An Analysis of Externality Costs of Freight Transportation in Vermont

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Abstract:

Given the vital nature of freight transportation to the economy of Vermont, we have set out to create a comparison of the external costs associated with both truck freight and rail freight shipments specifically within the Middlebury-Burlington corridor. We have calculated that the net benefits of increasing the use of rail in this area to 100% of its current capacity would be in excess of $13.5 million dollars every year comparing just the external costs of congestion, accidents, pollution, noise, infrastructure, enforcement, and CO2 emissions, and the internal costs associated with fuel savings. Therefore, a shift to transporting more freight by rail in the state would make Vermont cleaner, safer, and less costly.

Introduction:

Vermont's economy is inextricably linked with its 456 miles of rail track (CrossTies, 2005). Given the nature of some of Vermont's primary industries, freight shipment by rail is the only option. Lumber, grain, building materials, wood chips, petroleum products, granite, marble and calcium for winter road maintenance are all either extremely large or heavy therefore necessitating shipment by rail (Heaps and Woolf 2005). However, because of the cheap historic price of gas, and ease of point to point delivery associated with trucks, we see that rail freight shipments have fallen to around a seventh of truck shipments in Vermont (FHWA, Vermont State Profile). Given that we have found rail as having a net benefit in terms of the externalities associated with freight shipment, this ratio is in need of fixing.

Considering direct economic impact through the railroad industries output, employment and earnings as well as the indirect effects from the industry's substantial payroll and its payment of taxes and fees, the railroad industry has a total annual economic benefit of at least $19.2 million in wages alone (Heaps and Woolf 2005).

Although the industry substantially contributes to the Vermont economy, it is only operating at approximately 25% of capacity (Miller, 2005). Unfortunately Vermont's railroads do not meet the national specifications of Class I lines. National weight limits for such railroads are at 286,000 pounds and above while Vermont's lines have limits no higher than 263,000 pounds. This creates a serious problem for interline traffic traveling through Vermont from other rail networks (Cambridge Systematics, 1999). Furthermore, there are a limited number of trans-load facilities that make the transfer of freight from rail to truck easier. Together, these two issues are making the Vermont rail network increasingly unattractive for shippers.

It has been projected that the amount of freight that is shipped through the US will double by 2020 (Holly Stearns, 2001). This expansion is due mainly to the increase in offshore manufacturing of basic goods that used to occur within the US. Now, because goods can be produced more cheaply abroad due to globalizations[1], these goods have to get shipped from where they are made to the US, making their way through one of the many ports in the US, and need to get distributed to every Wal-Mart, Costco, Exxon station, and mom & pop store in America.

The plight of Vermont's rail infrastructure will grow in severity unless the problem is fixed soon. As the volume of imports from overseas increases, the importance of a robust national transportation network will also increase. If Vermont's railroad industry does not modernize it will be at a serious disadvantage and lose out on substantial economic gains.

Recognizing this situation, this study aims to quantify the external costs[2] and benefits associated with increasing freight transportation on Vermont's rail network. Although it is known that freight transportation by rail boosts fuel efficiency, reduces emissions, alleviates traffic congestion and improves the safety of hazmat transportation (Freight Rail Fact Book), these external costs of increasing freight transportation by rail in Vermont have not been quantified. We chose to ignore internal costs because they are readily known to industry experts and available in financial statements on request.

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[1] Globalization contributes to the narrowing of goods produced in each country to those within their comparative advantage. Since the US specializes in service and technology, manufacturing goods will continue to come from overseas as wages are lower, and the costs of production are lower.

[2] External costs (negative externalities) include those costs that do not have to be borne by those benefiting from the freight transportation (Goodstein, p32).

However, quantified external costs are sometimes much harder to calculate and internalize, so society must understand these costs not borne by individuals in order to have any idea of the true costs associated with various forms of transport. Since the infrastructure/ fixed costs for both rail and truck are already in place, the costs and benefits of expansion are likely to be external/hidden. Our findings serve to show why it makes sense just from society's standpoint (Vermont residents) to increase investment in rail advocating policies in order to lower the external costs associated with overall freight transport.

Methodology:

When looking at the expansion of rail freight in Vermont as an alternative to trucking, there are many things that we have to consider, not just the bottom line monetary costs and benefits, but all the social, and environmental costs and benefits as well. As our main goal of this project is to better understand the environmental costs and benefits associated with Freight transportation in Vermont, we first seek to determine what the externalities of rail and truck freight transportation are.

Specifically, we sought to analyze the total external costs and benefits of expanding rail freight transport between Burlington and Middlebury, VT. This area of the state is currently a major corridor for shipping both by rail (along the Vermont Railway line) and by truck (along Route 7); therefore, it provides a simplified, yet representative scenario of shipping in Vermont.

First, we quantified how expansion of current rail freight transport to three different levels (50%, 75% and 100% of potential capacity) would affect the total external costs of all freight shipping (assuming the total volume stayed the same), both by rail and by truck, in Vermont. To do so, we:

1) Found valid estimates (in cents/ton-mile) for seven major external costs (congestion, accidents, pollution, noise, infrastructure, fuel, and enforcement) of shipping by rail and by truck (see Appendix 1), and

2) Calculated the annual freight transport (in ton-mile) from Middlebury to Burlington by mode (see Appendix 2).

Multiplying the appropriate data allowed us to put a monetary value on the total external costs under each rail user level scenario, which we then compared to quantify the net benefits achieved by each expansion scenario.

Then we went on to quantify the associated Green House Gas (GHG) emissions of rail and truck freight movements not in monetary terms, but in terms of quantity given the four user-level scenarios. Although it would have been nice to have found monetary costs associated with these GHG's emitted by each mode, it is difficult to place values on the effects that these gases have on the environment. Nonetheless, given the importance of global warming today, we felt that it was important to at least calculate quantities of some of the harmful gases given off by each mode of transport under each user-level scenario. We were able to gather the quantities of NOx, CO, and Hydrocarbons given off from trucks and rail from other studies in order to show what the current total emissions are for freight transportation between Middlebury and Burlington.

Finally, we went ahead and calculate the tons of Carbon Dioxide (one of the most important GHG's) given off by each mode of transport based on their fuel efficiency which we calculated as an externality, and then used the abatement cost of that Carbon

Dioxide from Native Energy to include in a direct comparison. Native Energy will allow individuals to offset their Carbon footprints by purchasing coupons toward the creation of renewable power. Native Energy is another service learning partner with our class, and so we thought that this addition would fit well, plus it gives us some idea of the cost to society of adding the additional CO2 to the atmosphere.

Data:

Using Excel as a platform for gathering our data (See Appendix 3) first, we found the average daily truck traffic between Middlebury and Burlington to be around 862.4 trucks per day, and the average tonnage of a truck to be 40 tons (VTran daily counter). Multiplying this out for a year we get a total tonnage transported by truck between Middlebury and Burlington of 12,594,544 tons/year. Next we had to do the same thing for rail, and we found a total tonnage of 2,050,000 tons/year (Charlie Miller, 2005). By converting these numbers into ton-mile units for the trip between Middlebury and Burlington (a 39.4 mile trip), we get the following values:

Table 1

Current Freight Transport between Middlebury and Burlington, VT*:		
	Rail	**Truck**
Annual Ton-Miles	80,770,000	496,225,513
% of Total Transport	14	86

We assume that rails 80 million ton-miles/year is approximately based on operation at only 25% of capacity. Then we went ahead and keeping the combined total volume the same increased rails share of the freight ton-miles to 50% of its capacity, 75% of its capacity, and finally 100% of its capacity (Table 2):

Table 2

Increased Capacity Scenarios		
Rail operating at 50% of Capacity		
	Rail	**Truck**
Annual Transport(ton-mi)	161,540,000	415,455,513
% of Total Transport	28	72
Rail operating at 75% of Capacity		
	Rail	**Truck**
Annual Transport(ton-mi)	242,310,000	334,685,513
% of Total Transport	42	58
Rail operating at 100% of Capacity		
	Rail	**Truck**
Annual Transport(ton-mi)	323,080,000	253,915,513
% of Total Transport	56	44

Next, we obtained cent/ton mile values for the seven different external costs based on data retrieved from two separate studies, one from Canada and one from Australia. We decided to use these studies although they are not based in Vermont because they both come from rural areas, and so provide us with the most comparable estimates. These studies also give us a comprehensive analysis of the external costs, something that was absent in Vermont's case studies. Among the values that we found from the Australian study are enforcement costs associated with trucks, and noise costs associated with both trucks and rail (Gargett et. Al, 1999). From the Canadian Study we were able to attain the costs associated with congestion, and infrastructure with

Table 3:

External Variables	**Costs (cents/ton-mile)**	
	Rail	**Truck**
Congestion	0	0.8
Accidents	0.08	0.5
Pollution	0.29	0.89
Noise	0.02	0.04
Infrastructure (pavement, etc)	0	0.84
Fuel	1.1435	3.8879
enforcement	0	0.06
upgrade to new rail (flat fee)	$25,000,000	0

Non-monetary variables	**Costs (lbs/ton-mile)**	
(GHG emissions)	**Rail**	**Truck**
Hydrocarbons	0.46	0.63
CO	0.64	1.9
NO_x	1.83	10.17

trucks, and the accident, and pollution costs associated with trucks and rail (Transmode Consultants, 1995). The upgrade costs to higher weight limit rail structures within Vermont was obtained from Charlie Miller at VTrans. The fuel variables are included as a measure of efficiency only, and are the only internal costs we have included in our study (Transportation Research Board, 2002). The values we came up with in cents/ton-mile (except for the cost of upgrade to higher weight rail which is in dollars) can be seen in Table 3.

Looking at the variables and their associated costs it is easy to see what each takes into account. There are no external costs to rail associated with congestion, because rail can operate on a smoother scheduled time table, and there is no competition with public motorists. For trucks, congestion takes into account the added cost to society of delays associated with greater road use. Accident costs take into account both the frequency and severity of collisions by the various mode, showing that under more controlled environments such as rail there are fewer external costs. Pollution includes the external costs to society associated with the emission of particulates as well as oil spills, tire-treads, etc. The external costs of noise to society is pretty self explanatory, it accounts for the costs of noise pollution, and its effects on humans, and animals alike. Infrastructure costs are only incurred against trucks because of their degrading effect on public property, while trains operate on exclusive track. Since highways are a public good, the monitoring and enforcement costs are much higher, and borne by society, not individual truckers and are so an external cost, while there are no real enforcement costs for rail. The Fuel costs have been calculated as a measure of efficiency, trucks use .017 gallons of diesel for every ton-mile and rail uses .005 gallons for every ton-mile (Transportation Research Board, 2002).

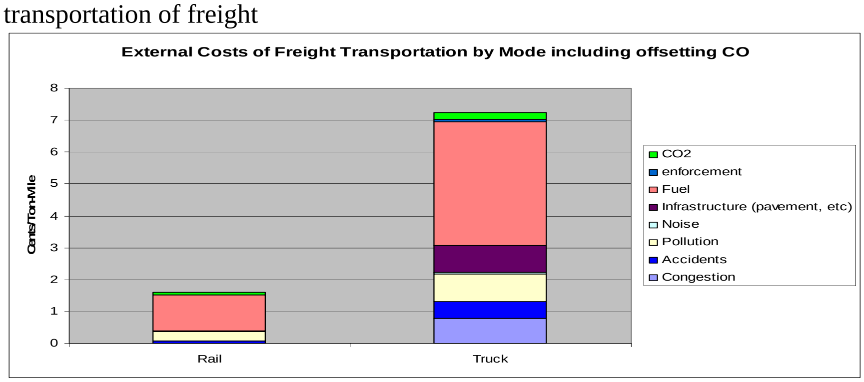
Then, the lbs/ton-mile emissions of GHG's for both rail and truck (Figure 1) were gathered (Transportation Research Board, 2002). For some reason there was no data available on CO2 emissions and their associated costs, we weren't sure whether the other variables would be an indicator for Carbon emissions as a whole or not. Therefore, we had to go ahead and get our own data for a measure of the associated costs of CO2. We did this in terms of the offsetting costs of CO2 per ton-mile for each mode[3] (Table 4):

Table 4

Costs of offsetting CO2 (cents/ton-mile)	
Truck	0.23
Rail	0.07

Now that we have calculated the additional costs of offsetting the CO2 emissions associated with each mode of transport into our analysis as well, we believe we have a fairly complete list of the external costs (and the internal cost associated with fuel, perhaps one of the main internal costs given the physical capital is already in place) as can be seen below in Figure 1.

Figure 1. This shows us a stacked bar graph of the external costs we calculated for both rail and truck transportation of freight



[3] A gallon of diesel fuel emits 22.4lbs of CO2, or .0112 tons. Once again, we want data on the emission costs for every ton-mile both trucks (using .017 gallons per ton-mile) and rail (.005 gallons per ton mile). We then took the costs to offset from Native Energy, at $12 per ton, and come up with a cost of offsetting. (NativeEnergy, 2005).

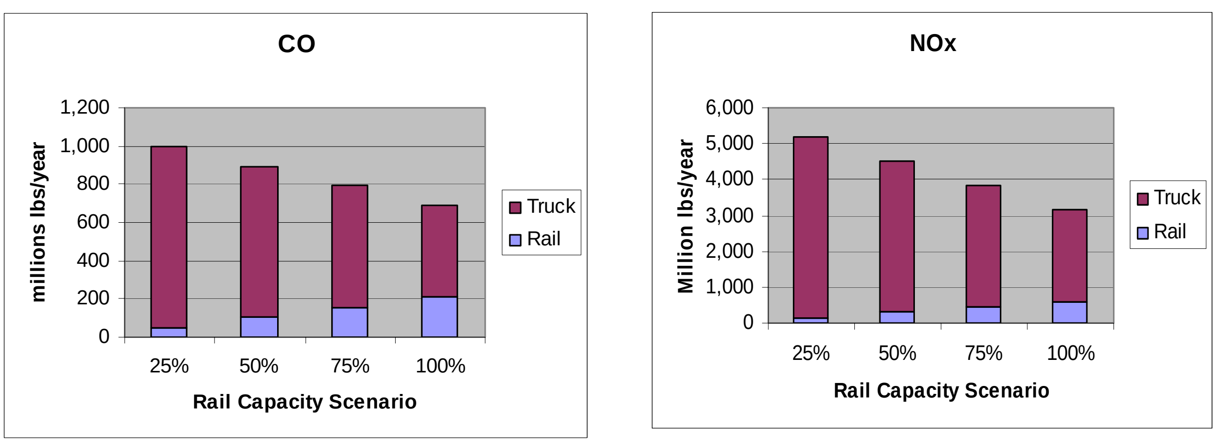
Results:

Table 5: Total combined externality costs of rail and freight travel in each expansion scenario (excluding the costs of abating CO2) along with the associated net benefits of that expansion.

	25%	**50%**	**75%**	**100%**
Total Externality Cost	$61,063,218	$56,633,468	$52,203,718	$47,773,969
Net Benefits of Rail expansion		$4,429,750	$8,859,500	$13,289,250

After working through the task of quantifying the external costs of increasing the capacity of rail freight transport from Middlebury to Burlington, as described in the previous section, we came upon results that showed a clear benefit of expanding the current Vermont rail system up to full capacity. The net benefits of expanding from the current operation at 25% to full capacity would have a net benefit of over $13 million per year (Table 5). This boost to full capacity would increase the modal share of rail freight to 56% from its current share of 14%.

Figure 2: (a) Carbon monoxide and (b) nitrous oxide emissions associated with each expansion scenario.



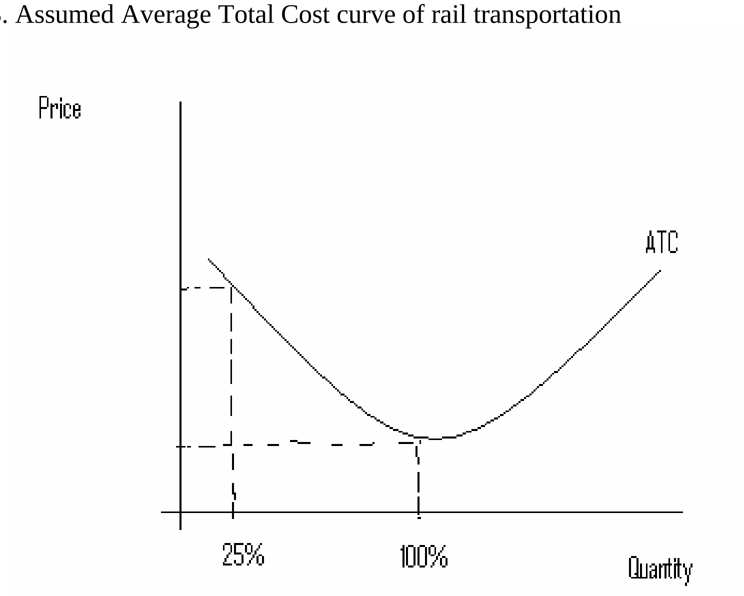
Clear benefits were shown when we looked at the changes in greenhouse gas emissions associated with the increases in rail freight. Carbon monoxide emissions would be reduced by around 300 million pounds per year (Figure 1a) from current levels emitted by these freight modes. Similarly, nitrous oxide emissions would be reduced by around 2 billion pounds per year from current levels (Figure 1b). Although not as stunning, the increased rail use would decrease hydrocarbon emissions by around 50 million pounds per year.

If we were to include the costs associated with having to abate the associated CO2 emissions contributed by each mode of transportation the total net benefits under each scenario would increase even further. At 100% of rail capacity, given the same volume of freight transport, by shifting more to rail, society would save an extra $388 thousand dollars through saved CO2 abatement costs, if we were to force the abatement of CO2. This savings adds on to create a new net benefit of increasing rail transportation to over $13.5 million dollars every year.

Along with these external variables that we chose to calculate in our analysis, there were many others that we were not able to quantify, such as employment benefits and the multiplier effects associated with them, and the benefits of transporting hazardous materials by rail. We found that for every $1 million dollars in revenues earned by Vermont's railroads, 11.4 new jobs are created in the economy, 5 in the railroad industry and the rest throughout the economy through the multiplier process These new rail workers, who receive an average wage of $48,265, would be boosting the state economy with this income (Northern Economic Consulting, 2005). The problem is that although we cannot give an accurate number, many more jobs would be lost by the decreases in truck transport because it is a more worker intensive industry. The transport of hazardous materials is a dangerous part of the transportation sector, but one that can be made much safer with the increased use of rail transport. Railroads are by far the safest way to transport hazardous materials, they have eight percent of the hazardous materials accidents that trucks have, despite having roughly equal ton-mileage (Freight Rail Fact Book, 2005).

While we have concluded that based on the external costs of freight transportation through Vermont, the more rail we utilize the better off we will be, we have not really addressed whether the demand for this increase in rail will materialize. Our analysis has not included any of the direct costs/operation costs, except for fuel costs, of either mode of transportation, although we have found figures that cite rail as being 1/10th the cost of trucking (Dunnigan, 2005). There are obviously other direct costs as well such as the increased trans-loading costs as we use more rail etc. However, it can be assumed that given a U-shaped Average Total Cost curve for using rail, and that we are only operating at 25% of capacity. The more we utilize rail, raising our use of its current capacity, the lower the direct costs become (Figure 3), meaning that the demand should be there as the price drops.

Figure 3. Assumed Average Total Cost curve of rail transportation



Conclusion:

To conclude we want to reiterate that the study we have implemented boils down to a cost comparison of the main externalities associated with freight transportation in Vermont, as well as a measure of the fuel efficiency of both trucks and rail. The externality costs take into account the costs to society as a whole that do not need to be internalized by the individuals transporting freight, and so are important to society in order to determine whether or not public money should be spent on rail services in order to avoid some of those costs. As you have seen from our data, the average externality costs in monetary terms and in GHG terms are smaller for rail given the current circumstances.

Assuming a constant amount of freight being moved through Vermont, the more that can be accounted for by rail, the better off society will be in terms of the reduction in externality costs, somewhere in the millions for reaching 100% capacity. This amount even discounted into the future each year would more then cover the costs of revamping the infrastructure. However even though we would like to be able to quantify all of the externality costs of the different modes of transport, it is almost impossible to do so, and some of the key hidden costs we left out were in employment (for every $1million in railroad revenues 11.9 new jobs are created, in rail and through multiplier, however we assume that more jobs would be lost by switching from trucks to rail, and so this would work out to be an overall cost to rail) and monopoly power. We have also not accounted for the transportation of Hazmat which we know would work to the advantage of rail.

Our analysis has also talked nothing about the actual internal costs of either mode of transport. We have not included any kind of operating costs, except for fuel costs, or the increased trans-loading costs associated with increased rail. However, we can assume that given a U-shaped long run ATC curve for rail freight, as we expand the use of rail, we will drive costs down, and realize economies of scale that will also work as a large benefit for rail.

Overall, given the reduction in GHG's and external costs by switching to rail, we can live in a cleaner, safer, and less costly Vermont!

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***Indicate articles provided by Anthony Otis**

Appendix 1: *Input Data – External Cost Estimates*

A number of studies have calculated estimates for external costs of shipping by rail and truck. We used two studies – the Brotherhood of Maintenance of Way Employees' study, "External Costs of Truck and Train", and Gargett et al.'s study, "Competitive Neutrality Between Road and Rail" – as sources for our estimated costs (Victoria Transport Policy Institute). The former was conducted in the region surrounding Ottawa, Canada, and the latter in Australia. We felt that the generally rural character of these two regions compared favorably with that of Vermont. Thus, in comparison with other studies which focused on "intercity" transport scenarios, these studies likely provided estimates more appropriate to our work. Additionally, each study provided estimates for several external costs and there was significant overlap between the two. This allowed us to maintain a high degree of internal consistency, as well as cross-check estimates between the two studies.

In each of these studies, the costs are presented in units of foreign currency/metric tonne-kilometer. Therefore, before doing our calculations, we converted into U.S. cents/ton-mile. While both studies were conducted in past, we found that because the cost estimates were so low (on the order of 10^{-4}), inflation had negligible effect. For accuracy, we compared any external costs estimated in both studies and found that, in most cases, differences did not exceed .01 cents/ton-mile. The only variable for which the estimates diverged significantly was congestion costs. In this case, we used the estimate from the Ottawa study on the basis of its geographic proximity to Vermont.

In addition to these monetary costs, we also included some environmental costs – namely, green house gas emissions – which are difficult to quantify in dollar-value terms. In this case, we used the Transportation Research Board's study, "Comparison of Inland

Waterways and Surface Freight Modes", which provides estimates for rail and truck emission of hydrocarbons, CO, and NO_X in lbs/ton-mile (Victoria Transport Policy Institute).

Appendix 2: *Input Data – Annual Transport by Mode*

We also calculated the current levels of rail and truck freight transport along the Burlington-Middlebury corridor. Because we needed these numbers in units of ton-mile, we first found the total tonnage transported by mode along the corridor, then multiplied by the approximate distance between the two cities (39.4 mi). Officials at Vermont Transit provided us with the approximate tonnage transported by rail along the corridor. Because there is no mechanism for counting exactly how many trucks travel from Middlebury to Burlington, we instead used average annual daily transport (AADT) determined along the route from the Vermont department of transportation. (http://www.aot.state.vt.us/techservices/Documents/TrafResearch/Publications/2003AVCfinal.pdf). These numbers provided us with the number of trucks passing daily through each site. We averaged the counts from each site, and then multiplied by the number of days in a year and the full capacity of each truck (80 tons) to get an estimate of the annual load transported by truck.

Under current conditions, rail in Vermont is operating at approximately 25% of the potential capacity it could operate at if the state paid to upgrade the system (Charlie Miller 2005). We assumed that if rail transport were to expand, total transport would remain constant. Thus, under an expansion to 50% of capacity, rail transport would double, and truck transport would decrease an equivalent amount to offset the rail increase. The same holds true for expansion to 75% and 100% of rail capacity.

Appendix 3:

Attached Excel spreadsheet, click here