long Haul Truck Transportation Of Mineral Concentrates, prepared for the Aboriginal Economic Development Division of Indian and Northern Affairs Canada, March 2006.