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"Economics of Increased Axle Loads: FAST/HAL Phase II Results,"

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Summary

Based upon the cases analyzed to date, the use of heavier cars, with attendant increased axle loads, may be a viable tool for achieving significant total savings in cost for specific rail operations. The potential net benefits for operations with 286,000 gross vehicle weight (GVW) cars are in the range of 2 to 6 percent. For 315,000 GVW vehicles, the net benefit is in the range of -1 to 1.3 percent; no significant improvement from 263,000 GVW operations.

Overall the Facility for Accelerated Service Testing and heavy axle load (HAL) research and subsequent economic evaluations performed through the end of Phase II confirm the basic conclusions and recommendations reached at the end of Phase I.

The economic results are highly route and service specific. Thus, individual railroads should analyze their particular service alternatives.

BACKGROUND

Phase I of the Heavy Axle Load (HAL) Tests at the Facility for Accelerated Service Testing (FAST) was designed to determine if operations with axle loads above the 33 tons allowed in interchange service (263K pounds gross vehicle weight — GVW — for four axle cars) were technically feasible and economically desirable. Results of Phase I testing were reported to the industry at the *Workshop on Heavy Axle Loads* held in Pueblo, Colorado, in the fall of 1990. Shortly afterward in 1991, a Phase I economic report to the industry was made. This study concluded (1) operation with increased axle loads was technically feasible, (2) economically desirable under favorable conditions, and (3) certain areas of concern must be addressed to resolve the uncertainties of HAL operations and improve their economics.

Phase II of the FAST/HAL testing was designed to (1) evaluate improved components and maintenance practices that offer cost reductions in areas where the Phase I tests suggested potential improvements and (2) allow the determination of the life of longer-lived track components, such as ballast and rail.

In addition to testing new components at FAST, additional data has been collected from revenue operations with HAL traffic. Also new models for analyzing the performance of steel bridges and track components, such as turnouts, ballast, and ties have been developed.

The purpose of this FAST/HAL Phase II Economic Study is to update the Phase I analysis and conclusions based on the additional information available from the FAST/HAL Phase II tests. The new information includes new component designs and maintenance procedures tested, the revenue experience on member roads, and the new theoretical models available concerning the performance of critical track components and steel bridges.

OVERVIEW OF ANALYSIS

Phase I

The Phase I study considered the direct operating costs of providing unit-train transportation of coal over four generic routes: (1) an "eastern" route characterized by moderate grades and significant curvature, (2) a "western" route characterized by moderate grades and less curvature, (3) a "mountain route" with extreme grades and curvature, and (4) a "level route" with very little curvature or grades. Trains traveling each route were (1) weight (drawbar force) limited or (2) length limited by considerations, such as siding lengths, loading or unloading loops, or other length limitations. Operations that were length limited were shown to gain a greater advantage from increased axle loads than those that were weight limited since the greater capacity per unit of train length of the HAL cars could be used to increase the lading in the train. The economics of two HAL cars were evaluated (1) the 315K GVW cars as tested at FAST, and (2) the 286K GVW cars as evaluated based on interpolations with the deterioration models calibrated to 263K GVW and the 315K GVW operations at FAST. This resulted in 16 evaluations of HAL equipment alternatives in two operating environments over four different route characteristics. In all cases, the 286K HAL traffic cost advantage was superior to the standard 263K with the advantage varying from 7.0 percent to 1.6 percent. The 315K HAL traffic had mixed results varying from 5.2 percent advantage over the 263K to a 3.0 percent disadvantage. In no case did the 315K traffic cost out perform the 286K option.

Beyond the generic studies, the Phase I report contained the results of two case studies where the AAR and the industry *Ad Hoc* FAST /HAL Economic Committee worked closely with two member roads to analyze specific proposed HAL services on those roads. The effects of HAL traffic on bridges on these case study routes were developed by the individual road's bridge departments. These more detailed analyses reached the same conclusions and provided additional validation to the generic studies.

Phase II

The Phase II economic studies use the same basic methodologies and many of the same tools employed in Phase I; however, there are some changes in the details of the analysis.

Changes in Scope — First, only the eastern and western generic studies are performed in Phase II. The extreme mountain and level routes did not produce the extremes of either relative advantage or disadvantage of either HAL equipment option, and they were not comparable to either of the actual routes used in case studies in Phase I. Thus, the Committee and staff did not feel the data collected from these routes added anything to the understanding of the economics of increasing axle loads. Given severe limits on both funding and time for Phase II, these routes were eliminated. Second, no case studies were conducted in Phase II, since the overhead to work with a new set of roads was beyond the time and resource constraints of the current study.

Changes in Analytic Tools — During the five years since the Phase I study, there have been several improvements in the analytic tools available to conduct this economic assessment. These changes involve both upgrades in existing tools and the development of new tools. First, the Train Energy Model that simulates the physical operation of the train consists over the route has undergone two major updates providing both better train handling and an aerodynamic subroutine that allows a more accurate computation of the aerodynamic component of train resistance. Second, the Total Right of Way Maintenance Analysis and Costing System has been upgraded with new models for turnout degradation, wood tie life, and ballast life. Third, a new model for the fatigue life of steel bridges has been developed that allows bridge impacts to be evaluated in our generic studies.

Changes in Relative Prices of Resources — Although the early 1990's have been characterized by lower average inflation rates than the previous decade, there have been some changes in both the absolute and relative prices of the resources required to provide rail transportation, and the relative price changes have had some impact on the relative advantage of HAL economics.

It is the total predicted advantage that determines the conclusions about the optimum choice of axle loads, but as the results of the current study are presented, the primary sources of any changes from the Phase I HAL study will be identified.

HAL ECONOMIC IMPACT ON BRIDGES

In the analysis of Phase I, the impact on bridges was included only in two railroad specific case studies. Since then the AAR has developed a steel bridge fatigue life assessment model that can assess the impact of HAL traffic on bridge component life. This model has been calibrated using data collected at HAL revenue sites through instrumentation of bridges. This bridge fatigue model coupled with the AAR's Steel Bridge Cost Model now permits bridge and route specific analysis of the impact of HAL traffic on steel bridges. The impact on timber bridges is included using expert opinion.

Steel Bridges — This analysis shows a decrease in the fatigue life of specific steel bridge components from HAL traffic. Detailed fatigue analyses were conducted on 34 bridges selected from more than 70 submitted by member roads as representative of the bridges on routes likely to be used for HAL traffic. These bridges were then used to represent the actual bridges on six specific routes that currently carry or are expected to carry HAL traffic. For 263K base traffic and the 286K and 315K HAL alternatives, the annual percent of total fatigue life consumed was calculated for each component of each bridge. The percent consumption was then multiplied by the replacement cost for each component to calculate steady-state annual component renewal costs. These component costs were summed for all critical components of each bridge to obtain the total annual steady-state renewal costs for the bridge. To calculate the cost for a generic route, the four routes typical of eastern coal routes (and similarly for the western routes) were assumed to be placed end-to-end, and a steel bridge cost per 1000 net-ton-miles was calculated.

Timber Bridges —The timber bridge analysis is based on expert opinion of selected AREA bridge committee members who form the HAL Bridge Evaluation Working Group. The major effect of HAL traffic is to accelerate timber cap or bridge replacement. The Bridge Working Group agreed on the following cap/bridge replacement rates for timber bridges:

- For 263 kip traffic, caps/bridges will be replaced beginning immediately and all caps/bridges will be replaced uniformly over a 20-year period. Two replacement scenarios were examined, replacing 25 percent of the timber bridges and 75 percent of the caps (Base Case) and replacing 75 percent of bridges and 25 percent of the caps (Pessimistic Case).

- For 286 kip traffic, caps/bridges will be replaced beginning immediately and all caps/bridges will be replaced uniformly over a 10-year period. Two replacement scenarios were examined, replacing 25 percent of the timber bridges and 75 percent of the caps (Base Case) and replacing 75 percent of bridges and 25 percent of the caps (Pessimistic Case).

- For 315 kip traffic on the 30 MGT eastern route, caps/bridges will be replaced beginning immediately and all caps/bridges will be replaced uniformly over a 5-year period. Two replacement scenarios were examined, replacing 25 percent of the timber bridges and 75 percent of the caps (Base Case) and replacing 75 percent of bridges and 25 percent of the caps (Pessimistic Case).

- For 315 kip traffic on the 80 MGT western route, all bridges will be replaced beginning immediately and all bridges will be replaced uniformly over a 5-year period.

This conservative approach was taken due to the lack of a deterioration model addressing specific timber bridge components. Costs for both cap and bridge replacements were obtained from member railroads. Estimates were also provided on the train delay times and costs resulting from the replacement or repair work. Relative amounts of cap replacement versus bridge replacement provide insight to cost sensitivity.

Results — Costs for the steel and timber bridges were added yielding a total cost per 1000 net-ton-miles for each of the routes. These costs are presented in Exhibits 1 and 2 as a percent of the cost of the base, 263K GVW traffic. Although the percent increases are large for HAL traffic, the impact on the total analysis is small because bridge maintenance and renewal is a small percent of the total cost (2-3%) of HAL traffic. However, for the six individual railroad routes evaluated, the total bridge costs varied by nearly an order of magnitude; therefore a specific route analysis is preferable when assessing the impact of HAL traffic on any route involving major steel structures or a significant number of timber structures.

Cost Changes Phase I (1991) to Phase II (1995)

The estimated cost elements have changed in the current study due to (1) changes in the models used to predict component life cycle costs, (2) changes in the component designs, maintenance practices, and materials used in the Phase II tests, (3) changes in the relative costs of certain resources, and (4) for turnouts, a correction in the calculation of routine maintenance costs that caused turnout costs to be overstated in Phase I. Exhibits 3, 4, 5, and 6 show the relative cost changes for the estimated direct operating and track cost elements in Phase II compared to the estimated Phase I costs including the correction to the turnout costs for Phase I. To gain a better understanding of these changes, let us consider each cost component individually.

Operating Costs

Crew— Although the cost per crew member has increased, the use of two-man crews in 1995 compared to the three-man crews assumed in 1991 along with the increase in the base miles from 108 to 130 have decreased the crew cost per net-ton-mile in all scenarios.

Car and Locomotive Ownership — Both car and locomotive ownership costs have increased over the period due primarily to a strengthening of the market for both types of equipment. The equipment prices in 1991 were influenced by a preceding decade of weak equipment demand.

Car and Locomotive Maintenance — Both car and locomotive maintenance have remained essentially constant during the 1991 - 1995 period. This is due to improvements in component performance such as the new specification wheels and the elimination of certain unnecessary regulations such as the discolored wheel removal rule.

Fuel — Fuel costs have decreased slightly from 1991 to 1995.

Since crew and fuel are reduced by increasing axle loads and these components have become relatively cheaper, the advantage of increasing axle loads has been slightly decreased since the 1991 study.

Track Costs

Rail — The performance of rail has remained as expected from Phase I testing. The cost of new rail has increased since 1991 due to a general increase in the demand for rail and a reduction in the domestic suppliers. The routine maintenance associated with the rail has been reduced by the development of improved field weld kits and procedures. Field weld performance was one of the key areas needing improvement noted during Phase I. Phase II has met this objective.

Ties — The estimated cost of ties has substantially increased since the 1991 study. This is primarily due to further development and calibration of the AAR tie life model leading to an increase in the expected life-cycle tie costs for all axle loads. In addition, the cost of ties and their installation cost in track have increased. For the increased axle loads, the Phase II testing has shown that premium fasteners are desirable for improving gage retention on curves of 3 degrees or greater. The cost of fasteners do not affect significantly the increased costs for HAL traffic. Ties remain a small part of the total costs and do not significantly increase with increasing axle loads.

Ballast — Additional tests of ballast during Phase II and model development by the AAR have suggested that ballast maintenance costs will be substantially lower than estimated during Phase I. The "good" ballast materials at FAST have shown little or no effects due to increased axle loads. Service testing and member road experience suggest that both surfacing requirements and eventual ballast renewal activities will be less than estimated during Phase I.

Turnouts — Phase II at FAST and revenue service tests have shown that turnouts of both conventional and improved design and improved materials can substantially extend life and reduce life-cycle costs for turnouts under all three traffic scenarios. The cost penalty for increasing axle loads has been reduced by improved turnouts, a major objective of Phase II.

Overall Phase II's investigation to determine ways to reduce the adverse impacts of increased axle load traffic on the track structure and to improve the economics of increasing axle loads has been successful.

SUMMARY OF THE ECONOMIC IMPACTS OF INCREASING AXLE LOADS

Track — After correcting the error in turnout maintenance costs, the Phase I study showed a 7.9 percent and 22.8 percent increase for track costs in the west for 286K and 315K traffic respectively and 10.9 percent and 23.1 percent respectively in the east. Exhibit 7 shows that for the west the increases are now 5.9 and 21 percent for 286K and 315K traffic respectively. In the east the increases are 11 percent and 24.2 percent respectively as shown in Exhibit 8. The estimates include the impact of increased axle load traffic on bridges in the Phase II results, while they were not included in the Phase I results. Without the additional impact of increased axle loads on bridges, the cost penalty for increased axle loads would be decreased in all cases. Certainly the areas targeted for improvement in Phase II — field welds (routine rail maintenance) and turnouts — have shown significant improvement as have ballast and surfacing.

Overall — Exhibits 9, 10, 11 and 12 show the total impact of increasing axle loads on direct transportation costs in the west and east for both length and weight limited operating scenarios. Overall, the 286K traffic is shown to be economically effective in all four scenarios evaluated while 315K traffic is better than 263K only in the length limited, western scenario. No scenario shows 315K traffic to be more economic than 286K traffic.

The degree of reduction in direct transportation cost due to increasing axle loads in this Phase II analysis is slightly less than estimated in the Phase I report. This slight decrease is due primarily to changes in the relative costs of resources. For example, crew and fuel benefited by increasing axle loads have decreased in cost, while track components deteriorated by increased axle loads have become relatively more expensive. In addition, the costs of bridges that are affected adversely by increased axle loads are included in Phase II results, while they were not in Phase I. Without the bridge impacts, the improved track components and maintenance procedures in Phase II would have resulted in increased advantages for increased axle loads.

CONCLUSIONS/RECOMMENDATIONS

Phase II test results show specific cost element estimates have changed in their absolute and/or relative importance and certain problem areas, such as turnouts and field welds, have been improved. Overall, the FAST/HAL research and subsequent economic evaluations performed through the end of Phase II confirm the basic conclusions and recommendations reached at the end of Phase I.

TECHNICAL FEASIBILITY OF 315,000-POUND BULK COMMODITY EQUIPMENT

Based on the physical and engineering test results at FAST through the end of Phase II in 1995, as well as the reported operational experiences of select North American and foreign railroads, there do not appear to be any unmanageable barriers to the operation of heavier (i.e. 39-ton) axle loads over well-maintained track that has good quality components and over bridges of sufficient strength.

Based upon the cases analyzed, track maintenance costs under HAL operations can be expected to increase by anywhere from about 5 to 20 percent under 286,000-pound cars and 20 to 40 percent under 315,000-pound cars. Capital programs can be expected to increase 2 to 10 percent under 286K cars and 9 to 22 percent under 315K cars, while routine maintenance may increase by 15-30 percent under 286K and 45-65 percent under 315K cars. Although the routine maintenance is a smaller dollar item than program maintenance, it is important to recognize that this maintenance cannot be deferred without immediate, severe consequences.

ECONOMICS OF HAL OPERATIONS

Based on the analyses to date, the use of heavier cars, with attendant increased axle loads, may be a viable tool for achieving *potentially significant* total savings in cost for certain rail operations. For the cases analyzed, potential net benefits in the range of 2-6 percent (including bridge costs, see Exhibit 13) would seem to warrant serious investigation as a means to increase the *productivity of specific routes and services.* Results are highly route and service specific. Following are critical variables:

(1) Bridge characteristics (extent of renewal/reinforcement required)

(2) Rail characteristics/maintenance (quality, i.e. metallurgy/condition of rail, and extent of lubrication and grinding) on running tracks

(3) Other running track support characteristics (quality of ties, ballast, and subgrade)

(4) Equipment characteristics and utilization (loading) policies (initial cost, net-to-tare ratio, load cycles and horsepower utilization)

(5) Operating constraints (train length or train weight limitations)

(6) The capability of support (yard and industry) tracks to handle heavier cars

While the 286,000-pound car was not the subject of the FAST/HAL tests, the design specified and analyzed offered significant net benefits when compared to the 315,000-pound cars used in the FAST/HAL tests or the conventional 263K cars extensively tested at FAST before 1986.

Exhibit 1. Bridge Cost in Percent of Cost for Base Case - 263K GVW Traffic
Typical Western Coal Route
With 80 MGT Per Year

Bridge Type	Scenario - 5.9 Feet/Mile of Timber Bridges 26.0 Feet/Mile of Steel Bridges	Car Gross Vehicle Weight (Pounds)		
Base Case		**263,000**	**286,000**	**315,000**
Timber	Replace 75% of caps and 25% of bridges for timber bridges, Replace all timber bridges for 315,000 pound case	100%	144%	584%
Steel	Fatigue Life Consumption of Components	100%	112%	155%
Total	**75% / 25% Caps Vs. Replace**	**100%**	**113%**	**173%**
Pessimistic Case				
Timber	Replace 25% of caps and 75% of bridges for timber bridges, Replace all timber bridges for 315,000 pound case	251%	362%	584%
Steel	Fatigue Life Consumption of Components	100%	112%	155%
Total	**25% / 75% Caps Vs. Replace**	**106%**	**123%**	**173%**

Exhibit 2. Bridge Cost in Percent of Cost for Base Case - 263K GVW Traffic
Typical Eastern Coal Route
With 30 MGT Per Year

Bridge Type	Scenario - 4.5 Feet/Mile of Timber Bridges 52.4 Feet/Mile of Steel Bridges	Car Gross Vehicle Weight (Pounds)		
Base Case		**263,000**	**286,000**	**315,000**
Timber	Replace 75% of caps and 25% of bridges for timber bridges.	100%	144%	177%
Steel	Fatigue Life Consumption of Components	100%	113%	156%
Total	**75% / 25% Caps Vs. Replace**	**100%**	**115%**	**157%**
Pessimistic Case				
Timber	Replace 25% of caps and 75% of bridges for timber bridges	252%	364%	448%
Steel	Fatigue Life Consumption of Components	100%	113%	156%
Total	**25% / 75% Caps Vs. Replace**	**110%**	**129%**	**174%**

Exhibit 3

Phase II Costs Compared to Phase I

Generic Western Route, Length Limited

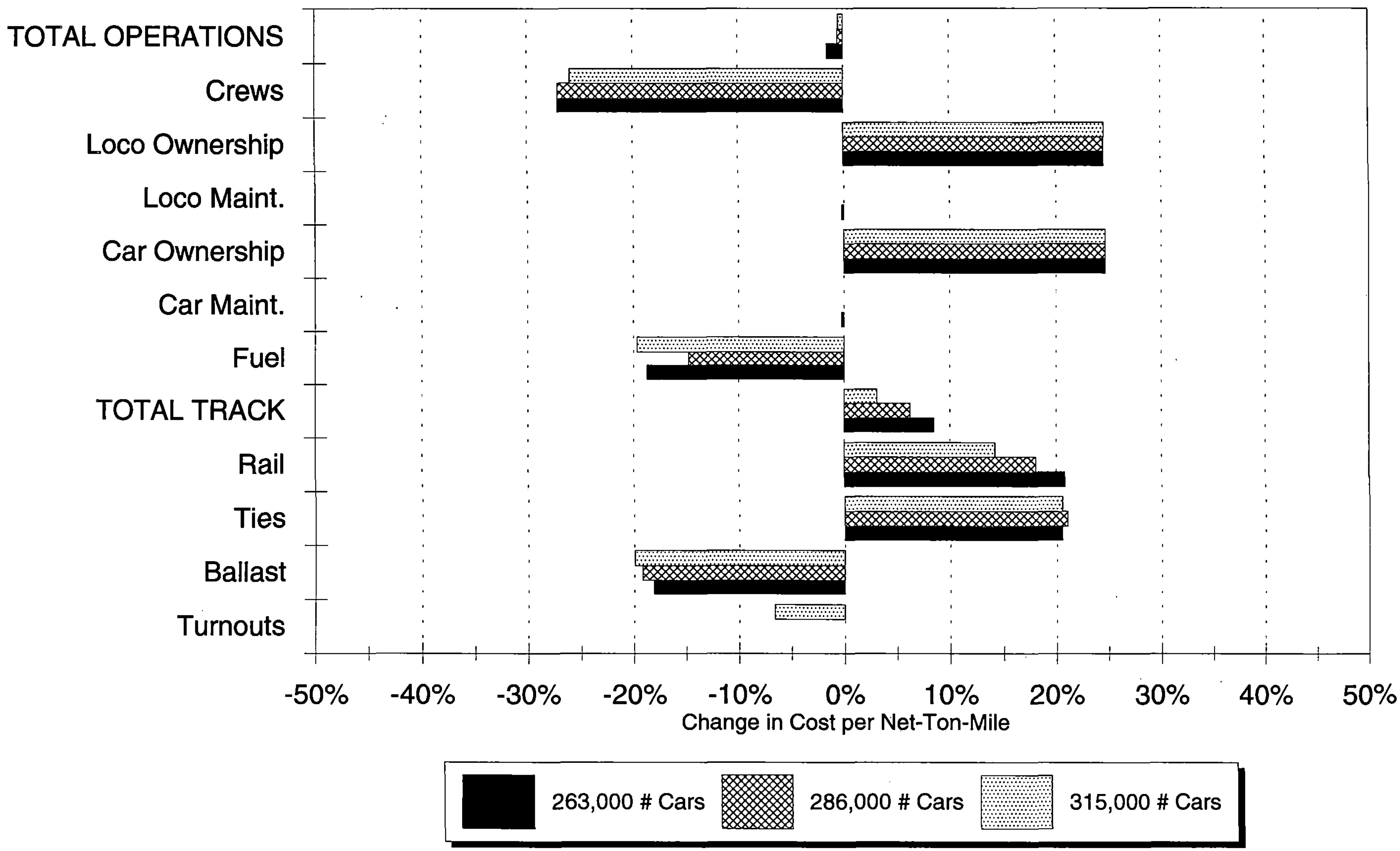


Exhibit 4

Phase II Costs Compared to Phase I

Generic Western Route, Weight Limited

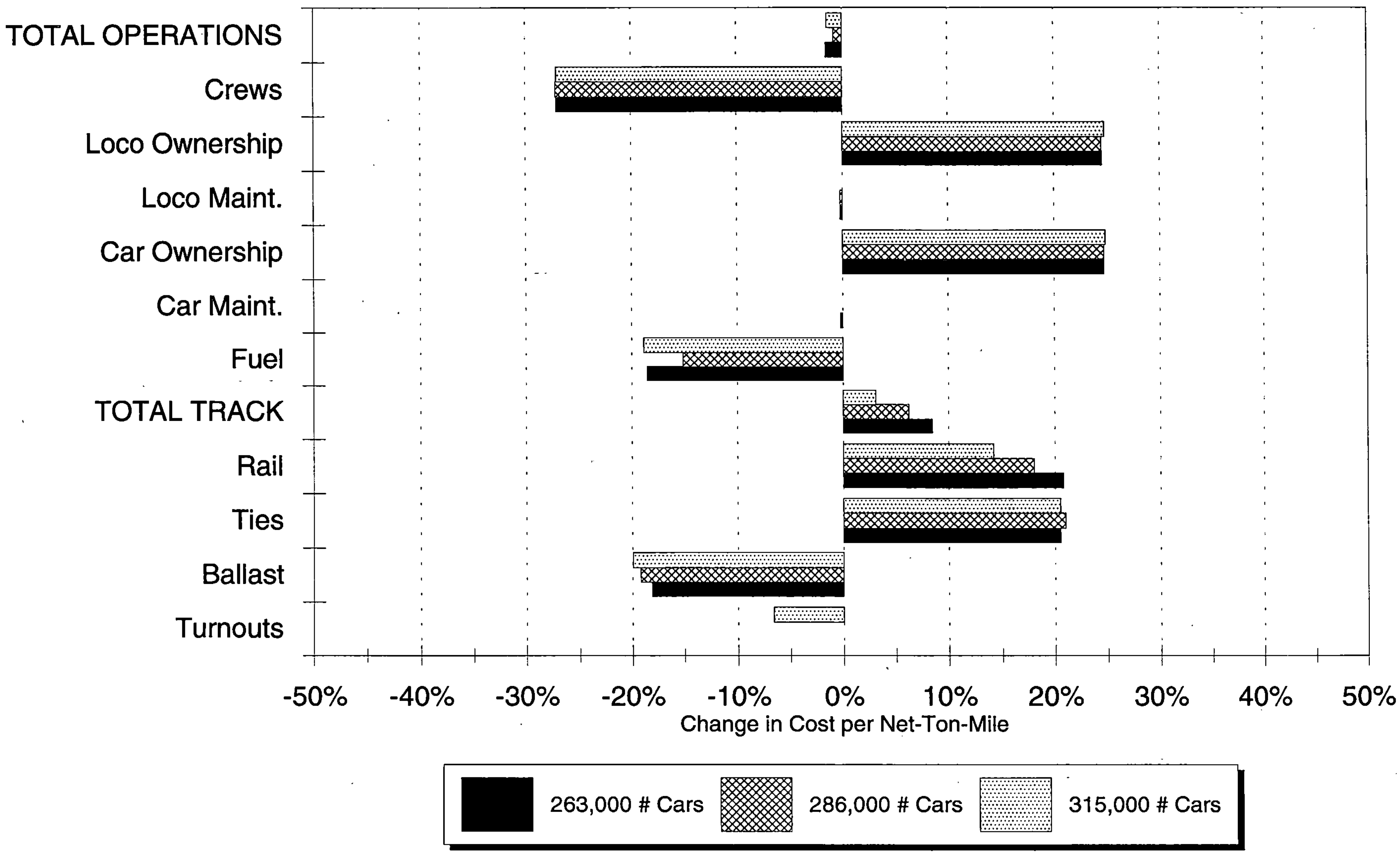


Exhibit 5

Phase II Costs Compared to Phase I

Generic Eastern Route, Length Limited

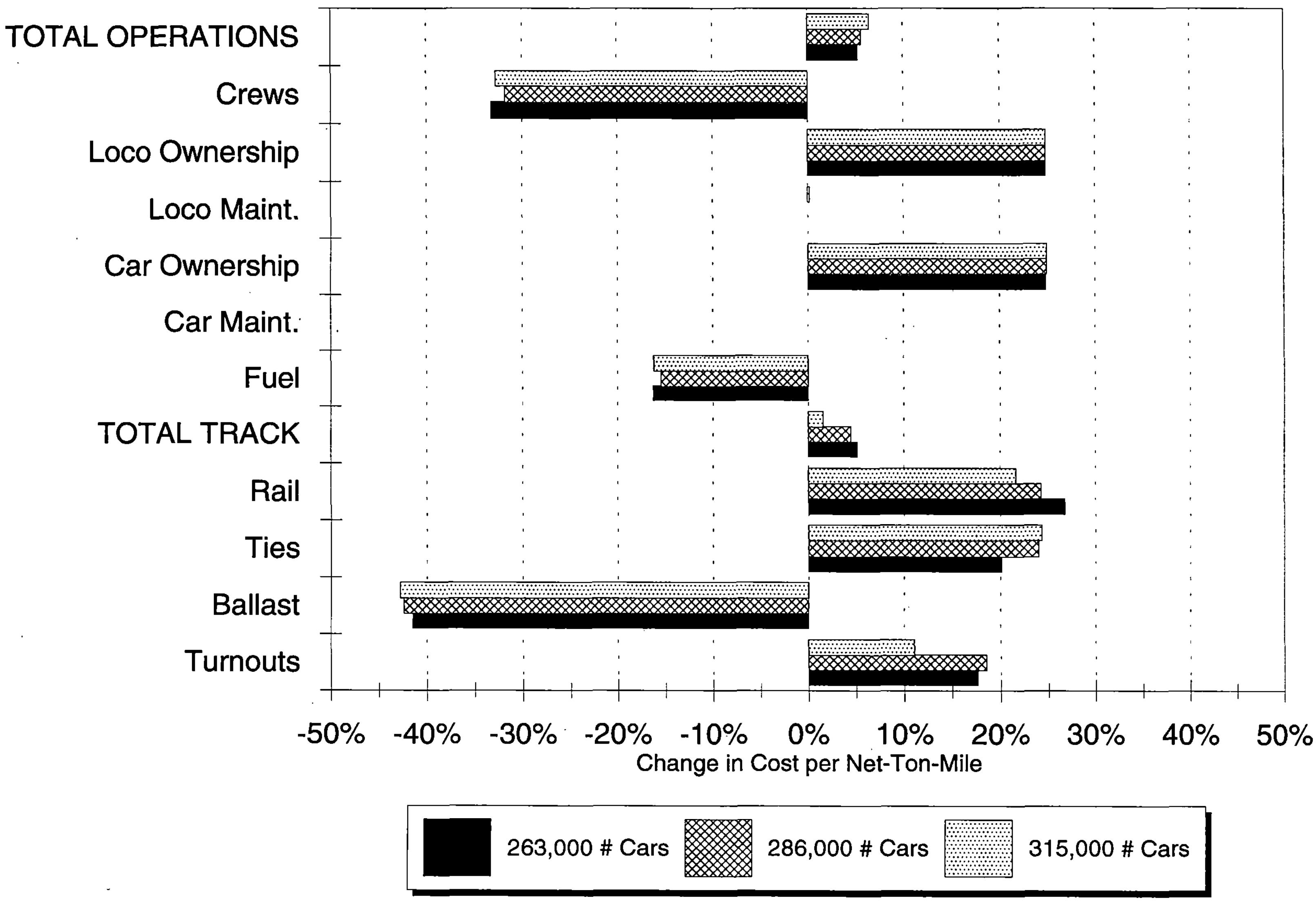


Exhibit 6

Phase II Costs Compared to Phase I

Generic Eastern Route, Weight Limited

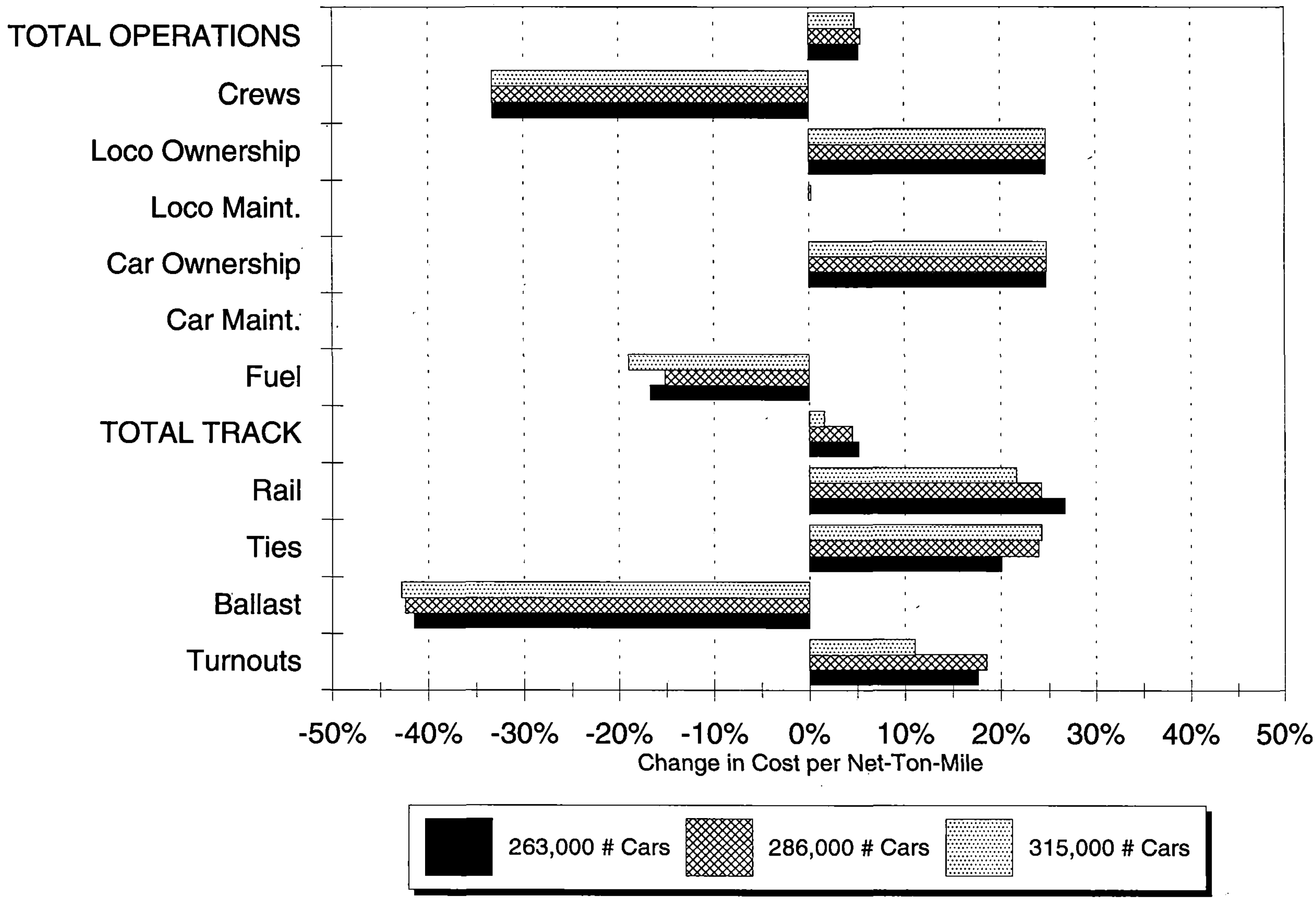
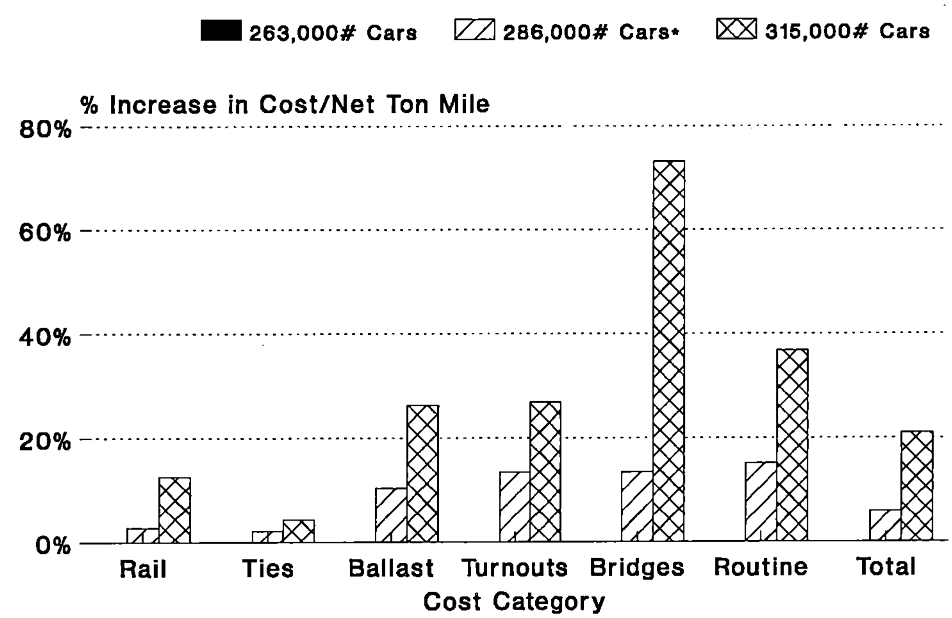
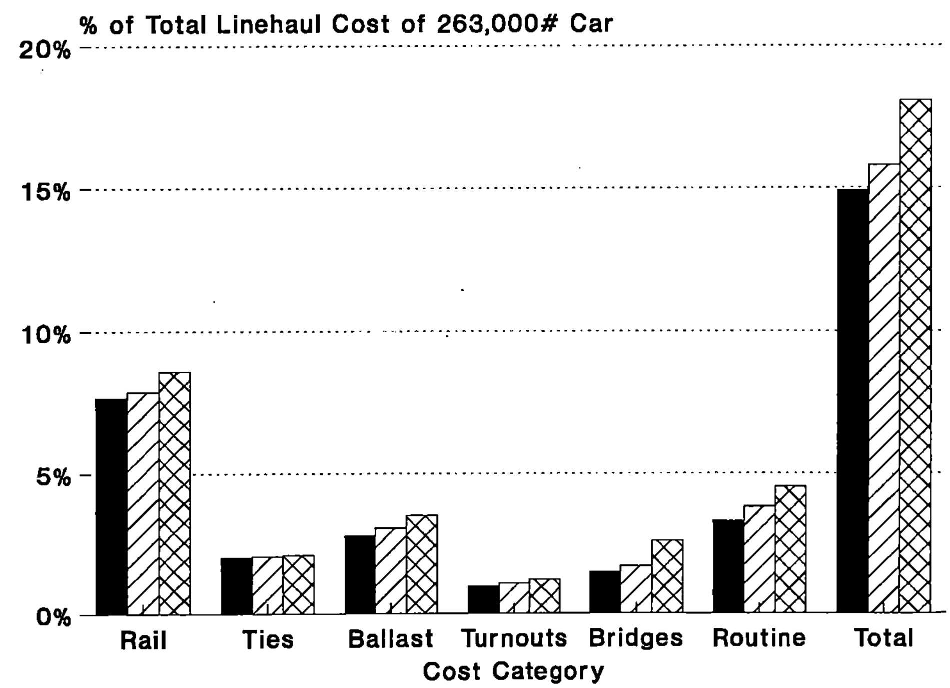


Exhibit 7

**HAL Track Maintenance Cost
Comparisons vs 263,000# Cars
Generic Western Route, Length Limited**



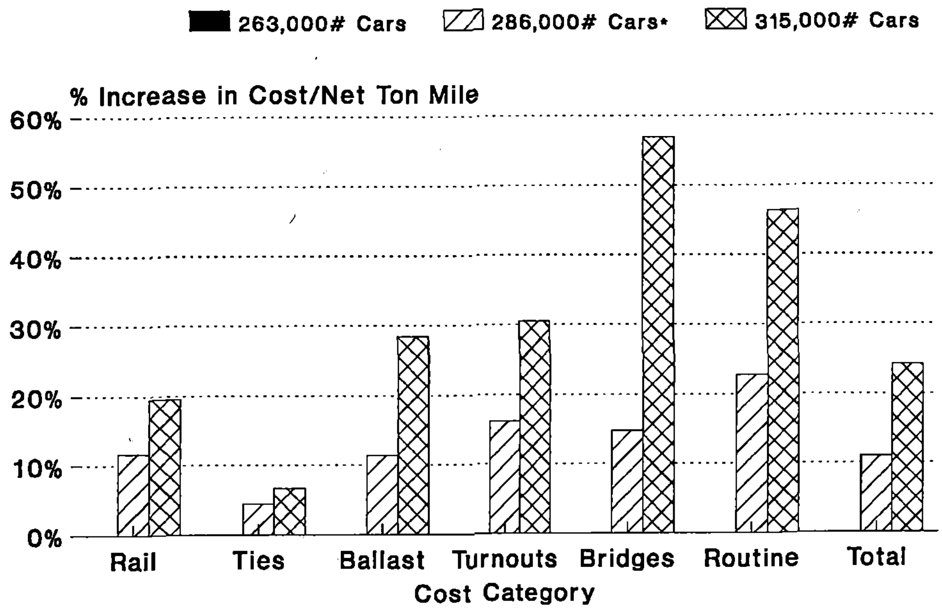
80 MGT



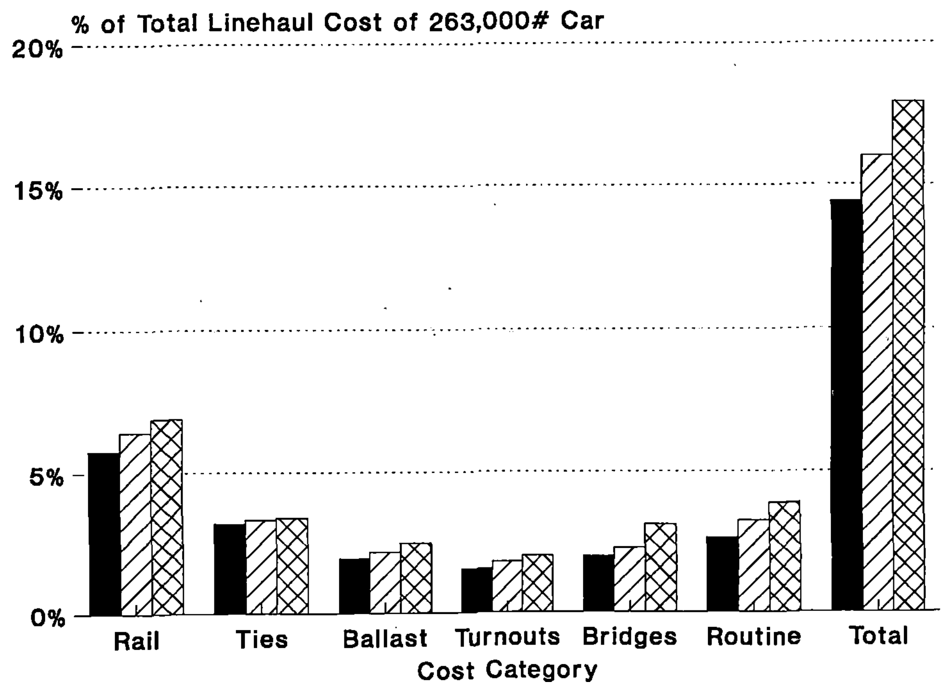
* Intermediate projection, not measured directly at FAST

Exhibit 8

HAL Track Maintenance Cost
Comparisons vs 263,000# Cars
Generic Eastern Route, Length Limited



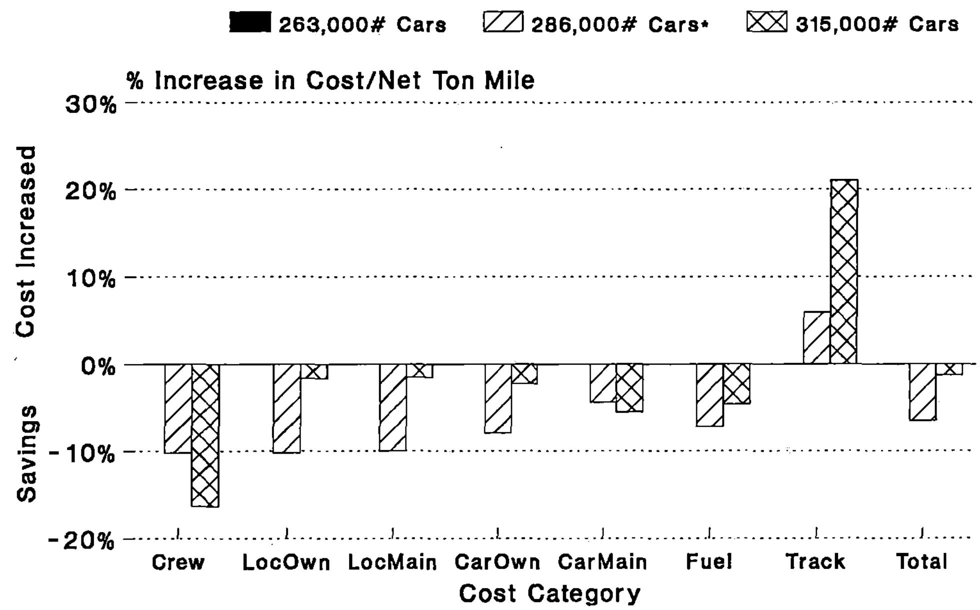
30 MGT



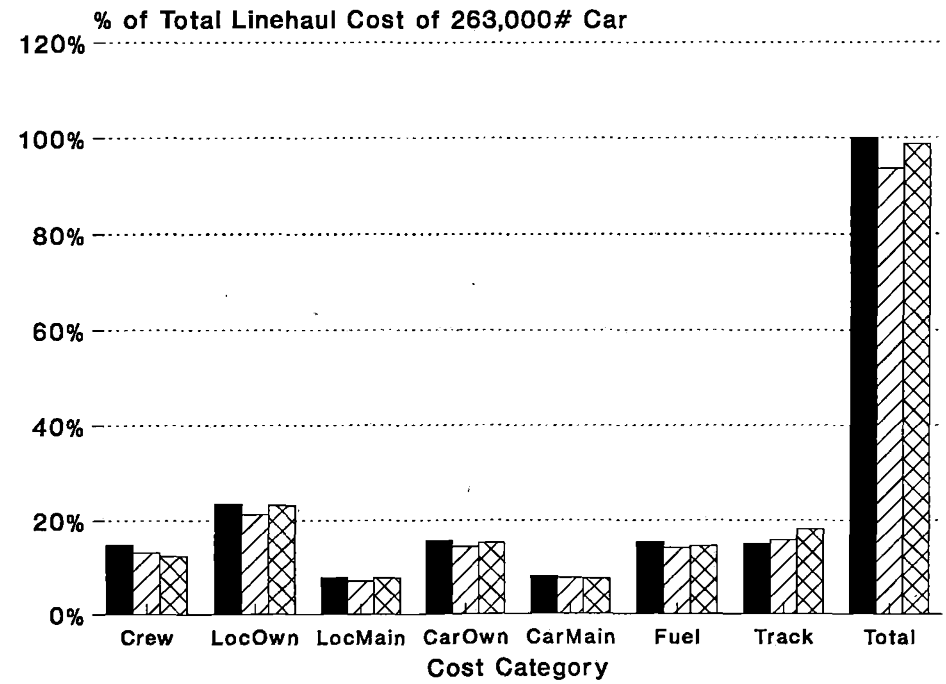
* Intermediate projection, not measured directly at FAST

Exhibit 9

**Linehaul Cost Comparisons
vs 263,000# Cars
Generic Western Route, Length Limited**



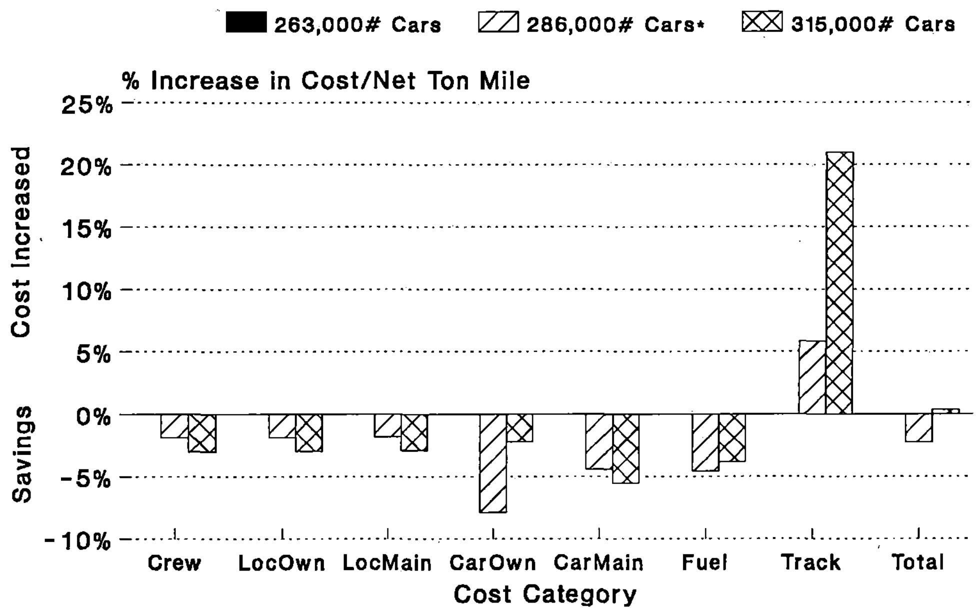
80 MGT



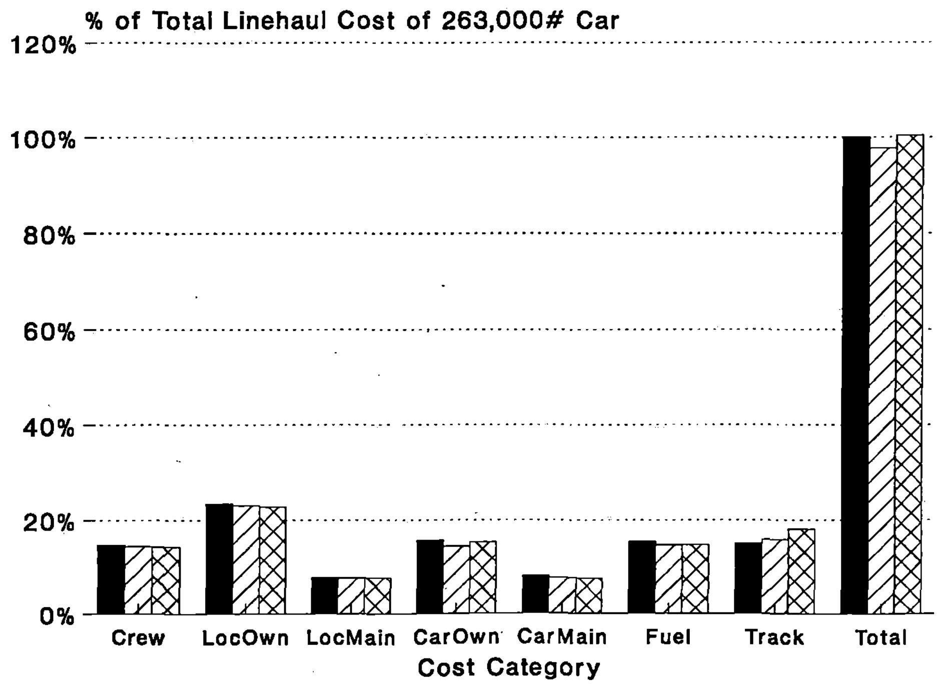
* Intermediate projection, not measured directly at FAST

Exhibit 10

Linehaul Cost Comparisons
vs 263,000# Cars
Generic Western Route
Equal Trailing Weight



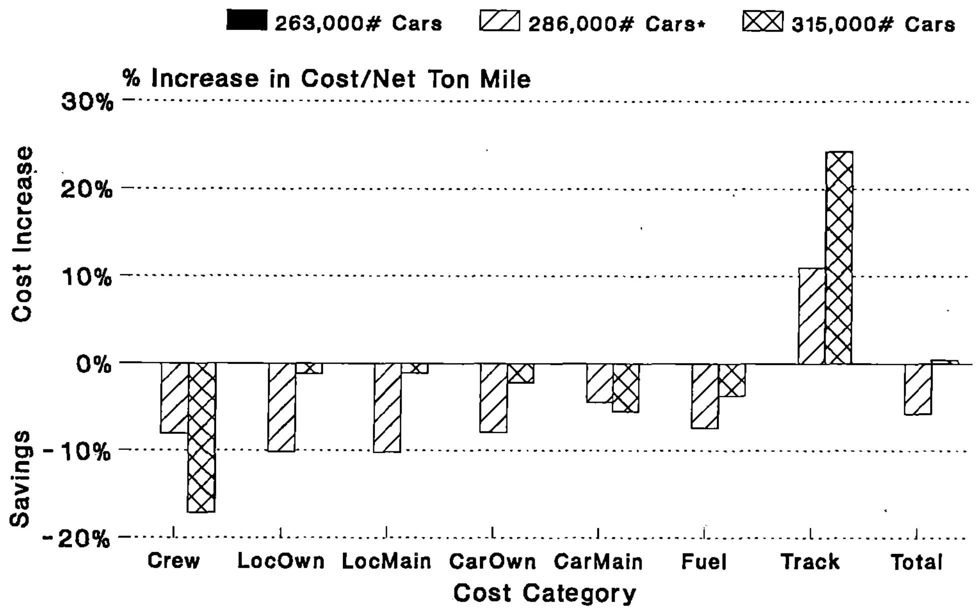
80 MGT



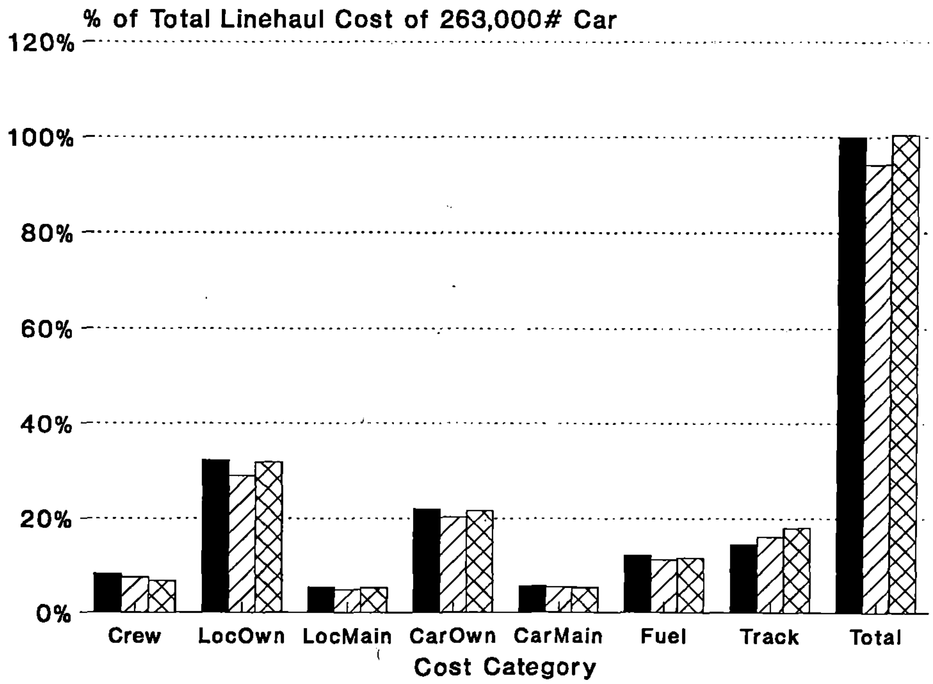
* Intermediate projection, not measured directly at FAST

Exhibit 11

Linehaul Cost Comparisons
vs 263,000# Cars
Generic Eastern Route, Length Limited



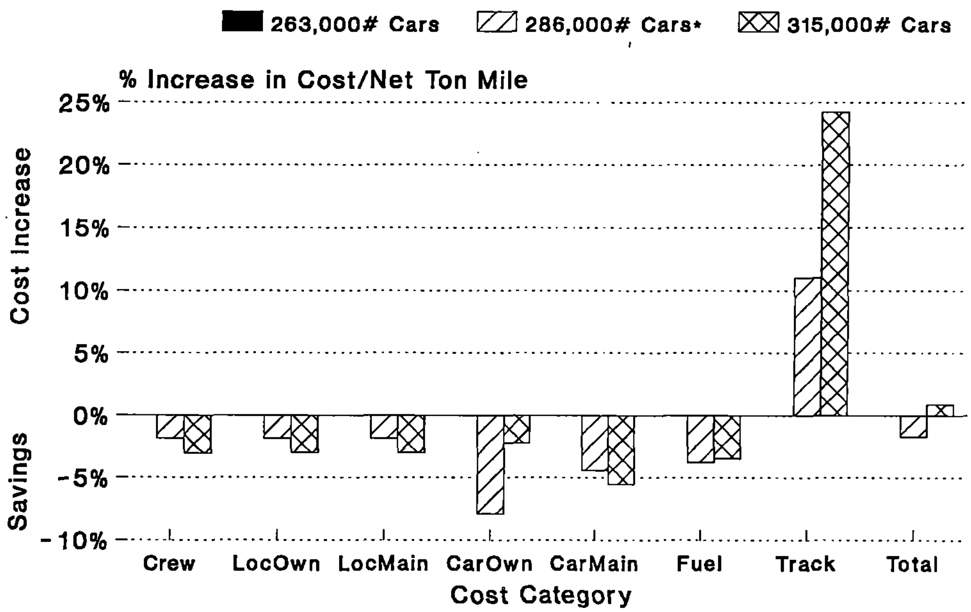
30 MGT



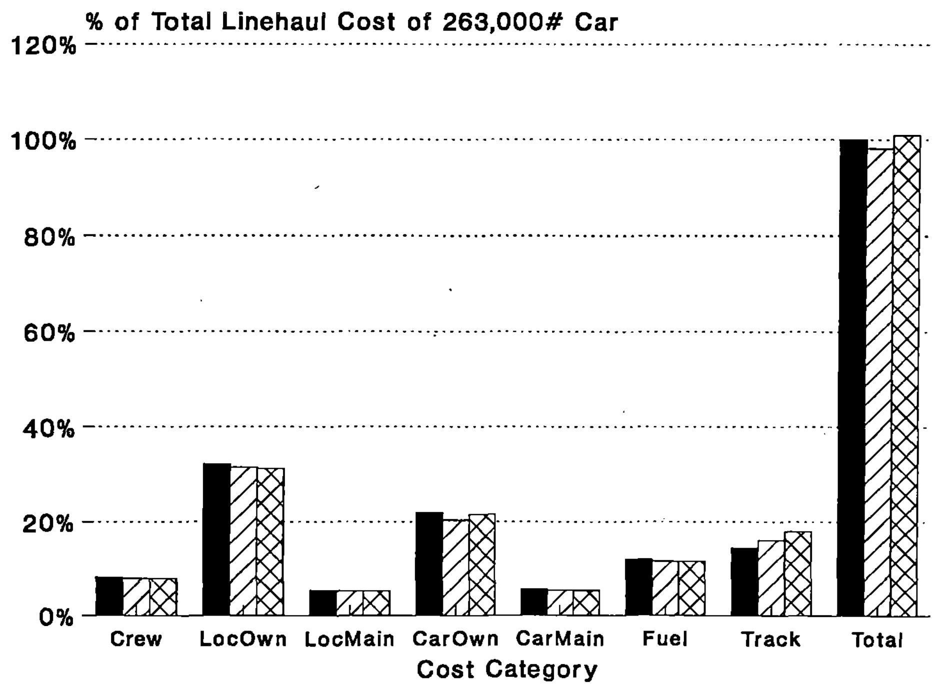
* Intermediate projection, not measured directly at FAST

Exhibit 12

Linehaul Cost Comparisons
vs 263,000# Cars
Generic Eastern Route
Equal Trailing Weight



30 MGT



* Intermediate projection, not measured directly at FAST

Exhibit 13. Line Haul Cost Comparison Versus 263,000 GVW Operations

Cost Category	286,000 GVW Operations				315,000 GVW Operations			
	Western Route		Eastern Route		Western Route		Eastern Route	
	Length Limited	Weight Limited	Length Limited	Weight Limited	Length Limited	Weight Limited	Length Limited	Weight Limited
Operations	-8.7%	-3.65%	-8.6%	-3.84%	-5.2%	-3.2%	-3.6%	-3.0%
Track & Bridges	5.9%	5.9%	11.0%	11.0%	21.0%	21.0%	24.2%	+24.2%
Total Savings	6.50%	2.3%	5.8%	1.7%	1.3%	-.4%	-0.4%	-0.9%