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An Investigation of Truck Size and Weight Limits Technical Supplement Vol. 7

Carrier, Market and Regional Cost and Energy Tradeoffs Part I

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16. Abstract

This volume expands upon the summary results in the Secretary's Report to Congress and provides a more comprehensive treatment of the productivity and fuel tradeoffs among the categories of truck size, weight and configuration limits. Disaggregations of impacts among freight service user groups are reported to provide information to the interest groups most affected by alternative limit changes. It also presents an analysis of the sensitivity of the reported transport cost and fuel impacts of alternative limits to the possible inaccuracies in the analytical methods and data available to the study.

Appendix E of this Technical Supplement is the technical letter report (bound as a separate volume) prepared by Gordon Fay Associates Inc. and the Traffic and Distribution Service, Inc. under contract to TSC in 1979. Appendix E has served as a major source for TSC analysis of the Western Doubles issue.

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PREFACE

This is one of six technical reports prepared by the Transportation Systems Center (TSC) in support of the Secretary of Transportation's response to Congress on the Truck Size and Weight (TS&W) Study mandated by Section 161 of the Surface Transportation Assistance Act of 1978. This report, Volume 7, synthesizes the results of several areas of investigation undertaken by TSC since May 1978 as part of the Office of the Secretary's multiyear study of the effect of size and weight regulation on productivity and energy conservation in the motor freight industry.

Volume 7 expands upon the summary results presented in the Secretary's Final Report to Congress and provides a more comprehensive treatment of the productivity and fuel trade-offs among the categories of truck size, weight and configuration limits. Disaggregations of impacts among freight service user groups are reported in this volume to provide information to interest groups most affected by alternative size and weight limit changes. It also presents an analysis of the sensitivity of the reported transportation cost and fuel impacts of alternative limits to the possible inaccuracies in the analytical methods and data available to the study. Bridge, pavement, safety and environmental impacts are not addressed in this volume.

Modal diversion estimates have been isolated from other truck impacts in the presentation of transportation cost, service quality and fuel consumption effects of specific changes in axle load limits, gross weight limits and vehicle length and configuration limits. It is the opinion of the analysts that the potential modal diversion estimates are small and much more conjectural than estimates of other impacts. The report shows that the relative ranking (with respect to transport cost or fuel consumption) of the alternative size and weight limit scenarios reported in the Final Report are not greatly changed by the estimated potential rail/truck modal diversions nor would they be changed by other consistent systems of estimating diversions. Therefore, the estimates of modal diversion potential, attributable to the specific limit changes considered, appear adequate, for the objectives of the DOT/TS&W Study.

Appendix E of this report is the "technical letter report" prepared by Gordon Fay Associates and Traffic and Distribution Services (TDS), Inc. under contract to TSC, dated January 1980. It has served as a valuable source for several aspects of TSC's investigation of the "Western Doubles" issue.

This volume reports on the analytical work performed by several analysts at TSC, supported by the computer services provided by Systems Development Corporation (SDC). The analysis of the local (Type 2) traffic and analysis and documentation of aggregate fuel consumption in Appendix A was the responsibility of Joseph J. Mergel. The extensive analyses of the origin to destination (O/D) demand projections, network flows, truck choice, service attribute, fuel impacts of the interregional (Type 3) traffic, and the extensive sensitivity analysis presented in Section 4 were performed by D. Michael Nienhaus. Indirect energy consumption was analyzed by J.K. Pollard. The computer modeling, computer programs for data analysis, the merger of very large files, and the preparation of numerous intermediate data reports which are the foundation of this volume were the reponsibility of Subhash C. Mahajan and Annette R. Tramontozzi of SDC. The basic unit vehicle cost/rate analysis of Richard J. Kochanowski and Daniel P. Sullivan, and fuel analysis of David A. Knapton are essential inputs to this entire project. Overall technical direction and management of the TSC effort was provided by Domenic J. Maio.

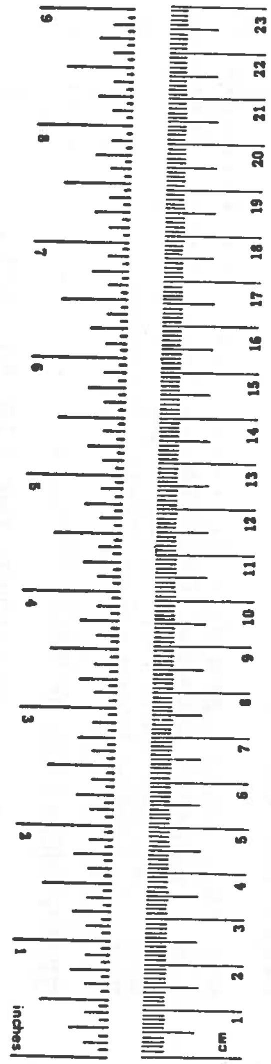
Carl Swerdloff and Philip Barbato of the Office of Economic Analysis and Public Investment, Herbert Weinblatt of Jack Faucett Associates, Mark Jelavich of Peat, Marwick, Mitchell & Co., Harry Cohen, Joseph Sinnott and Joseph Stowers of Systems Design Concepts, Inc., provided valuable assistance to TSC by way of critical reviews of intermediate and final results, specific data, analytical inputs, and consultation.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

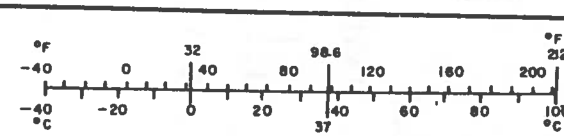
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I. INTRODUCTION

1.1 PURPOSE AND SCOPE

This report is one of six technical supplements prepared by the Transportation Systems Center to document its contributions to the Department-wide investigation of Truck Size and Weight Limits. It focuses on the productivity and fuel conservation opportunities attending each of several truck size and weight limit alternatives. The transportation cost and fuel reductions (which were TSC's assignment) may be termed the benefit side of the benefit/cost ratio, whereas the decreased life and increased maintenance of pavements and bridges and increased highway congestion and exposure to accidents may be termed the cost side (which were assigned to others). The Secretary's Final Report* indicates that the transport cost effects of the limit alternatives outweigh by a factor of two the pavement and bridge lift and maintenance cost impacts.** It shows that increasing the payload capacity of trucks improves overall transportation system productivity and decreasing truck capacity degrades productivity. The Final Report provides a net national aggregate view of transport cost and fuel impacts which incorporates many compensating positive and negative effects on many different interest groups. This technical supplement focuses attention on the constituent elements of the national aggregate impacts. If the transportation cost impacts dominate the assessment of the attractiveness of the various limit alternatives, then a more disaggregate examination of these impacts must precede recommendations for specific changes in the existing system of size and weight regulation.

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*An Investigation of Truck Size and Weight Limits, Final Report of the Office of Secretary of Transportation to the United States Congress, NTIS PB-82-1888-71, August 1981.

**The Secretary's Final Report also points out that the investments for the strengthening and reconstruction of highway pavements and bridges to accommodate heavier or larger trucks is substantial. If these investments are not made, the condition of the highways involved would deteriorate significantly under the additional loadings. If the highways deteriorated significantly below the level assumed for the study, the pavement and bridge costs and overall highway user operating costs would be significantly increased beyond the levels reported.

This volume has several purposes:

1) To expand upon the productivity, fuel and service quality impacts presented in the Final Report to Congress and to make a more detailed presentation of trade-offs among categories of limits;

2) To display in tabular and graphical form the distributions of positive and negative transportation cost effects among the freight transport markets and classes of freight service users;

3) To provide a management perspective of the level of confidence that may be placed on the magnitude and direction of the transport cost, the truck activity, modal diversion and fuel consumption impacts presented in the Final Report. Specifically, this involves evaluation of the sensitivity of the reported impact values to alternative input assumptions and to the possible inaccuracies of critical input data; and

4) To document the methods used in assembling the aggregate transport fuel and cost effects reported in the Final Report and to add estimates of the shipment transit time effects not covered there.

In fulfillment of these purposes, this volume synthesizes the results of three separate investigations into the effects of axle load limits, gross weight limits and length and configuration limits on average unit vehicle payloads,(1) on average shipment cost/rates,(2) and on average unit vehicle fuel consumption.(3) It also combines these average unit vehicle impacts with the national aggregate truck vehicle miles traveled (VMT), cost, fuel

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[1] Mergel, Joseph J., An Investigation of Truck Size and Weight Limits: Analysis of Truck Payloads Under Various Limits of Size, Weight and Configurations, Volume 1, DOT-TSC-OST-80-3, February 1981.

[2] Kochanowski, Richard J. and Daniel P. Sullivan, An Investigation of Truck Size and Weight Limits: Truck and Rail Cost Effects of Truck Size and Weight Limits, Volume 2, DOT-TSC-OST-80-6, December 1980.

[3] Knapton, David A., An Investigation of Truck Size and Weight Limits: Truck and Rail Fuel Effects of Truck Size and Weight Limits, Volume 3, DOT-TSC-OST-81-2, June 1981.

and modal diversion impacts[4] to provide a more comprehensive treatment of the trade-off options among the categories of limits.

The Final Report properly focuses on the aggregate national benefits and costs of a limited set of feasible limit scenarios with some treatment of the regional distribution of the aggregate impacts. This volume treats another level of concern - the distribution of impacts among freight markets, industry/commodity groups, and carrier services. The small shipment markets, the general commodity services, the refrigerated services, the tank service, etc. are not uniformly affected by axle load limits, by gross weight limits or by length and configuration limits. This volume provides the more disaggregate tabulations and displays of impacts on the various segments of the total freight system. Results presented are based on application of the alternative limits to all Federal-aid primary highways (FAP) including the Interstate System. No attempt is made to address the issue of application of limits to only the Interstate System, as did three of the study scenarios in the Final Report. A selected subset of possible limit changes has been used for this disaggregate presentation of impacts to reduce the total volume of data and to focus attention on trade-offs among size limits and weight limits rather than system application.

No attempt has been made in this study to estimate the short term and long term impacts on individual motor carriers, or the rail carriers' responses to motor carrier rate reductions. Impacts reported for the large groupings of carrier services may mask much greater positive or negative effects on individual carriers within a group.

The analytical approach used in this study assumes some form of equilibrium in the industry by 1985, relative to responses to any limit changes. During some undefined period of transition, some dislocations are inevitable. No attempt

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4 Mergel, Joseph J. and Michael Nienhaus, An Investigation of Truck Size and Weight Limits: Truck Traffic Forecasts and Truck Size and Weight Limit Scenario Analysis Methods, Volume 4, DOT-TSC-OST-82-1, January 1982.

has been made to identify and quantify specific transition problems.

Several areas of uncertainty are treated in this volume, quantitatively when feasible and qualitatively when necessary. As in many transportation studies of this scope, the analytical tools (models and input data) used are imperfect. In this study the debatable nature of the base year truck activity statistics, the uncertainty of the motor carrier reponses to the changing regulatory environment and the national economy, coupled with the current instability of energy costs and the potential for major redistribution of highway use taxes, have added to the usual burden of determining the accuracy of the projected impact results.

Documentation of methods, input data, and the numerous assumptions required for most of the separate parts of the DOT study are contained in the preceeding six volumes of the Technical Supplement. Volumes 1, 2 and 3 document the unit vehicle payload, cost/rates and fuel estimating, respectively. Volume 4 documents the truck activity projections, including the 1985 Status Quo Base Case and the effects of alternative scenarios. Volume 5 documents the mode shift analysis, and Volume 6 (authored by Sydec)* document the bridge and pavement impact analysis methods. The methods for estimating impacts on aggregate transportation costs, fuel consumption and shipment transit time (the only measure of service quality attempted) are documented in Appendices A, B and C of this volume.

The transport cost and fuel impacts of several alternatives for establishing national uniformity of size and weight limits have been estimated:

a) Reduce all axle load and gross weight limits to the existing Federal maximum for Interstate roads;

b) Increase axle load and gross weight limits in "Barrier States" to the existing Federal maximum for Interstates;

c) Allow "Western Doubles" to operate in eastern states;

d) Reduce all axle load and gross weight limits to the pre-1974 Federal maximum for Interstates;

*System Design Concepts, Inc., Lead firm of Consortium under Contract to the Office of the Secretary for the DOT TS&W Study.

e) Reduce all axle load limits to pre 1974 Federal maximum but use Bridge Formula A for gross weight limit;

f) Increase all axle load limits to approximate existing levels in the eastern states (22.4/36) and use Bridge Formula C for gross weight limit;

1.2 SUMMARY OF CARRIER/SHIPPER/REGIONAL SERVICE ATTRIBUTES AND FUEL IMPACTS

The major findings of the disaggregate analysis of the above limit alternatives may be summarized as follows:

1) Eliminating the existing high "Grandfather" and Special Permit weight limits increases shipping costs for the short haul and local truck activity in the eastern regions and the south-western region more than in any other region. This alternative has only a slight effect on medium and long haul freight movements in the eastern and southern regions.

2) Eliminating the existing "Barrier State" weight limits reduces shipping costs for Midwest Barrier Region Consignees, Special Commodity haulers and the Chemical and Grain Industries, more than other groups.

3) Eliminating the eastern states' prohibition against "Western Doubles" combinations reduces transport costs for Less-Than-Truckload (LTL) shipments in the eastern regions, as well as the abutting Midwestern Barrier and the southwestern regions. The dollar savings from increased use of Western Doubles for General Commodity LTL services are greater than for elimination of the "barrier" weight limits or for increased axle load limits or for use of Bridge Formula gross weight limits.

4) "Rolling back" axle load limits to the pre 1974 Federal maximum increased transport costs in the eastern and the southwestern regions more than any other region. This increase is shared fairly uniformly by several industries rather than being concentrated in one or two. Although all long haul truckload services have their respective costs increased, the local and short haul truck activity experience cost increases that are substantially greater.

5) When the Bridge Formula is used to establish the gross weight limit rather than an arbitrary fixed value for all, the use of truck configuration with more axles increases payload capacity, and the cost increases of rolling back axle load limits to the pre-1974 Federal maximum are greatly reduced or eliminated primarily for the Exempt and Special Commodity Services.

6) Modal diversions between truck and rail are possible results of many of the limit alternatives, but the magnitudes of the net transport cost impacts attending the diversions are not great enough to change the relative ranking of the alternatives. Whether the reader's perspective is one of a region or an industry user or a carrier service provider, the impacts resulting from just the shift among truck types and sizes determine the relative attractiveness of the limit alternatives. The modal diversion estimates are, at best, speculative in that they assume no price/service reaction by the rail carriers in response to any price change by the highway services. This assumption, coupled with the assumed 100 percent pass-through of motor carrier cost changes, creates the potential for modal diversion. Any change in rail prices in response to motor carrier reductions would reduce the potential modal shifts reported. Rail carriers have a large portion of common costs amenable to reallocation among classes of traffic and are thus in a position to match motor carrier price changes to retain traffic.

7) This study has not determined what portion of the motor carrier cost changes attributed to limit alternatives will indeed

be reflected in the freight rates. The pass-through will tend to vary by market and with the level of intra-modal competition as well as inter-modal competition. It is not clear which of these competitive forces will have the greatest effect in countering the very powerful motor carrier incentive to retain substantial portions of the savings as contributions to net revenues. Transport cost reductions reported in this study range from a low of 1 percent to a high of 12 percent of revenues for the regulated carriers as an example. Net operating revenues for regulated carriers between 1977 and 1980 are reported as ranging between 3.6 percent and 5.5 percent. This level of potential increase in net revenues could attract truck competition into a market, if regulations permit free entry. Adequate competition in each market affected is the only assurance that the transport cost savings resulting from TS&W limit changes will ultimately be realized by the users of the transportation services.

8) Shipping service quality, as measured by system average shipment transit time (or door-to-door speed), is improved by only one of the many limit alternatives examined. Circuity differences between the limit alternative and the Base Case are very small for most traffic. The elimination of the eastern states' prohibition against "Western Doubles" promises to improve the overall performance of the general commodity LTL services by as much as 35 percent. This results from the ability to bypass a significant number of the many terminal handlings involved in this service. Other carrier services experience no shipment speed changes in some alternatives or are actually slower for those alternatives in which they reduced cost by use of the tandem-axle short Doubles combination in lieu of conventional semi-trailer combinations. These Doubles combinations incur small terminal area time penalties for assembly and disassembly of the Doubles units.

9) Fuel consumption impacts of the limit alternatives are directly related to the truck miles generated. Those alternatives which allow higher capacity vehicles result in a reduction in truck trips for a given shipment demand. Conversely, reductions in truck capacity produce increases in truck trips for a given shipment de-

mand. Therefore, fuel impacts are greatest in those alternatives ar in those regions with the greatest change in truck miles. Percent changes on the whole are small for each alternative in each region. The largest regional net reduction is about 5.5 percent of the re- gion's total freight fuel consumption. This is in the Southern Bar rier region in the limit alternative which increases axle loads abo the existing Federal maximum. Elimination of the Barrier weight limits reduces fuel by a maximum of 2 percent (also in the Southern Barrier region), and elimination of the eastern states' prohibition against Western Doubles reduces fuel a maximum of 3.6 percent (aga in the Southern Barrier region). All other regions and alternativ combinations display much smaller percentage reductions in fuel co sumption. Although the gallons of the fuel saved in many regions a significant and certainly desirable, it is unlikely that fuel savi alone will determine the most desirable limit alternative.

10) Detailed analyses of the transportation cost effects of specific limit changes indicate that of all the alternatives con- sidered, use of the Bridge Formula for determining gross weight l or permitting the use of 65-foot Doubles on all Federal-aid prima highways (FAP) produces the greatest improvements in over-the-roa truck productivity. Increasing the axle loads above the existing Federal limit resulted in the least improvement in over-the-road truck productivity.

11) Analysis of the sensitivity of the reported results to critical study inputs (i.e., fuel cost, user charges, relative co of competing transport services, total truck activity and altern tive assumptions about modal shift and use of Doubles combinatio in response to limit changes) indicate that the only appreciable variation in the relative ranking of the limit alternatives repo would occur as a result of the study assumptions on the use of s axle and tandem-axle Doubles embedded in scenario J.

1.3 TRAFFIC, PRODUCTIVITY AND FUEL ANALYSES - METHODS OVERVIEW

1.3.1 TS&W Project Requirements

The Department's Truck Size and Weight Study required separate, in-depth analyses of several distinct areas of public concern. Three of those areas are covered in this report:

1. The change in truck traffic on the Federal-aid highway system (for a given level of transportation demand), attributable to vehicle capacity changes and any attendant modal diversions;
2. The productivity of systems providing freight transportation services as measured by the costs; and
3. The consumption of petroleum-based fuel for freight transportation services, including the effects of market shifts between modes having substantially different fuel intensiveness attributes.

The changes, attributable to specific truck size and weight limits, were isolated from other factors affecting the economic environment of the motor carrier industry. Comprehensive national aggregate estimates of these changes were accomplished by the distribution of these aggregate effects among the various interest groups (carrier services and markets).

1.3.2 Traffic Impacts

The general analytical approach used in the TS&W study has been to compare a series of discrete alternative limit senarios to a Base Case representing the current limits situation. Since 1977 was the most recent year for which a comprehensive set of traffic, operations and cost data was available, this became the base year to which all changes were made in order to project a 1985 Status Quo Base Case. The choice of 1985 for impact assessment reflected a study team consensus on the earliest period for which the full effects of any legislative changes resulting from this study might be felt. It is also a year within the time frame of the most credible long range economic forecasts.

Growth factors were applied to the 1977 truck activity, measured in vehicle miles traveled, to project the 1985 Status Quo

Base Case traffic volume. Truck freight ton-mile growth factors, developed by Jack Faucett Associates* are compatible with revenue forecasts developed for the Federal Highway Administration's (FHWA) Highway Cost Allocation Study. Growth factors were applied to the 1977 truck activity data at the level of 23 industry/commodity groups and 12 geographical regions. This procedure implicitly assumes that in the Status Quo Base Case each truck type will continue to be associated with the same markets as in the base year and that the truck vehicle-miles will increase proportionately with the truck ton-miles. Changes in productivity attributable to vehicle capacity changes are estimated for each limit scenario. Changes attributable to other economic environment factors (e.g., major economic disruptions and major changes in the attributes of competing modes) are not treated until the end of the study (i.e., in the form of sensitivity analyses). In other words, all operating, economic and competitive characteristics remain as defined by the base year data. The exception to this ground rule is that fuel costs and highway user taxes were projected to increase in real dollar terms. This was done to account for the obvious leadership that fuel exerts on the inflationary trends of late and the apparent need to update the user tax structure. The change in relative truck/rail rates attributable to these adjustments was judged to be too small to disturb the base year mode shares.

Reliable data on truck activity was the greatest problem faced by the study team. No one source of truck activity data provided comprehensive coverage of all truck activity, origin to destination flow information or sufficient truck type and gross weight detail. Four sources of truck freight flow data from the Bureau of the Census and the Federal Highway Administration were merged to synthesize the specific traffic attributes required into a single data base. The 1977 Truck Inventory and Use Survey (TI&U) public use file has been adjusted by TSC in collaboration with FHWA to reflect the FHWA's es-

*Member of Sydec Contract Study Team

timate of 1.3 million* combination trucks. This adjusted file provides the national aggregate control totals for vehicle miles traveled for all trucks with six or more tires, other than "off-road" activity.**

The TI&U file provides no indication of the interregional flow of trucks. Item 9 of the questionnaire "base of operation" is totally inadequate for distributing the total truck VMT among the 50 states. Therefore, the Census Bureau's Commodity Transportation Survey (CTS) was used to obtain origin to destination flows of commodities by shipment size and mode, and a network analysis was used to assign the flows to the TS&W study regions after conversion of ton-miles to truck miles. This procedure was suitable only for the flows of manufactured goods between BEA Economic Areas which originated at manufacturing plants. Long haul movements of farm products were added using Department of Agriculture data. Local truck activity (e.g., utility trucks, cement mixers, garbage trucks, etc., and short haul movements associated with forest, mines and farming activity as well as retail and wholesale distribution) was extracted directly from the TI&U file for each state of operation. Long haul and short haul household goods movements were also extracted from the TI&U file because the Commodity Transportation Survey file provided no such data.

Distribution of the activity of various truck axle configurations among administrative highway classes and among gross weight groups in each state was developed from FHWA data by the Sydec contract study team.

TSC's specific contribution to the truck traffic impacts involved: a) the construction of the 1985 Status Quo Base Case truck activity VMT, b) the estimation of the changes in truck VMT for each of 12 alternative TS&W limit scenarios, and c) the creation of 13 machine readable data files of 1985 truck VMT for each of the 50 states, 4 highway classes, 15 truck axle configura-

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*This estimate was later revised by FHWA to 1.02 million. Table IV-12, p. IV-23, Final Report, Federal Highway Cost Allocation Study, May 1982

**Technical Supplement Volume 4 fully documents the truck traffic projections and estimation of impacts of alternative limit scenarios.

tions and 15 gross vehicle weight groups. These 13 files became the basis for an independent series of analysis of pavement and bridge effects and traffic safety and environmental impacts for each scenario conducted by the Sydec contract study team.*

The TSC treatment of long haul (Type 3) traffic involved very detailed flow information files, which were analyzed in a stylized fashion, using a few representative truck types and payload weights. The VMTs resulting from this process were then distributed into the "15x15" TI&U format according to rules described in Volume 4 and merged with the local (Type 2) VMTs. Sydec then adjusted these VMTs to account for "overweight" activity and to provide a more diffuse distribution of the effects of load limits over weight blocks, than had resulted from the stylized code 3 analysis. These adjustments retained the distribution of ton-miles and vehicle-miles among truck types in each scenario, and also the magnitudes of shifts in ton-miles and vehicle-miles for each truck type between scenarios. Nevertheless, the VMT adjustments made it necessary for TSC to do the disaggregated impact analysis to be described here in two stages. The first involved analyses of impacts on disaggregated traffic streams by TSC. The second phase involved application of the phase one results to the aggregated VMT files after the Sydec adjustments.

TSC estimated changes in aggregate fuel consumption and the freight transportation bill and overall freight service quality for each of the scenarios. These changes were distributed among geographical regions and among several categories of carrier services (e.g., less-than-truckload, "for hire" exempt, and private trucking) and several commodity/industry users of freight services.

1.3.3 Freight Service Productivity Impacts

All freight carrier services are not alike, nor are all truck types and all truck trips affected equally by each specific TS&W limit change. The payload effect of a broad array of limit com-

*Technical Supplement Volume 6 fully documents the analysis of pavement and bridge impacts.

binations on a large variety of truck types has been estimated, not only to provide input data for analysis of the alternative limit scenarios but also to provide a perspective of the range of trade-offs which may be economically and politically feasible.

Forecasting the effect of specific vehicle capacity changes on future freight rates in individual markets is next to impossible. Forecasts of changes in the competitive environment that will prevail between now and 1985 as a result of current activity in regulatory reform is pure conjecture. Therefore, to estimate price changes attributable solely to specific size and weight limit changes, this study has postulated a 1985 economic environment which is only slightly different from the base year as measured in real dollar terms. The rate of inflation for all of the factors of production of freight services is assumed equal. The level of productivity of these factors remains essentially as in the base year except for the vehicle capacity change under study. Also the competitive attributes (e.g., service reliability and availability) remain essentially as in the base year. The only exceptions to these study ground rules are (a) that some improvement in the fleet average fuel consumption rates (about 25 percent) and an increased cost of diesel fuel (about 166 percent in constant '77 dollars) were projected relative to the base year and (b) highway user taxes were projected at about double the base year level in constant dollars in the absence of a final result from the FHWA highway cost allocation study* to account for alleged inflation losses prior to '77.

A comprehensive set of equations for estimating cost based rates for the various truck and rail freight services potentially affected by the size and weight limit changes were developed. Separate equations have been developed for each of several regions, representing the variations in climate, geography, labor and congestion. Separate equations have been developed for general commodity services and several special commodity services and for

*A comprehensive treatment of this subject is in Technical Supplement Volume 2.

full and partial truckload sized shipments as well as less-than-truckload shipments. Separate cost based rate equations have been estimated for several tractor trailer combinations for each of these carrier services. The rail service counterparts, including Trailer-on-Flat-Car (TOFC) and general consist operations, have been priced using methods and data consistent with the truck prices.

Cost based rates (including average industry profit levels for each carrier group) are estimated for each truck trip and the total door-to-door trip cost, including all system inefficiencies (e.g., average industry capacity utilization), are allocated to the shipment payload to obtain a total shipment charge in 1977 dollars per hundred weight. This estimated "rate" varies with the truck configuration used and the payload allowed by the gross weight limit.

1.3.4 Intermodal Competitive Relationships

Improving productivity of truck services, while a desirable objective in itself, may not be without cost in other areas. The concern of this TS&W study effort is the assessment of total system effects. This requires some estimate of potential effects on other modes of freight service. To date the study team has uncovered potential effects on the competitive relationships between only the truck and rail services. The competitive impacts on air freight and pipeline services are nonexistent and the effect on water transport has yet to be determined, but is believed to be small.

Implicit in the modal shift results of this study is the assumption that the rail service attributes remain static while the highway limits are changed, thus disturbing the current competitive balance. This is only one of several plausible assumptions that could be made about the study forecast year - 1985. It it conceivable that the rail service productivity could significantly improve by 1985, thus lowering the rail rates relative to truck in competitive markets. Even if the competitive balance between rail and truck changes significantly by 1985 because of operational or technological innovations or marketing strategies motivated by regulatory reforms, truck size and weight limit changes will be an additional disturbance. The relative magnitudes of the diversions attributable to each size and weight alternative should not be substantially affected by changes unanticipated in the Status Quo Base Case market shares.

However, for this study the attributes of the competing rail and highway services have been fixed at the base year levels, with exceptions of fuel costs and highway user taxes. On this basis market shifts between truck and rail have been estimated for each of the study scenarios.

One additional aspect of the overall approach to this TS&W study effort deserves mention here. In order to provide greater visibility of the effects of modal shifts, the modal diversion effects for each scenario have been segregated from the axle, configuration and gross weight change effects within the truck mode. The segregation of these effects permitted the study team to assess the sensitivity of the final conclusions and recommendations to the mode shift impacts. This segregation of the mode shift effects should be of particular interest to any reviewers who may be able to provide more accurate estimates of specific market shifts.* Basically, the mode shift method assumes that the changes in capacity of the various truck types affected by each limit scenario cause a change in the price of the truck service involved. This disturbs the competitive balance between some truck and rail services and causes a change in the truck share of a specific market. The critical assumptions here are that the changes in motor carrier operating cost are "passed through" in the form of decreased truck freight rates and that rail carriers do not match these price decreases. Given these assumptions, the mode choice decision is driven by this price difference, even though other service attri-

*The methods used in estimating the modal shifts are fully documented in Technical Supplement Volume 5.

butes may remain unchanged.* However, the smaller the price elasticity, the more important these other attributes become.

1.3.5 Fuel Consumption Impacts

A comprehensive set of equations was used for estimating fuel consumption effects attributable to specific changes in the size and weight limits under various operating environments. Motor carrier services, body types, axle configurations and terrain types as well as loading conditions have been disaggregated to obtain representations of the myriad operating conditions which affect fuel consumption. The effects of the truck size and weight limit changes are reflected by the change in the vehicle miles traveled, the mix of truck axle configurations and gross weight distributions in each of the markets served. In order to forecast the change in the fuel intensiveness of the 1985 truck fleet, two generic vehicle technologies have been defined: the standard technology, which dominated the fleet before 1974 and the "fuel saver" technology, which represents vehicles equipped with all the fuel saving innovations available to a truck purchaser in 1979. The latter is projected to dominate the fleet in 1985. The vehicles used in the Department of Transportation/Society of Automotive Engineers (DOT/SAE) Truck and Bus Fuel Economy Measurement Study are the models for these two technologies. The effects of adhering to 55 mph and 65 mph speed limits have also been considered.

The Cummins Engine Company's truck performance model was used to simulate truck runs representing over 350 combinations of these parameters. TSC constructed a series of equations using the simulation results for direct line-haul fuel consumption. Factors for terminal area collection and distribution functions and for empty mileage were added. The equations are used to estimate fuel consumption for each type of truck movement and for each category

*The effects on average speed of TS&W limits are estimated, but service reliability is implicitly assumed to remain unchanged.

of payload defined in the truck activity forecast. The national and regional aggregate fuel consumption impacts of the size and weight scenarios are dependent upon estimates of the truck activity. Rail services have also been estimated, but only to the extent that freight shipments are diverted to or from the rail mode by truck limit changes.

It should be noted that all of the aggregate fuel estimates are based on the base year operating attributes of truck and rail services, projected to 1985. The truck industry was apparently further along in implementing fuel conservation equipment and operations than was the rail industry, and this has been reflected in our projections. The TS&W study is projecting a forecast year competitive environment which may change by 1990 or 1995 if truck improvements come more slowly than rail improvements after 1985. Therefore, the fuel savings atrributed to certain limit changes may be overestimated from this perspective.

2. TRANSPORT COST AND SHIPPING TIME

This section examines the distribution of the national aggregate impacts among various groupings of users and suppliers of freight transportation services. It presents the impacts attributable to six separate alternative sets of truck size and weight limits on a) nine geographical regions, b) six carrier services and c) 11 industry/commodity groups. The national aggregate impacts are disaggregated with respect to only one of these groupings at a time.

In order to keep the presentation of information manageable and to avoid presenting the reader with an overwhelming volume of data, only those limit changes having large impacts, have been selected for disaggregation and discussion in this chapter. Table 2-1 lists the specific alternative limits selected. They are identified with their respective scenarios in the Final Report. The numerical code was used during the study effort and is retained here to maintain a clear audit trail. The alphabetic code assigned in the Final Report is also shown. The prime and double prime denote subdivisions of the Final Report scenarios to display disaggregations of the reported results to show the impacts of each individual limit change as follows:

- 4'(F') is that portion of scenario 4 (F) impacts attributable to elimination of the barrier state weight limits only
- 4"(F") is that portion of scenario 4 (F) impacts attributable to elimination of the eastern states' prohibitions against 65-foot Doubles combinations
- 8'(K') is that portion of scenario 8 (K) impacts attributable to rollback of axle load limits coupled with use of Bridge Formula A for gross weight.

The abbreviated titles used occasionally throughout the report are shown in parentheses. The order of presentation and discussion of the limit alternatives in this section is also shown on Table 2-1. Appendix D of this volume contains tables of disaggregate impacts for all the study scenarios presented in the Final Report.

TABLE 2.1 ALTERNATIVE LIMITS FOR NATIONAL UNIFORMITY

STUDY CODE	REPORT CODE	CHANGE FROM BASE	NATIONAL UNIFORMITY IN WEIGHT	CONFIGURATION & LENGTH
2A	C	Eliminating High Grandfather and Permit Limits (Grandfather Elimination)	No Change	NO CHANGE
4'	F'	Eliminating Barrier State Weight Limits (Barrier Elimination)	$20/34/80^{K}$ Pounds	NO CHANGE
5	H	Rolling Back Axle Load + Gross Weight Limits (Pre-1974)	$18/32/73^{K}$ Pounds	NO CHANGE
8'	K'	Rolling Back Axle Load + Use Bridge Form. 'A' (Rollback & Formula A)	18/32/Bridge 'A'	NO CHANGE
6	J	Increasing Axle Load + Use Bridge Form. 'C' (Increased Limits)	22.4/36/Bridge 'C'	NO CHANGE
4"	F"	Eliminating Eastern States Prohibition to 65-Ft Doubles (65-Ft Doubles in East)	20/34/80	65-Foot Doubles

Notes: Codes 4' and F' denote the portion of scenario 4(F) attributable to the Barrier State Axle and Gross Weight Limit Changes Only

Codes 4" and F" denote the portion of scenario 4(F) attributable to the Eastern States Double Prohibition Change only

Codes 8' and K' denote the portion of scenario 8(K) attributable to Rollback of Axle Load and Gross Weight Limits by Bridge Formula A

For full description of the TS&W Study Scenarios see Appendix A, Volume 4 Technical Supplement.

The transportation cost data presented in this report are all in 1977 constant dollars and include only the carrier charges to shipper/receivers for transportation services. The aggregate charges are synonymous with transportation revenues of the motor carriers and rail carriers involved. When the focus of the discussion is on a user group, total charges for transport service are referred to as cost. When the focus of the discussion is on the carriers' business impacts, revenue of the carrier service group is the term used. In either situation, the focus is on the change in the charges or revenues from the Status Quo Base Case attributable to the specific alternative set of TS&W limits. Shipper cost impact is the term used when the change in rail charges for diverted traffic is included.

The effects of potential modal shifts have been isolated from the impacts from truck use shifts (i.e., choice of route, truck configuration, etc.) in all cases so that the reader may judge the relative importance of this issue in assessing the relative merits of specific limit alternatives to obtain uniformity. The transport cost impacts of modal diversions disaggregated by region or by industry/commodity group include the net cost change experienced by the user from the Base Case (i.e., the algebraic sum of increases in charges for the mode receiving the diverted traffic and the decrease in charges for the mode losing the diverted traffic).

Table 2.2 shows the national aggregate impacts for the limit alternatives discussed in this section. These values are compatible with values shown in Exhibit 5.4* of the Final Report. An inflation factor of 1.36 was applied to these 1977 dollar values to obtain the 1980 values shown in the Final Report. Table 2.3 shows the projected regional total truck transport cost for the 1985 base case against which to compare the impacts for each of the limit alternatives.

*An Investigation of Truck Size and Weight Limits, Final Report, Aug. 1981, prepared by DOT, Office of the Secretary, p. V-8.

TABLE 2.2 1985 NATIONAL AGGREGATE TRANSPORT COST IMPACTS

	(MILLIONS 1977 DOLLARS)					
STUDY CODE	2A	4'	5	8'	6	4"
FINAL REPORT CODE	C	F'	H	K'	J	F"
SHORT CODE	(Grandfather Elimination)	(Barrier Elimination)	(Pre 1974)	(Rollback + Formula A)	(Increased Limits)	65 Ft. (Doubles in East)
NET IMPACT	+628	-183	+2779	- 44	-3362	-1599
TRUCK USE IMPACT*	+703	-486	+3114	-167	-3737	-1599
MODE SHIFT IMPACT	-146	+833	- 715	+392	+1134	+ 19
RAIL LOSS (GAIN)	+ 71	-530	+ 380	-269	- 759	- 19

*For all trucks greater than 10,000 lbs registered gross vehicle weight.

Source: Table D-2 of Appendix D.

Transport cost (or revenue) impacts are presented in terms of absolute dollar values as well as in percentage changes from the Status Quo Base Case because there are situations where either or both of these measures are important to a particular interest group.

Shipment transit time (door-to-door speed) changes are shown only in percentage change terms because percent change is considered the most relevent measure of service quality impact. The absolute values are, however, available in the tables in Appendix D.

Figure 2.0 is a map defining the aggregation of the 48 mainland states into the nine study regions. Region 2 does not exist because the 10 study regions were defined at the beginning of the project in 1979 and later revised. The revisions merged regions 1 and 2 into region 1 and shifted Iowa from region 6 to region 7 in order to update the Status Quo Base Case limits to reflect the 1980 situation.

2.1 REGIONAL IMPACTS

Regional shipper/receiver transport cost impacts are displayed in 1977 constant dollars in Figures 2.1 through 2.6. The first bar in each region represents the net impact, the second represents the truck use (i.e., choice of route, truck configuration, and level of tripmaking) impact, the third represents the truck impact due to modal shift and the fourth represents the rail impact due to the loss or gain in diverted traffic.

The shipper/receiver transport cost impacts associated with each study region reflect the assignment of shipment transportation cost (or charges) to the region of destination of specific shipments. These absolute values, therefore, are the product of the volume of total traffic terminated in the region and the dollar magnitude of the charge for each unit of traffic.

The reader's perspective will determine the most important findings from these displays, but a few general observations are in order here.

TABLE 2.3 BASE CASE TOTAL TRUCK TRANSPORT COST BY REGION

REGION			(Millions 1977 Dollars)
U.S. TOTAL			143,333
NE	1	Northeast	28,691
SE	3	Southeast	22,637
ME	4	Mideast	16,923
SB	5	Southern Barrier	4,377
MWB	6	Midwestern Barrier	18,567
NC	7	North Central	8,133
WC	8	West Central	7,661
SW	9	South West	30,039
NW	10	North West	5,931
	11	Alaska	214
	12	Hawaii	160

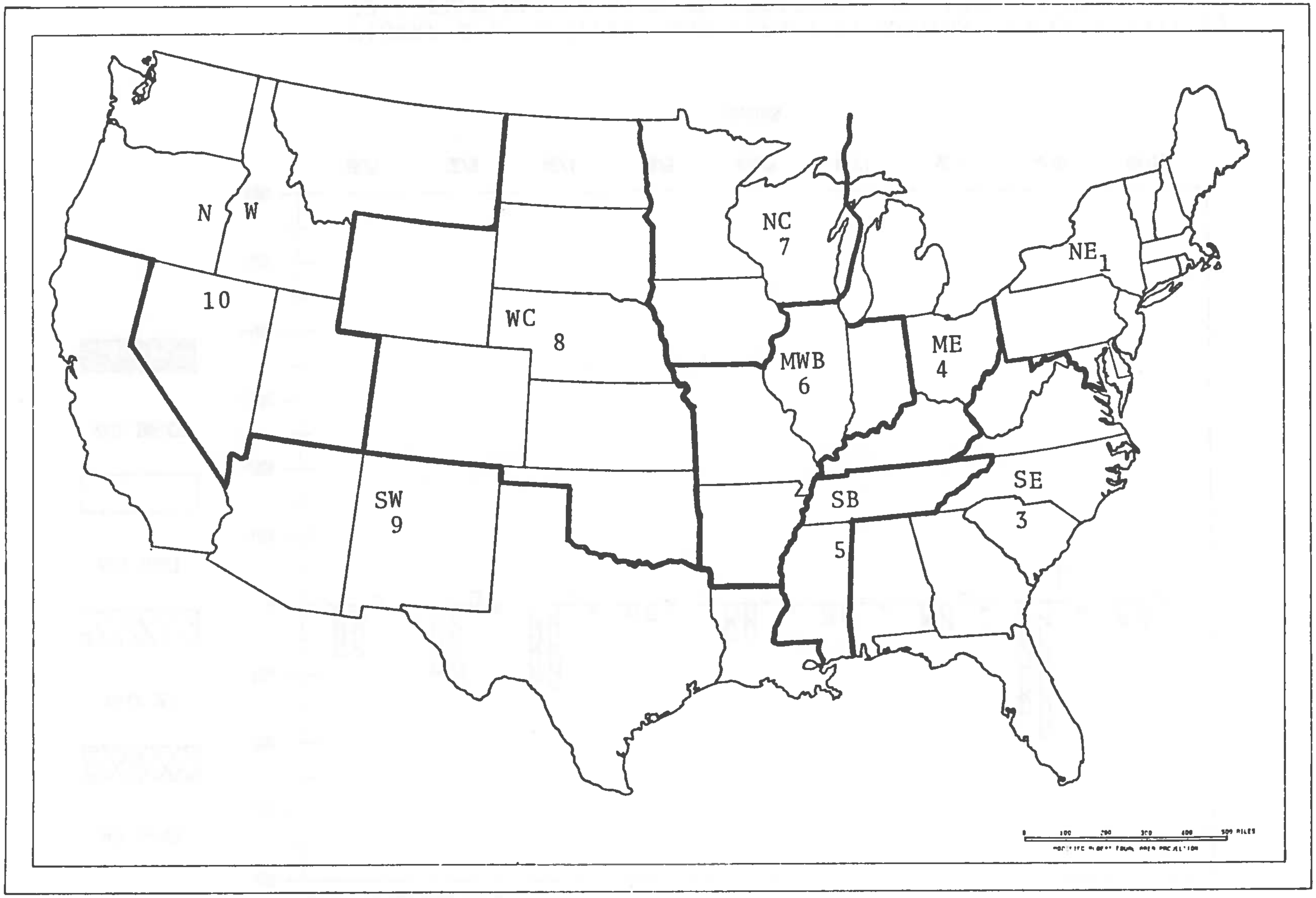

FIGURE 2.0 REPORTING REGIONS FOR LIMIT ALTERNATIVE IMPACTS
(See Table 2.3 for Region names.)

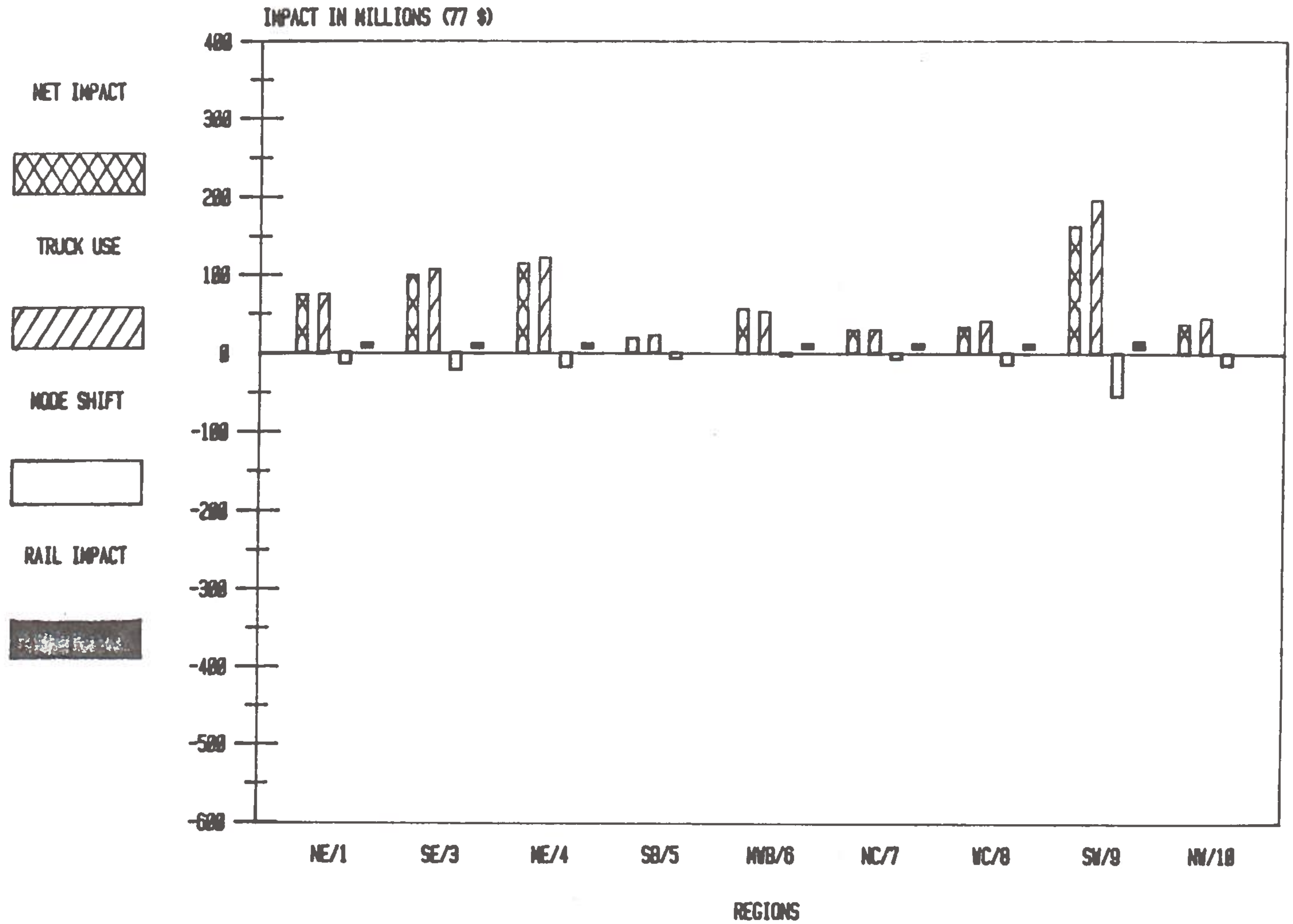

FIGURE 2.1 SHIPPER COST IMPACT BY REGION (TRUCK & RAIL Δ)
(2A) ELIMINATING HIGH GRANDFATHER AND PERMIT LIMITS

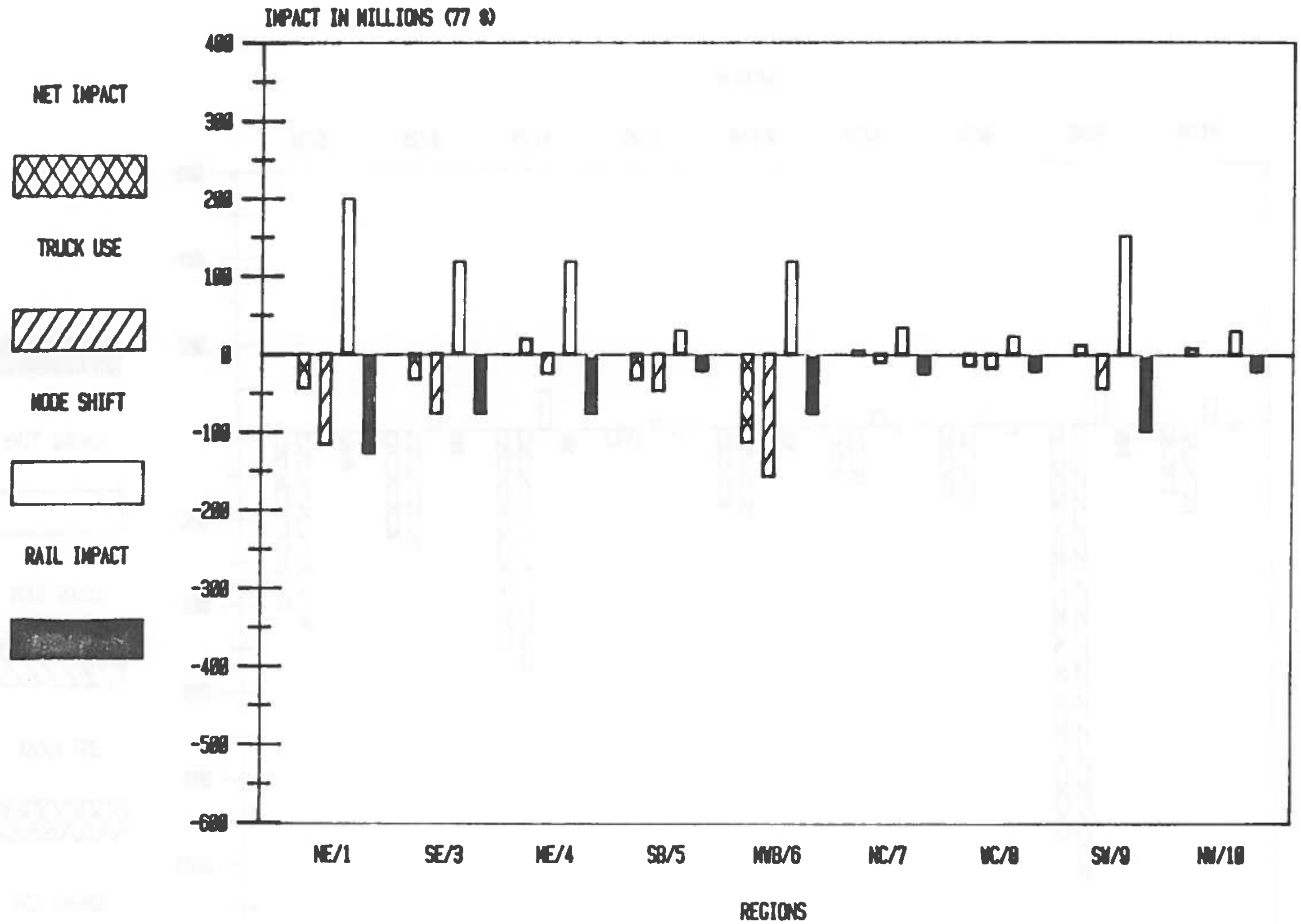

FIGURE 2.2 SHIPPER COST IMPACT BY REGION (TRUCK & RAIL Δ)
(4') ELIMINATING BARRIER STATE WEIGHT LIMITS

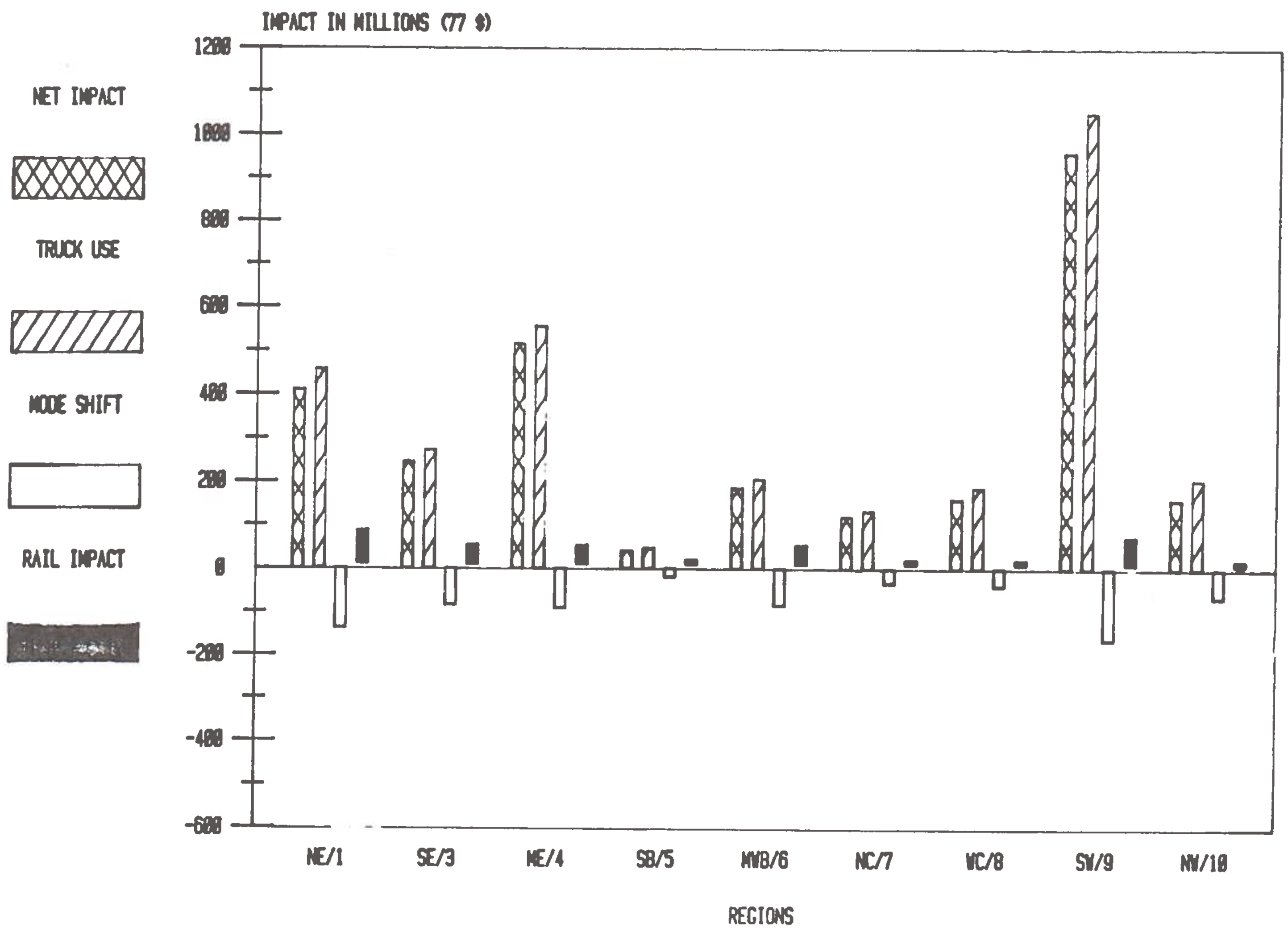

FIGURE 2.3 SHIPPER COST IMPACT BY REGION (TRUCK & RAIL Δ) (5) ROLLING BACK AXLE LOAD AND GROSS WEIGHT LIMITS

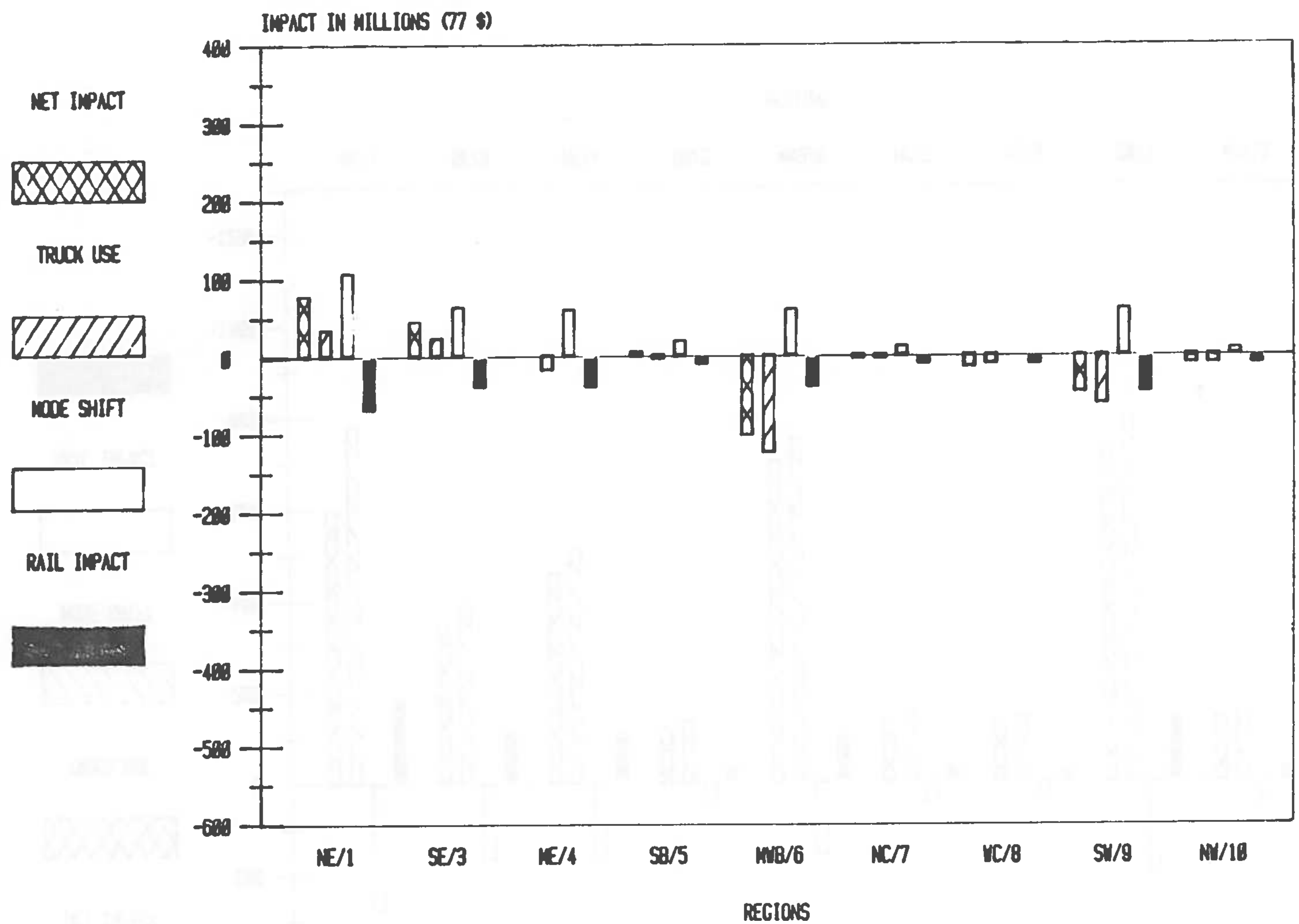

FIGURE 2.4 SHIPPER COST IMPACT BY REGION (TRUCK & RAIL Δ)
(8') ROLLING BACK AXLE LOAD BUT USE BRIDGE FORMULA 'A' GROSS WEIGHT

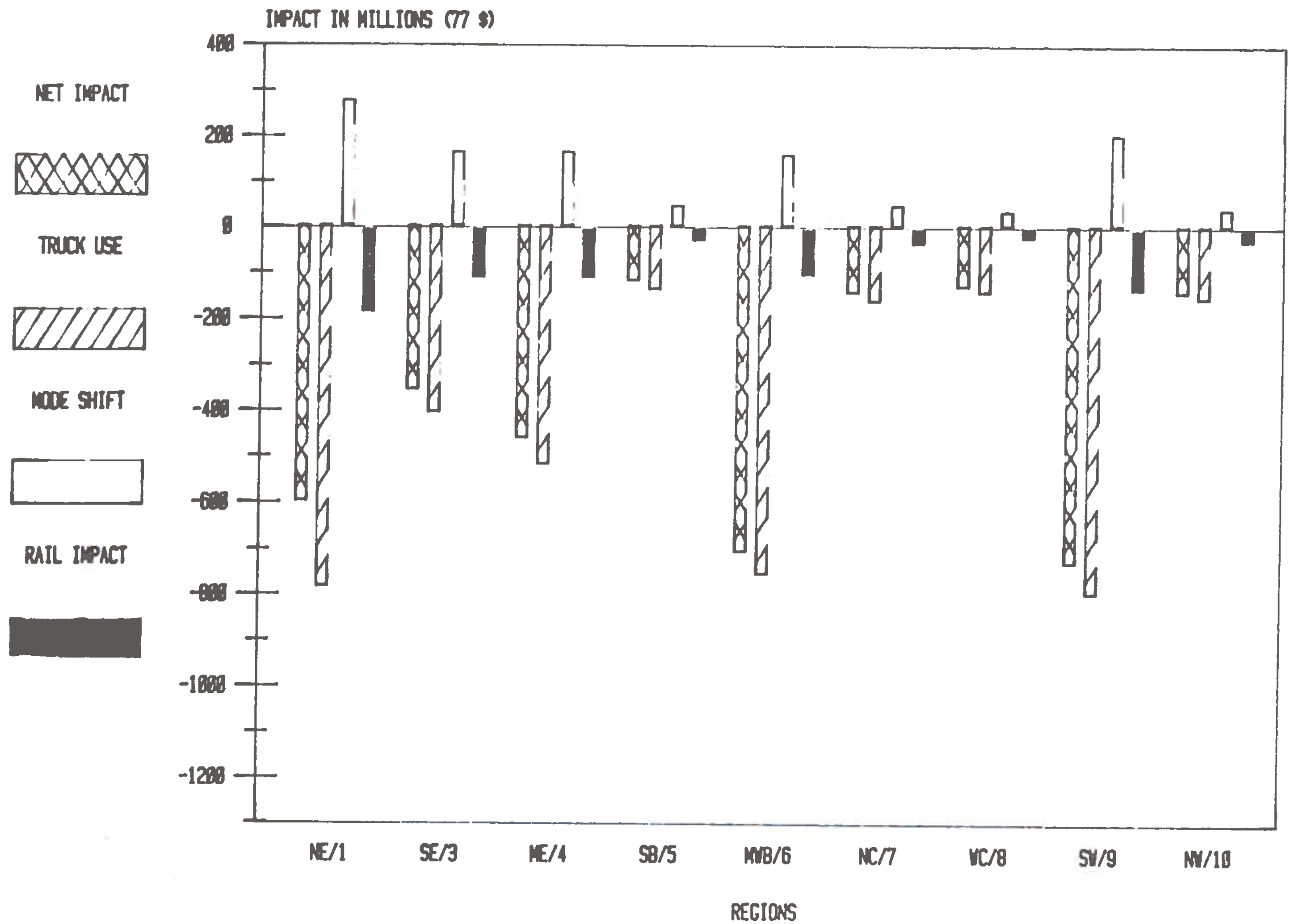

FIGURE 2.5 SHIPPER COST IMPACT BY REGION (TRUCK & RAIL Δ)
(6) INCREASING AXLE LOAD AND USE BRIDGE FORMULA 'C' GROSS WEIGHT

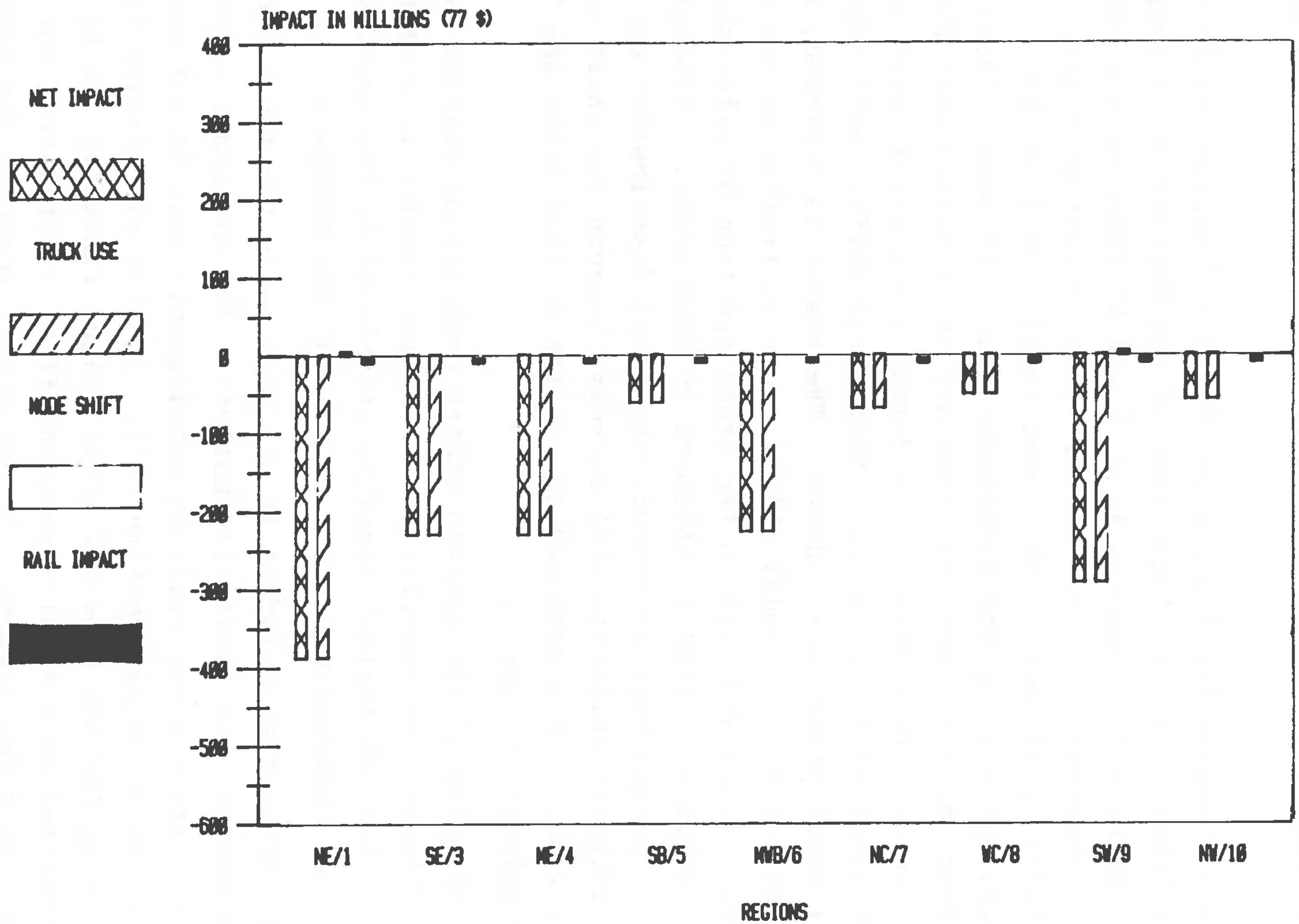

FIGURE 2.6 SHIPPER COST IMPACT BY REGION (TRUCK & RAIL Δ)
(4") ELIMINATING EASTERN STATES PROHIBITION OF SHORT DOUBLES

The southwestern region (9) has the most to lose or gain by elimination of the high grandfather and permit limits, the roll-back of axle and gross weight limits to pre-74 levels or the increase of axle load limits and use of Bridge Formula C for gross weight.

The Midwestern Barrier region (6) itself appears to be the greatest beneficiary of elimination of the Barrier State weight limits (Figure 2.2). Regions 4, 7, 9 and 10 experience a small increase in transport charges because of diversions of traffic from a less costly rail service to a more costly truck service. The truck services causing the diversions from rail reduce their prices from the Base Case, but they are still higher than the rail services losing the traffic. The demand elasticities used in the mode shift analysis indicate that these shifts could take place if truck prices are reduced. The reader is reminded, at this point, that these modal shifts occur in traffic at the margin between truck and rail in the broad spectrum of price/service quality packages offered to shippers by both modes. Although the transport charges have increased, the total distribution costs for the diverted shipments will decrease because the shift is to a faster mode. For a detailed discussion of this issue see Technical Supplement Volume 5.

Elimination of the eastern states prohibition against Western Doubles (Figure 2.6) benefits the Northeast (region 1) more than any other, but substantial benefits are shared by the Southeast, Mideast, and Midwestern Barrier as well as the Southwest.

The dominant cost impact in all regions is the truck use impacts in each of the limit alternatives. The net modal shift impack (i.e., truck minus rail) is considerably less in all but the Barrier Elimination Alternative (4'). In this alternative (Figure 2.2), raising the low axle and gross weight limits in the barrier states resulted in a modal diversion effect greater than the truck use impact in a few regions. In any event, scanning the magnitude of the impacts of the alternatives for any one region suggests that modal diversions do not influence their relative attractiveness.

Figure 2.7 presents the transport cost impacts in each region in terms of the percent increase or decrease in that region's truck costs without consideration for modal diversion. Five bars are shown for each region, one bar for each of the limit alternatives, 4', 5, 8', 6, and 4", in that order. They are double labeled with the study code and the abbreviated limits, as shown in Table 2.1. This display suggests that for each limit alternative, the percent change from the Base Case varies substantially among the geographical regions of the country. The two barrier state regions show the greatest potential transport cost savings for those alternatives which increase the limits, while the two western regions show the greatest potential increased transport cost for the alternative that roles back the weight limits, to the pre- 74 Federal levels.

Alternative 8' suggests that use of the Bridge Formula for gross weight in conjunction with rolled back axle limits could produce small savings in transport cost in all regions except the Northeast and Southeast which display a small increase in costs. Alternative 8' assumes the use of tandem-axle Doubles (in states which, in the Base Case, permit Doubles) by a portion of the shipments which tend to move at the gross weight limit.

By far the greatest potential savings in transport cost by all regions is displayed under alternative 6, which permits increased axle loads as well as much higher gross weights. The use of the Bridge Formula and tandem-axle Doubles in those states, which in the Base Case permit Doubles, is responsible for most of this potential savings.

Modal diversion impacts are shown separately in Figure 2.8. These are the net transport costs (i.e., cost increase for the mode receiving the diverted traffic minus the cost decrease for the mode losing the traffic). The cost impacts are shown as a percent change to the Base Case regional cost for the diverted traffic only. The relative attractiveness of the limit alternatives does not appear to be changed by consideration of these modal diversion impacts.

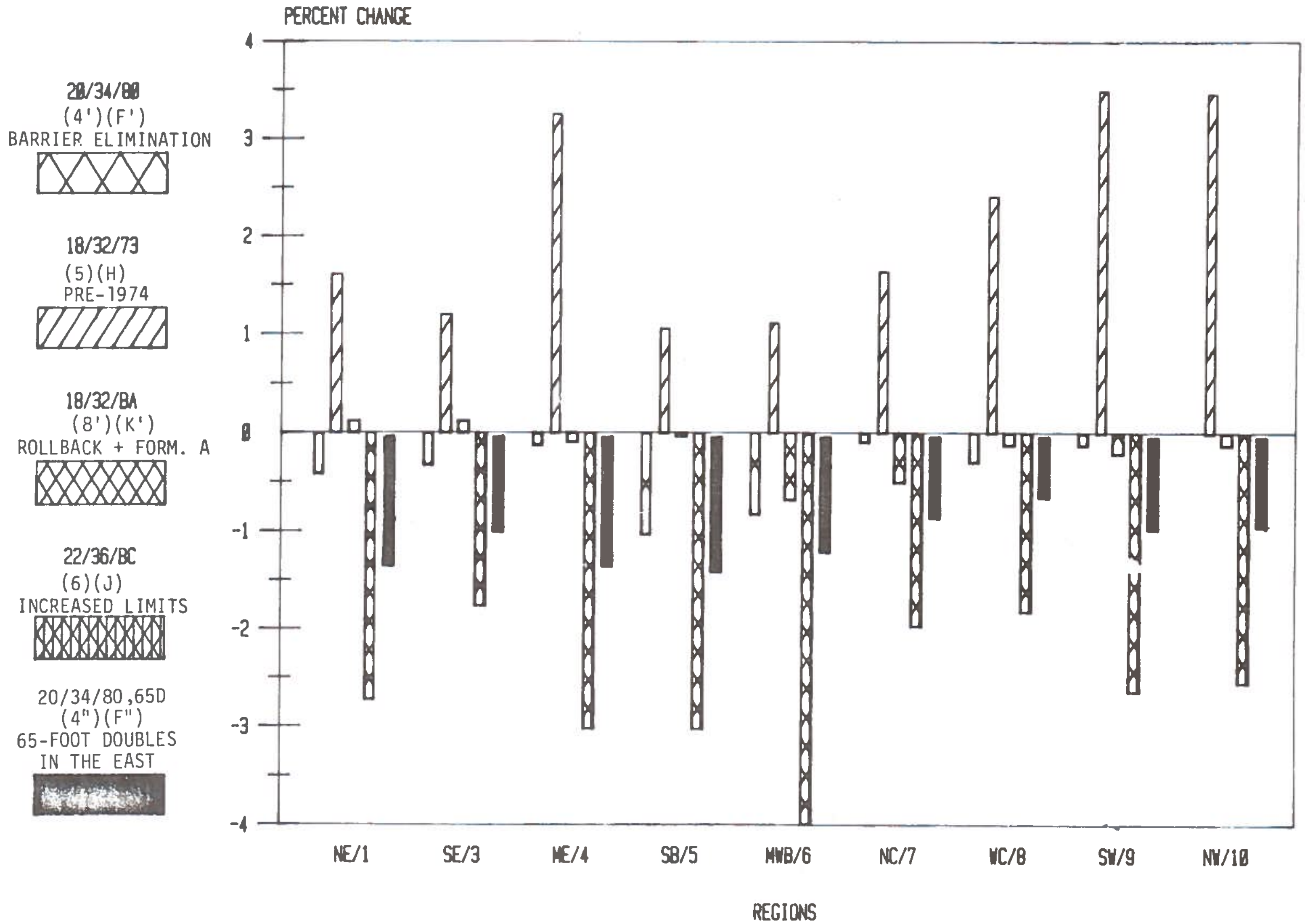

FIGURE 2.7 RELATIVE COST IMPACTS ON REGIONS
NO MODE SHIFT (TRUCK Δ ONLY)

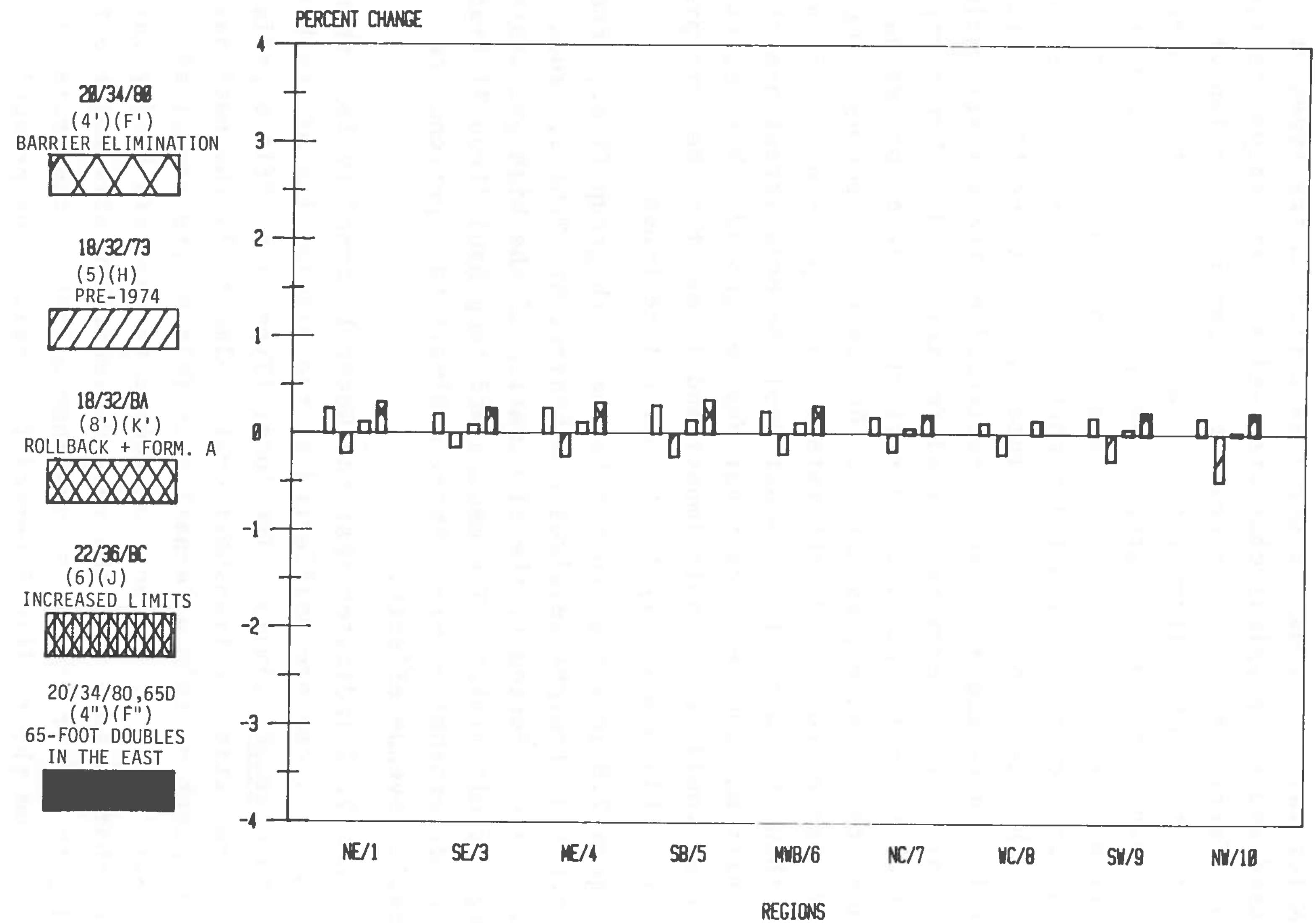

FIGURE 2.8 RELATIVE COST IMPACTS ON REGIONS
MODAL DIVERSION (TRUCK & RAIL Δ)

2.2 CARRIER REVENUE IMPACTS

Motor carrier transport services differ in the types of equipment used and the physical characteristics of the shipments transported. Carrier services, therefore, differ in their impacts attributable to the limits alternatives. Table 2.4 shows the projected carrier service national aggregate shipper/receiver transport cost (or carrier revenue) for the 1985 Base Case against which the impacts for each of the limit alternatives are compared. Figures 2.9 through 2.14 display the absolute values of the '77 constant dollar increases and decreases experienced by the six all inclusive classes of carrier services defined for this study. The perspective is that of the motor carrier and reflects increases or decreases in the carriers' revenues, assuming a 100 percent direct pass-through of cost changes to the freight rates. If no pass-through is assumed, then the modal shift impact would be nonexistent and the modal shift bar and net impact bar may be ignored. The second bar, truck use, would be the only impact and it may then be interpreted as a contribution directly to carrier net revenues.

Figure 2.9 indicates that only the sixth group (i.e., local, and short haul freight services and nonfreight, Type 2, truck activity) are effected by the elimination of the high grandfather and high permit limits. The medium and long haul (Type 3) traffic were determined by preliminary analysis to experience no measurable revenue effects.

Figure 2.10 indicates that the General Commodity less-than-truckload services are unaffected by the elimination of the barriers state weight limits. The local (Type 2) traffic experiences a slight reduction in transport cost. Almost all the national aggregate impact of this alternative is felt by the truckload operations; with those of the Special Commodity carriers having the largest share. Note that the revenue reduction attributable to shifting to larger trucks is more than offset by the increase in revenues from the traffic diverted from rail, thus producing a net increase in revenues to the motor carriers. Rail revenue changes attributable to the traffic that shifts to truck are not included

TABLE 2.4 BASE CASE TOTAL TRUCK TRANSPORT COST (CARRIER REVENUE) BY CARRIER SERVICE

	Millions 1977 Dollars
ALL SERVICES	143,333
GENERAL COMMODITY - LTL	23,144
GENERAL COMMODITY - TL	10,616
EXEMPT COMMODITY - TL	4,408
SPECIAL COMMODITY - TL	10,683
PRIVATE-NON-LOCAL - TL	8,408
LOCAL & NON-FREIGHT*	86,074

*Also referred to as "Type 2" Traffic in this study, the first five services constituting "Type 3" Traffic.

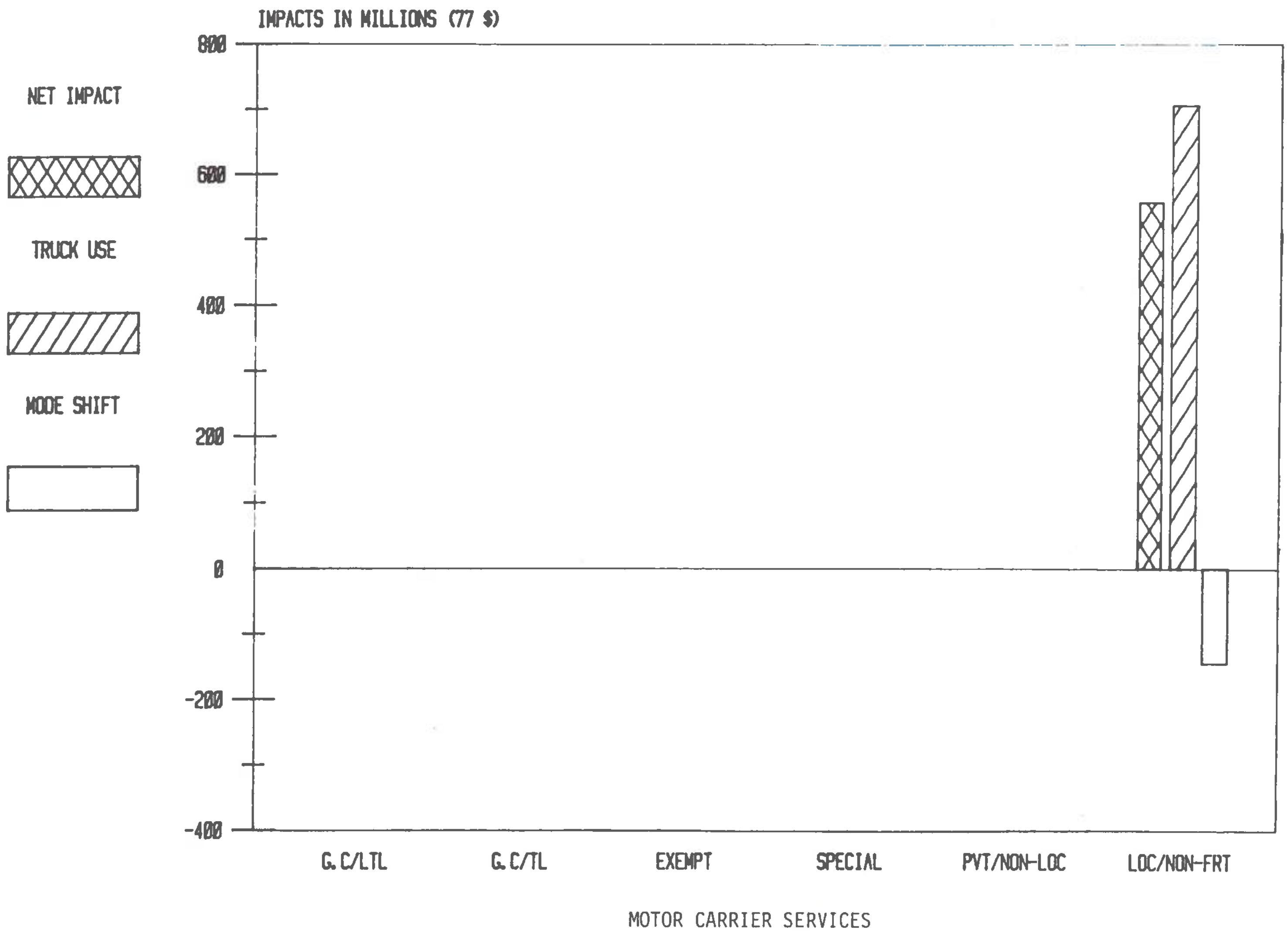

FIGURE 2.9 CARRIER REVENUE IMPACTS (TRUCK Δ ONLY)
(2A) ELIMINATING HIGH GRANDFATHER AND PERMIT LIMITS

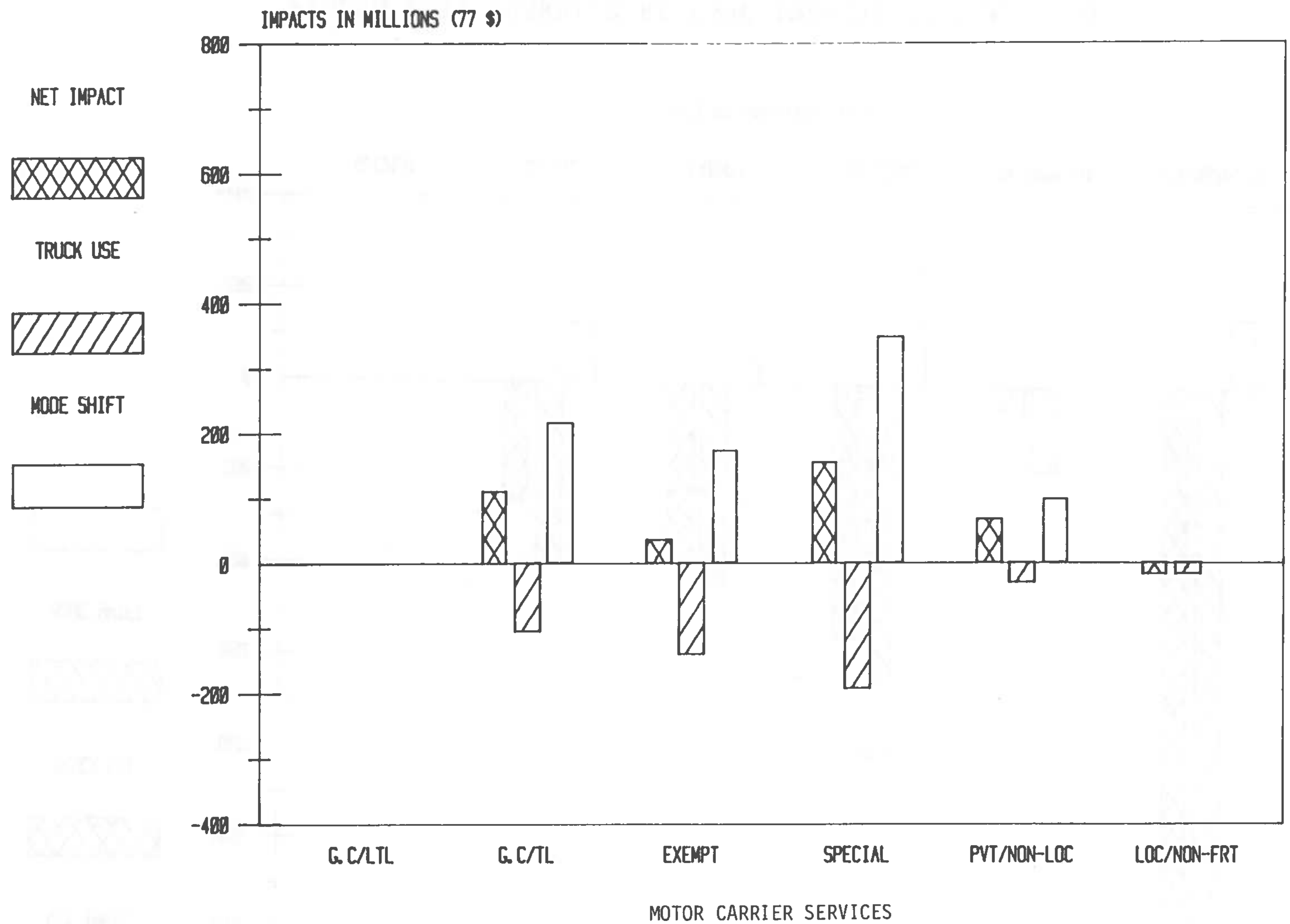

FIGURE 2.10 CARRIER REVENUE IMPACTS (TRUCK Δ ONLY)
(4') ELIMINATING BARRIER STATE WEIGHT LIMITS

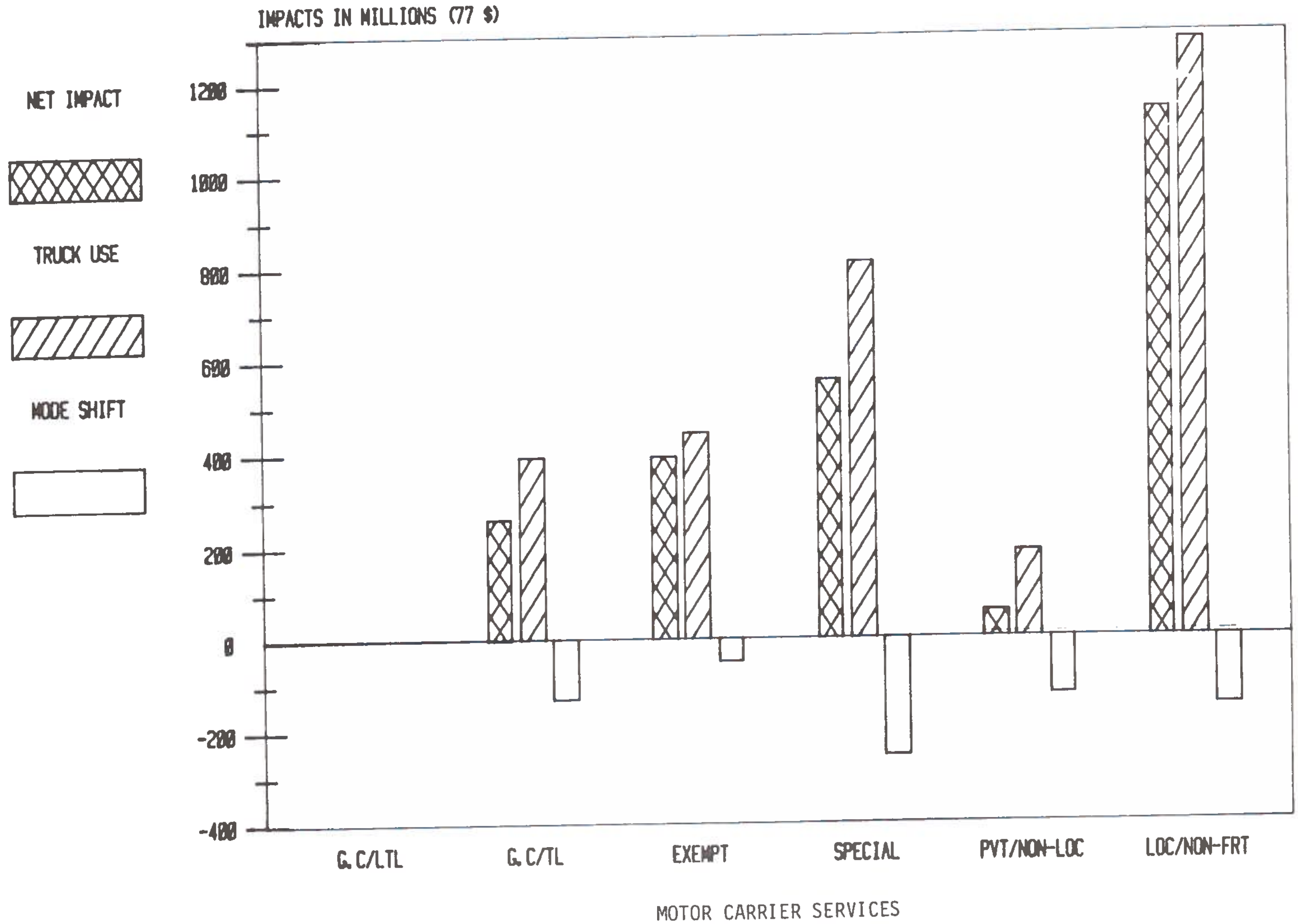

FIGURE 2.11 CARRIER REVENUE IMPACTS (TRUCK Δ ONLY)
(5) ROLLING BACK AXLE LOAD AND GROSS WEIGHT LIMITS

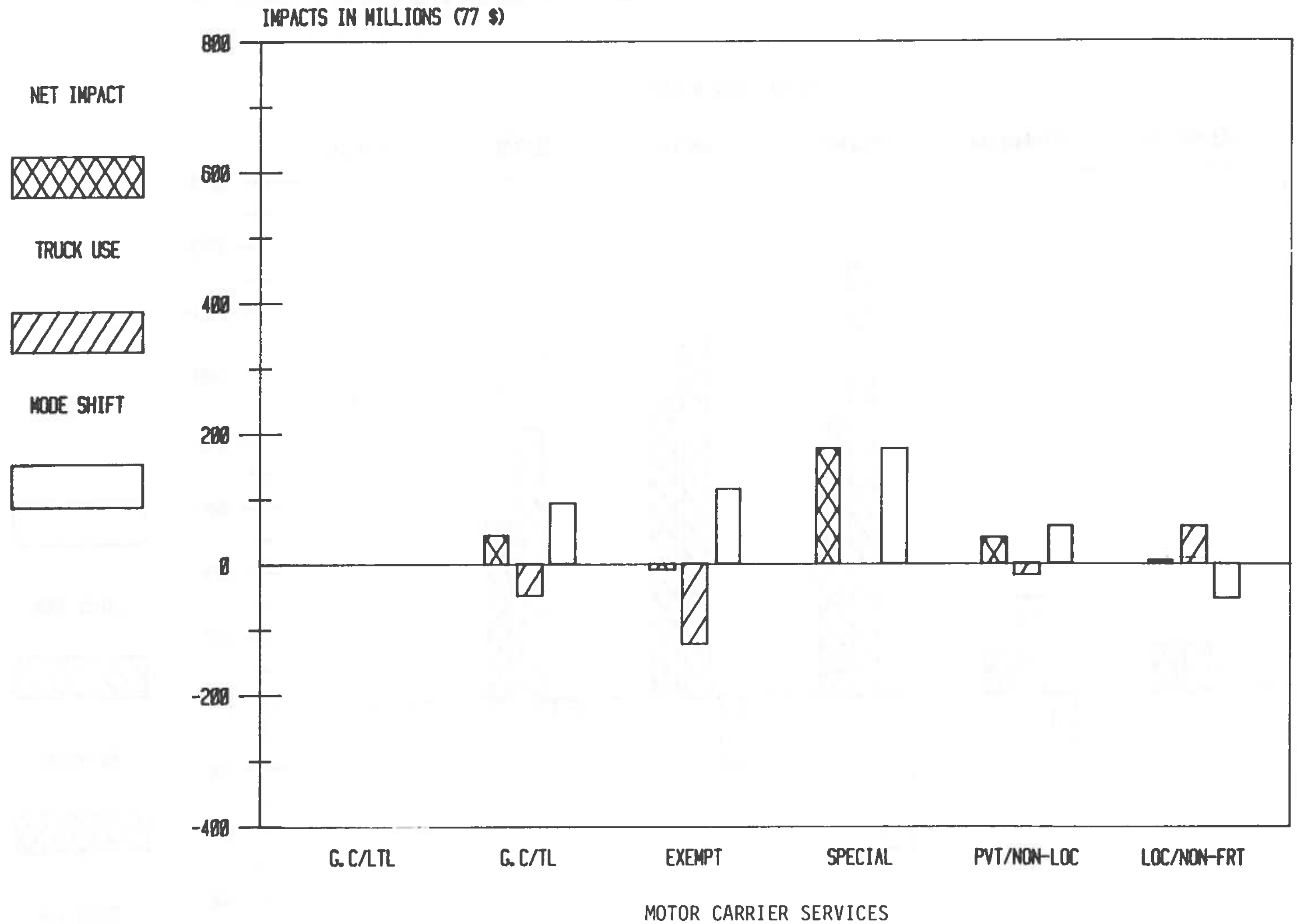

FIGURE 2.12 CARRIER REVENUE IMPACTS (TRUCK Δ ONLY)
(8') ROLLING BACK AXLE LOAD BUT USE BRIDGE FORMULA 'A' GROSS WEIGHT

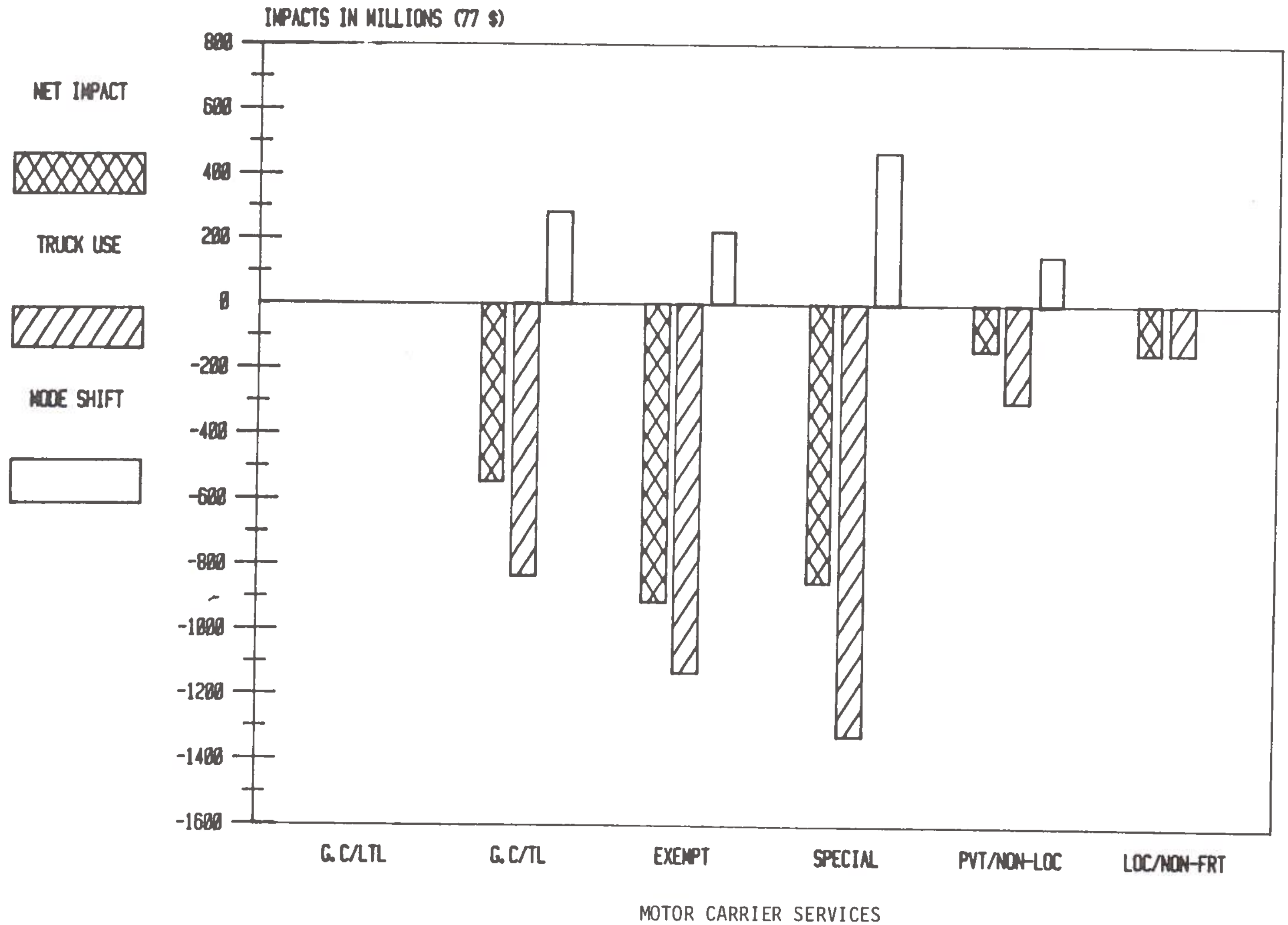

FIGURE 2.13 CARRIER REVENUE IMPACTS (TRUCK Δ ONLY)
(6) INCREASING AXLE LOAD AND USE BRIDGE FORMULA 'C' GROSS WEIGHT

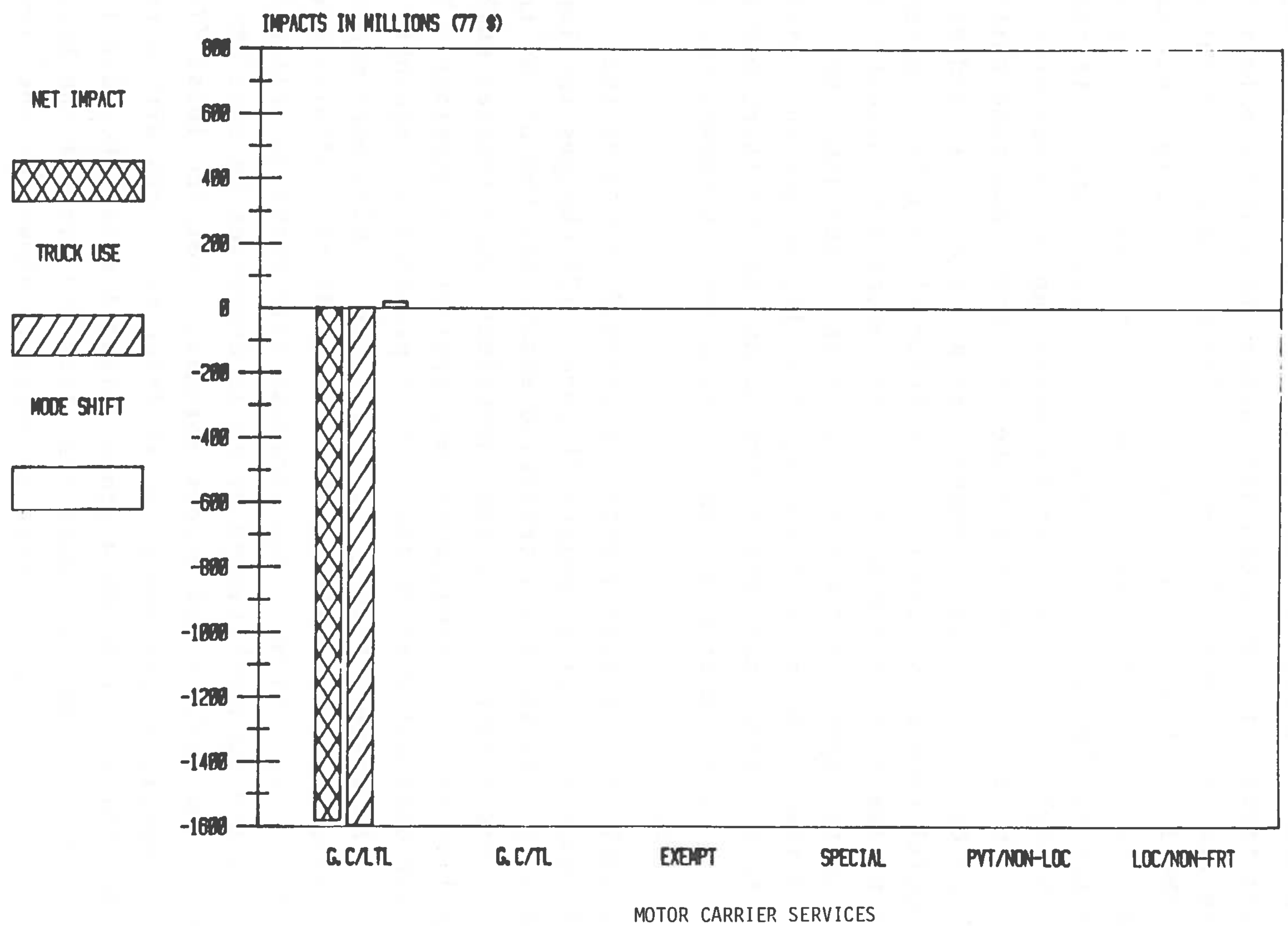

FIGURE 2.14 CARRIER REVENUE IMPACTS (TRUCK Δ ONLY)
(4") ELIMINATING EASTERN STATES PROHIBITION OF SHORT DOUBLES

in Figures 2.9 through 2.14. They are accounted for elsewhere in calculating total shipper/receiver transport cost charges.

The effect of a rollback of the axle load and gross weight limits to pre-74 levels is shown in Figure 2.11. The local and nonfreight truck activity shown here experiences the greatest increase in transport cost. The modal shift component is relatively small. The less than truckload services are unaffected, but all truckload services experience increases in revenues, assuming a pass-through of the cost increase to the freight rates. If there is no pass-through, then these cost increases can be interpreted as reductions in carrier profits and the net impact and mode shift impact bars can be ignored. However, of all the truck load services, Special Commodity carriers experience the greatest increase. From the perspective of the shipper, the second bar indicates the increase in transportation costs if no modal diversion takes place. If the shippers shift modes, then they reduce the total payments to the motor carriers by the amount of the third bar and concurrently incur additional costs, which are not shown, for the rail services.

Rollback of axle load limits compensated by use of the Bridge Formula A for gross weight (Figure 2.12) changes the impacts substantially because this alternative encourages the use of tandem-axle 27—foot twin trailer and equivalent truck-trailer combinations in lieu of the conventional semi-trailer combinations. This alternative does not disturb the current prohibitions against Doubles in the eastern states; it only makes Doubles more productive in those states permitting their use. In this alternative all the truck load service cost increase attributed to rolled back axle limits are counterbalanced by small decreases in cost attributed to the Doubles and Bridge Formula. Even the local (Type 2) traffic benefits, presumably by shifting to trucks with more axles under the Bridge Formula gross weight limits; they display a much smaller increase in costs than they did without the Bridge Formula provision. The increase in revenues shown for the truckload services are the result of diversions of traffic from rail services. General Commodity LTL services experience no change due to rollback of axle and gross weight limits. Exempt truck load carriers show a larger reduction in revenues (or transport costs) attributed to truck use shifts than do the Special Commodity carriers. This situation exists because the geographical distribution of exempt commodity flows coincide to a great extent with those states permitting the Doubles combinations. The Special Commodity carriers, on the other hand, are constrained in many of their origin to destination markets by state prohibitions against Doubles combinations.

Establishing national uniformity of axle load and gross weight limits at levels greater than the current Federal standard (Figure 2.13) produces very large improvements in truck transport productivity. The truckload services of all carrier groups benefit, with the Exempt and Special Commodity carriers having dominant shares of the aggregate improvement. Private trucking and local activity experience relatively small savings, and the General Commodity LTL services receive none at all. These large savings in transportation costs are attributable to two changes - axle load limits and Bridge Formula gross weight limits in study scenario 6. The primary cause of the savings is the use of the Bridge Formula for gross weight in lieu of an arbitrary single value limit. Bridge Formula limits encourage the substitution of vehicles with more axles. In those states which presently permit the use of tractor-semi-full trailer Doubles and truck-trailer Doubles, tandem-axles offer greater payload weight capacity for the higher density shipments. The effect of the increased single and tandem-axle load limits alone is far less than the effect of the Bridge Formula gross weight. The magnitude of the shift of traffic from the conventional semi-trailer configuration to the tandem-axle short Doubles is displayed in Appendix D, Tables D-6, D-7A and D-7B.

Of all the size and weight limit change alternatives addressed by this study, the one single action which promises the greatest cost reduction to freight transportation is the elimination of the eastern states' prohibition against the use of lightweight Doubles configurations, often referred to as the "Western Doubles" (i.e., the cab over tractor with a 27-foot semi-trailer and a 27-foot full trailer, all with single axles and an overall length of 65 feet). Figure 2.14 shows the magnitude of these potential savings at nearly 1.6 billion '77 dollars. This is attained without any significant diversion of traffic from rail because this is LTL traffic only. This reflects a substantial increase in the use of these combinations for LTL service nationwide.

Preliminary research* into the "Western Doubles" issue indicated that there are numerous operating reasons why all LTL traffic and other low density shipments do not now, and may not in the future, move in these combinations. Many, but not all of these operating constraints, would be removed along with the elimination of individual state prohibitions against Doubles' use. The Fay/TDS contract study found increasing carrier reluctance to use Western Doubles for LTL services as they moved from the West Coast to the East Coast in their examination of published truck data and selected carrier operations. The need for mixed fleets of equipment to operate both in restrictive states and in non-restrictive states was most often cited by carriers as the reason for not using the Doubles (other market and operating reasons were also given). The Fay/TDS report "anticipated" a penetration of 10 percent to 33 percent into the general commodity markets in the east by Western Doubles if the state prohibitions were eliminated. These combinations are attractive to General Commodity LTL carriers because they permit substantial reductions in terminal handlings of small shipments according to those who used them.

The TSC commodity flow and network analysis of the Type 3 traffic** places the Western Doubles share of national aggregate LTL ton-miles at about 38 percent in the Status Quo Base Case. Eliminating the prohibition against 65-foot light Doubles' use in the eastern states raised that share to about 66 percent of the total LTL and about 44 percent of the total general commodity traffic nationwide. This represents about 9 percent of all the

*Fay/TDS Study, Appendix E.
**Described in detail in Technical Supplement Volume 4.

Type 3 ton-miles and about 5 percent of all truck ton-miles. This projected penetration of the 1985 LTL markets may be somewhat greater than can be realized in actual practice as suggested by the Fay/TDS study because of operational constraints and the structure of carrier systems.

The TSC projections are based on a TSC estimate of substantial terminal handling cost savings attributable to Western Doubles' use. The projection was tempered by a constraint on their universal use in response to the Fay/TDS conclusions. General Commodity motor carriers' choice between 45-foot conventional semitrailers and tractor combinations and 65-foot overall Western Doubles combination for the LTL services is motivated by differences in operating costs and shipment transit time differences. Savings in both variables are claimed by those that use the Doubles. A carrier decision to use Western Doubles may be motivated by either or both considerations, but the cost savings may not be passed through to the freight transportation charges, whereas the improved service quality would. The cost savings would certainly pass through in a competitive market where entry is free and unconstrained by operating rights controlled by Government regulations.

The Fay/TDS study was designed to identify reductions in freight rates (or shipment charges) attributable to the use of Western Doubles. The intent was to relate such rate reductions to market characteristics which were applicable in the eastern states. However, the Fay/TDS study was unable to find evidence of rate reductions, attributable solely to the use of Western Doubles, in the LTL rate structures of regions permitting Western Doubles. The Fay/TDS study was focused, by design, on freight rates taken from published tariffs, actual carrier revenues taken from TDS internal traffic data files and operational considerations obtained from their direct contacts with representative carriers.

Fay/TDS did report substantial reductions in terminal handlings and door-to-door transit time for LTL shipments when Western Doubles were actually used. Reduced handlings and by-passed intermediate terminals must translate into cost savings to carriers, attributable to the use of Western Doubles even though these cost savings were not evident in the published tariffs or shipment charges. Fay/TDS was unable to identify any pass-through of savings to the freight rates. This would indicate either that cost savings were internalized by the carriers as contributions to net revenues because the competitive pressures which would encourage pass-through did not exist or that increases in other operating costs in those regions masked the Western Doubles savings. The Fay/TDS contract statement of work excluded a definitive treatment of LTL operating costs, although useful cost data was uncovered and used by TSC in developing the cost based rates for LTL services. (See Technical Supplement Volume 2.)

The Fay/TDS contract study may be characterized as one performed by physical distribution practitioners with a very pragmatic view of carrier services, tariffs and the rate-making process. This study was based on the current competitive environment and was constrained by data which reflected existing regulations and offered no hint of how carriers would react to changes in these regulations. The Fay/TDS estimate is for the eastern states only and may be somewhat low at 10 percent to 33 percent market penetration.

On the other hand, the TSC internal study is somewhat abstract in its approach, making required assumptions based on what ought to be, when evidence to the contrary was unavailable. The TSC projection is for the nation in aggregate, not just the eastern region and may be on the high side.

Even if TSC's estimate of Doubles usage is halved, the net saving is still about $800 million. This is a net saving to the freight system involving no increase in axle loads or gross vehicle weights, matched in magnitude only (up to this point in the presentation) by the Exempt and Special Commodity Truckload TL carriers with increased axle loads and gross weights in alternative 6.

Figure 2.15 views the limit alternatives impacts from the perspective of motor carrier management rather than from the perspective of the users of the transport services as Figures 2.9 through 2.14 have done. Figure 2.15 displays the effects on the motor carriers net operating revenues (i.e., change in operating costs).

Five bars are shown for each carrier service, one bar for each of the limit alternatives 4', 5, 8', 6, and 4" in that order. The absence of a specific limit bar over a carrier service means a negligible or zero change attributable to that specific limit alternative. For example, the General Commodity LTL services, the first group, is unaffected by any of the first four limit alternatives. Only a change in the eastern states' prohibition against the Western Doubles affects the total transportation costs for these services. In the aggregate the savings to the LTL services are responsible for the largest percent savings of all the limit alternatives. Conversely, the local and nonfreight activity, the sixth group, is significantly affected only by limit alternatives 5 and 6, which reduce and increase the truck capacities, respectively.

Figure 2.15 shows that the greatest single beneficiary in terms of percent improvement are the Exempt Carrier Services under alternative 6 followed by the Special Commodity Services also under alternative 6. These are truckload operations with high percentages of "weighted-out" movements, which benefit most from any increase in weight capacity limits as opposed to volume capacity limits. These reductions are reductions in motor carrier net operating revenues.

Continuing with the motor carrier management perspective, Figure 2.16 displays modal diversion effects on motor carrier gross revenues. Diversion of markets from rail to truck (or the reverse) translate into increased (or decreased) gross revenues for the motor carrier. These percentage changes are based upon the study assumption of 100 percent pass-through of the cost reductions shown on Figure 2.15. Note that motor carrier management does not equate a 1 percent increase in gross revenue with a 1

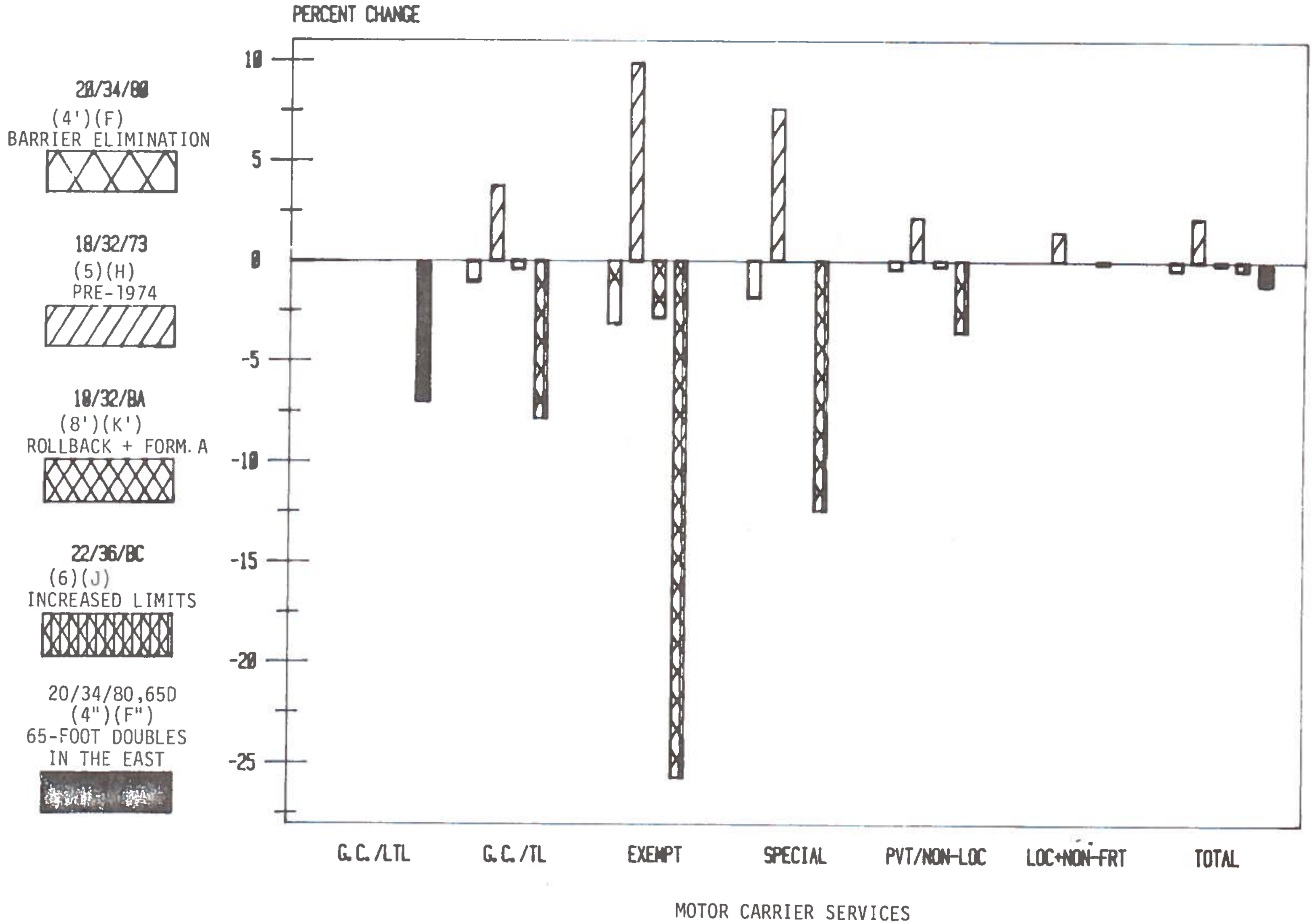

FIGURE 2.15 RELATIVE COST IMPACT ON CARRIER SERVICES
NO MODE SHIFT (TRUCK Δ ONLY)

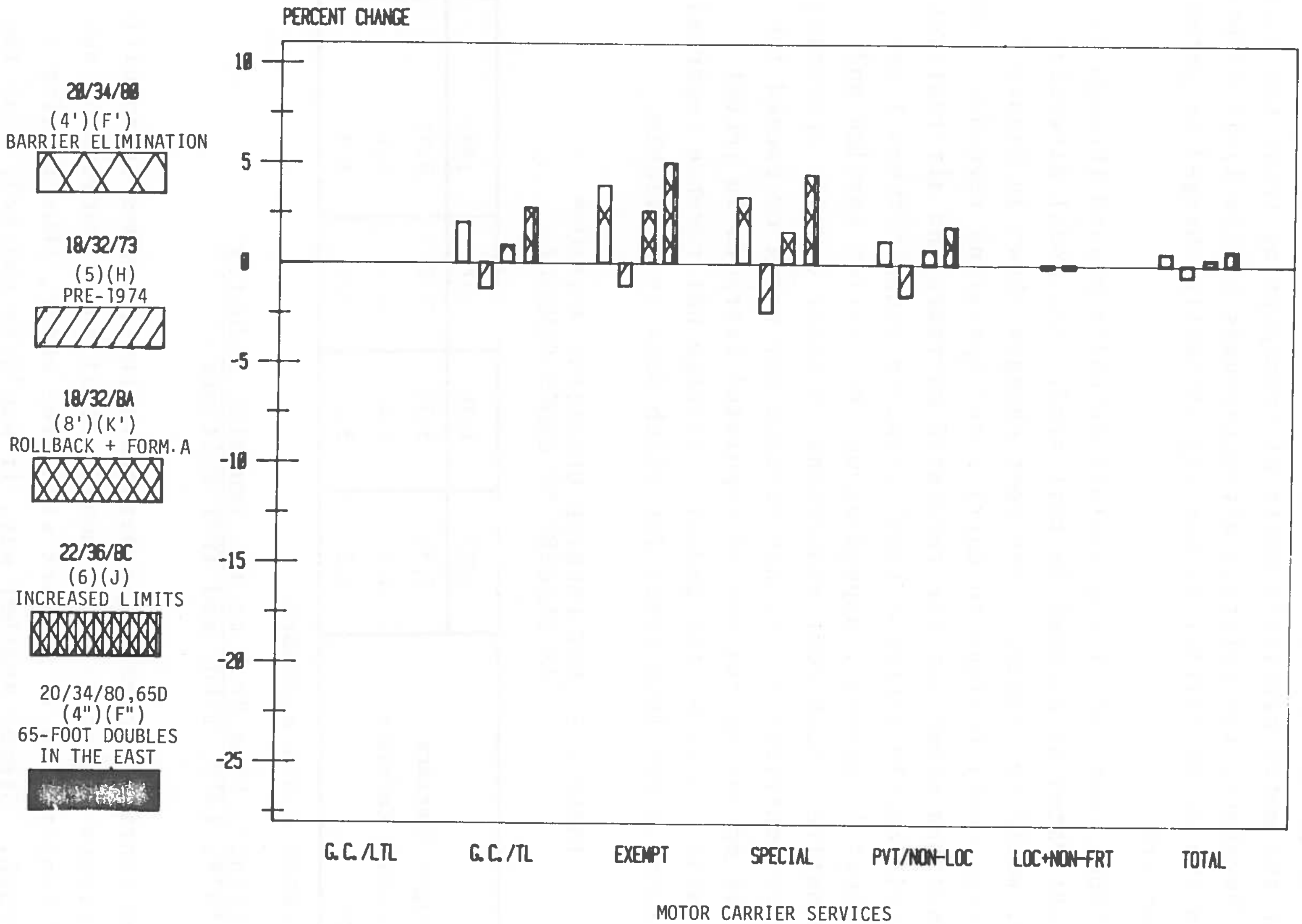

FIGURE 2.16 RELATIVE CARRIER REVENUE IMPACTS MODAL DIVERSION (TRUCK Δ ONLY)

percent reduction in operating costs. Therefore, to properly view from the carrier's perspective, the attractiveness of the modal diversion, the percent changes on Figure 2.16 must be discounted to allow for the motor carrier's costs of transporting these new shipments. Therefore, the relative attractiveness of the limit alternative to the motor carrier is not significantly changed by potential diversion.

If truck cost reductions are not actually passed through to the freight rates as assumed in this study, the modal diversion potential would be reduced. The cost changes shown in Figure 2.15 would become contributions to carrier net operating revenues. The cost reductions shown for the regulated carriers and alternatives which significantly increase truck capacity range between 1 percent to about 12 percent, depending on the carrier service and the alternative. Such cost reductions in motor carrier operating expenses or contributions to net revenue may equal or exceed the average net operating revenue of regulated carriers in recent years. Table 2.5 shows the industry average net revenue reported for the most recent four years for which data is available.

TABLE 2.5 NET CARRIER OPERATING REVENUE* AS PERCENT OF GROSS REVENUE

	1977	1978	1979	1980
General Freight Carriers	5.5%	5.3%	3.6%	4.3%
Special Commodity Carriers	4.5	4.8	4.2	4.1
All Carriers	5.1	5.1	3.8	4.2

*Gross revenue minus expenses.

Source: Trinc's Blue Book of the Trucking Industry 1978, 1979, 1980, and 1981 Editions.

Substantial increases in net operating revenues to specific carrier groups and/or markets should result in attraction of substantial competition in markets with free entry, thus forcing a pass-through. Stated another way, it would be unlikely that the cost changes would be retained internally as a contribution to net revenues unless new competition was effectively precluded by regulation.

To sum up, the transportation cost reductions reported in the study are estimated as changes to the system as a whole or the ultimate users of the services. The fundamental assumption is that competitive pressures will force the pass-through of the truck operating costs in all markets. In reality, 100 percent pass-through would probably occur in some markets, no pass-through at all would be observed in other markets and some portion of the cost savings would pass through in still others. Some users would experience the benefits of new TS&W limits and some motor carriers would increase their net operating revenue. Estimating the distribution of the benefits of new TS&W limits between the motor carriers and the customers they serve was beyond the resources of this project. To the extent that the cost savings are passed through them, the benefit to the motor carrier would be the amount of the savings from the new limits which are retained plus the net revenue increase from the diverted traffic. Alternative 4" (eliminating prohibition of Western Doubles in eastern states) is the only alternative without significant modal diversion.

It should be apparent from this review of limit alternatives that the greater the truck payload, the greater the truck productivity, and the greater the potential savings in transport cost. If pavement and bridge impacts are excluded from consideration, a combination of high axle load limits and the use of bridge formula gross weight limit, coupled with the use of multiple trailer combinations, offer the greatest truck productivity increases for a broad spectrum of markets. However, if pavement and bridge costs are to be minimized, then lower axle loads and use of Bridge Formula gross weight limits coupled with the use of multiple trailer combinations offer a compromise which may be more universally attractive.

2.3 CARRIER SERVICE SPEED IMPACTS

The change in door-to-door average shipment transit time or speed from the Status Quo Base Case is the only measure of service quality impact attempted in this study. No change in reliability of delivery time can be attributed to the specific limit alternatives considered, other than whatever improvement might attend large changes in average shipment transit time.

Changes in average shipment speed in this study are attributed to routing changes (i.e., more or less circuity between the origin and the destination of the shipments) to take advantage of higher limits or changes in terminal area delays, attributable to the use of multiple trailer configurations, or to shifts between the truck mode and the rail mode which have substantially different terminal area delays and somewhat different line-haul speeds. The weighted average percentage change in shipment speed for all traffic using each carrier service is shown in Figure 2.17, without consideration for modal diversion. Limit alternatives 8', 6, and 4" show substantial percentage change in speed. Study scenarios 2, 2A, 2B, 2C, 3, 4', and 5 have either insignificant or no change in speed. Figure 2.17 shows alternative 8' has an impact essentially equal to alternative 6 and that the percent change in average shipment speed for the national aggregate of all truck services is hardly measurable for all limit alternatives except 8', 6, and 4". Appendix Tables D-9, D-10 and D-11 list ton-mile, ton-day and average speeds for truck and rail services for all study scenarios that are in the Final Report.

The reduction in terminal area delays (which are significant) for General Commodity LTL traffic, attributed to the universal availability of Western Doubles, is evident in the 35 percent increase in shipping speed. This is the only service showing substantial improvement in shipping speed attributable to the alternative limits.

The Exempt and Special Commodity services and Private Truck (which have very little terminal time) reduce their respective average speeds between 6 percent and 15 percent in alternatives 8' and 6. This reduction is the result of substituting tandem-axle, 27-foot, twin trailer and equivalent truck trailer configurations for the conventional semi-trailer combination used in the Base Case. The Doubles combinations provide reduced line-haul costs which are attractive, but they incur delays at each end of the trip to assemble

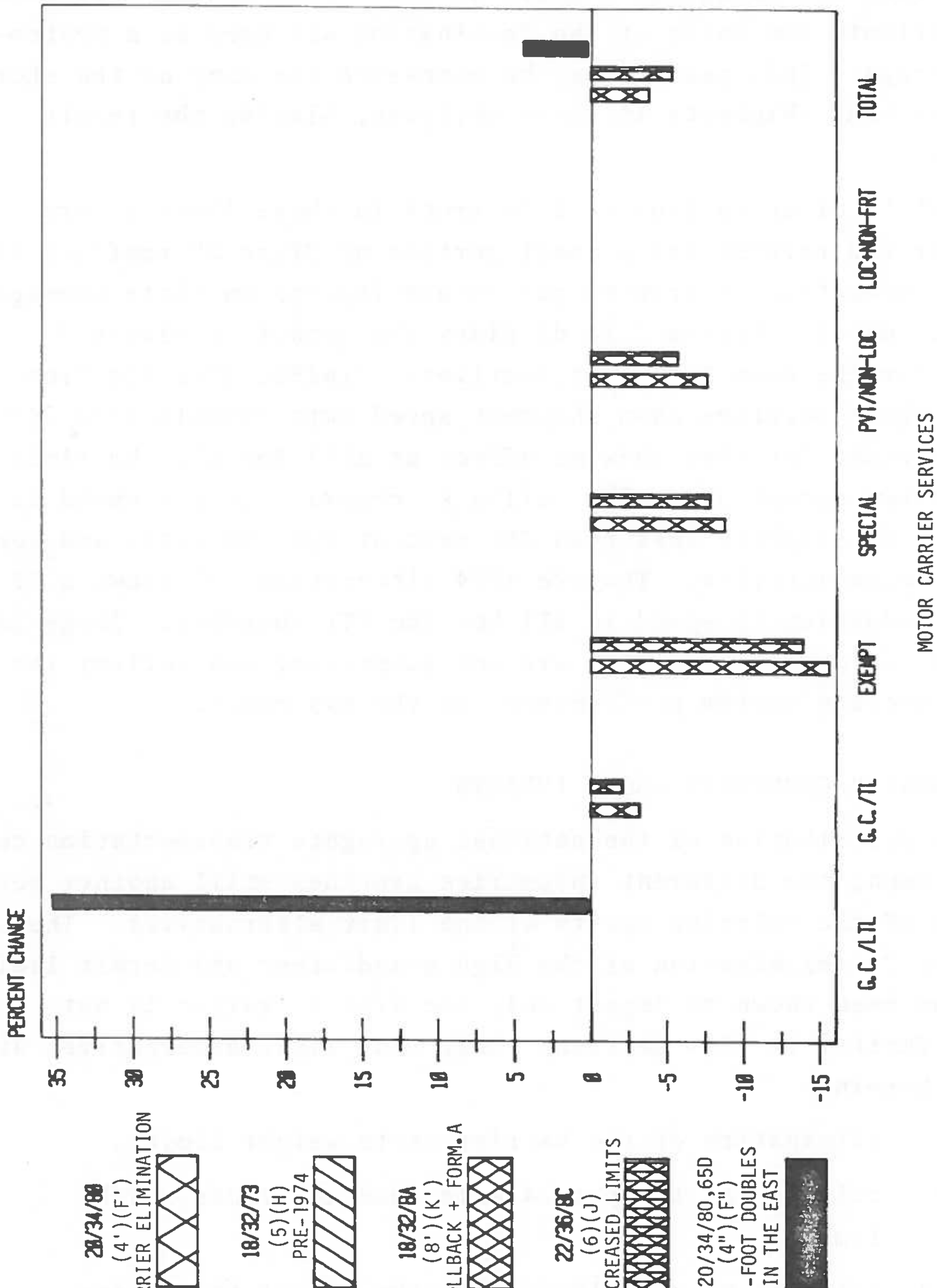

FIGURE 2.17 RELATIVE SHIPMENT SPEED IMPACTS
NO MODE SHIFT (TRUCK Δ ONLY)

or disassemble the Doubles combinations. A penalty of about one hour at each end to assemble units at the origin and to disassemble and distribute the units at the destination was used as a system-wide average. This penalty may be excessive for many of the short to medium haul shipments in these services, biasing the result somewhat.

Traffic diverted from rail to truck in these limit alternatives (or the reverse for a small portion of "Type 2" traffic) experience dramatically greater percentage impacts on their average shipment speeds. Figure 2.18 displays the impact on diverted traffic for the same limit alternatives. Traffic diverted from rail to truck services show shipment speed improvements from 260 to 290 percent (or they show no effect at all) for all the limit alternatives except one. The rollback scenario shows a speed improvement of slightly less than 200 percent for the local and non-freight truck activity. The pre-1974 alternative (5) shows a 75 percent reduction in speed in all but the LTL services. These impacts on the diverted traffic are not surprising and reflect the current average system performances of the two modes.

2.4 INDUSTRY/COMMODITY GROUP IMPACTS

The distribution of the national aggregate transportation cost impacts among the different industries provides still another perspective of the relative merits of the limit alternatives. The alternative 2A (elimination of the high grandfather and permit limits) which has been shown to impact only the Type 2 traffic is not treated further in this section. Only four limit alternatives are treated herein:

- (4') elimination of the barrier state weight limits,
- (5) rollback to the pre-74 axle load and gross weight limits,
- (8') rollback of axle loads with the use of the Bridge Formula 'A', and
- (6) increasing axle loads and weight limits with the Bridge Formula 'C.'

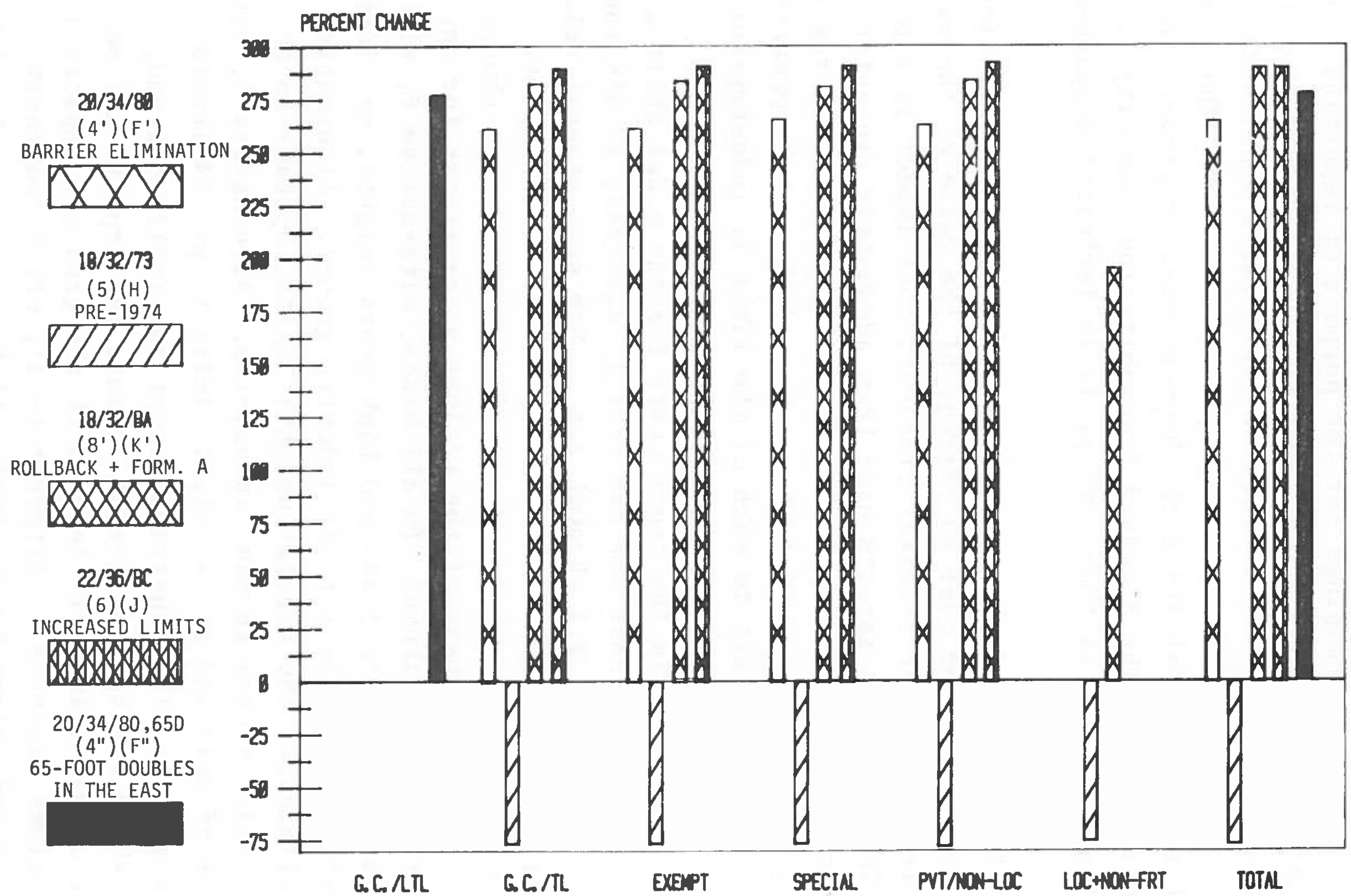

FIGURE 2.18 RELATIVE SHIPMENT SPEED IMPACTS
DIVERTED TRAFFIC (TRUCK & RAIL Δ)

No further disaggregation of "Type 2" traffic has been developed, but Type 3 traffic has been disaggregated into 13 all inclusive, commodity groupings for the purpose of reporting national aggregate impacts. Table 2.6 lists the 13 groups and gives the code number used on the subsequent plots and a short title of each group. It also provides the projected 1985 Status Quo Base Case truck transport cost for each shipper/receiver group. The complete description and the Standard Transportation Commodity Code (STCC) context of each of these groups is in Technical Supplement Volume 4.

About 85 percent of the total Type 3 traffic is represented in the first 12 groups, and over 98 percent of the value of the national aggregate shipper/receiver transport cost impact is experienced by them. The LTL group impacts have been adequately presented in the previous section and are not treated here. Therefore, Figures 2.19 through 2.22 display the '77 dollar value of the net shipper/receiver transportation cost impact to each of the first 11 industry/commodity groups. The net cost impact includes the changes from truck use shifts, the change in the truck costs for the modal shift and the change in the rail cost for the traffic diverted, as did the regional plots (Figures 2.1 through 2.6). The same general relationships appear among the alternatives in both sets of plots where the modal shift impacts are significant but do not change the relative attractiveness of the various alternatives for any of the interest groups shown. In all cases, alternative 6, with its uniformally high axle loads and high gross weights, provides the greatest cost savings for all industry groups. Alternative 4', which eliminates the barrier weights limits, appears to be a matter of indifference to many industries. Alternative 5, with its rollback of axle and gross weight limits to pre-74 levels, increases costs for all industries except two (mill work and, machinery) which may be indifferent because the impacts are so small. The chemical industry leads with the greatest impacts in all alternatives except 8'. Alternative 8', which compensates for axle load reductions by permitting higher gross weight with more axles through the use of Bridge Formula A for gross weight, displays

TABLE 2.6 BASE CASE TRUCK TRANSPORT COST BY INDUSTRY/COMMODITY GROUPS (TYPE 3 TRAFFIC ONLY)

TSC CODE	SHORT TITLE	MILLIONS 1977 DOLLARS
12	Millwork	473
20	Food Products	3,814
24	Lumber Products	2,148
26	Paper Products	989
28	Chemicals	4,615
32	Stone, Clay and Glass	3,280
33	Primary Metals	2,451
34	Fabricated Metals	583
35	Machinery	695
B-1	Grain	2,366
B-2	Fruit & Vegetables	2,041
LTL	Less-Than-Truck Load Shipments	23,144
Other*	All Industries Not Included Above	10,658
Total	Type 3 Traffic	57,259

*This category includes about 15% of the total Type 3 traffic and experiences less than 2% of the impact for any of the alternative limit scenarios.

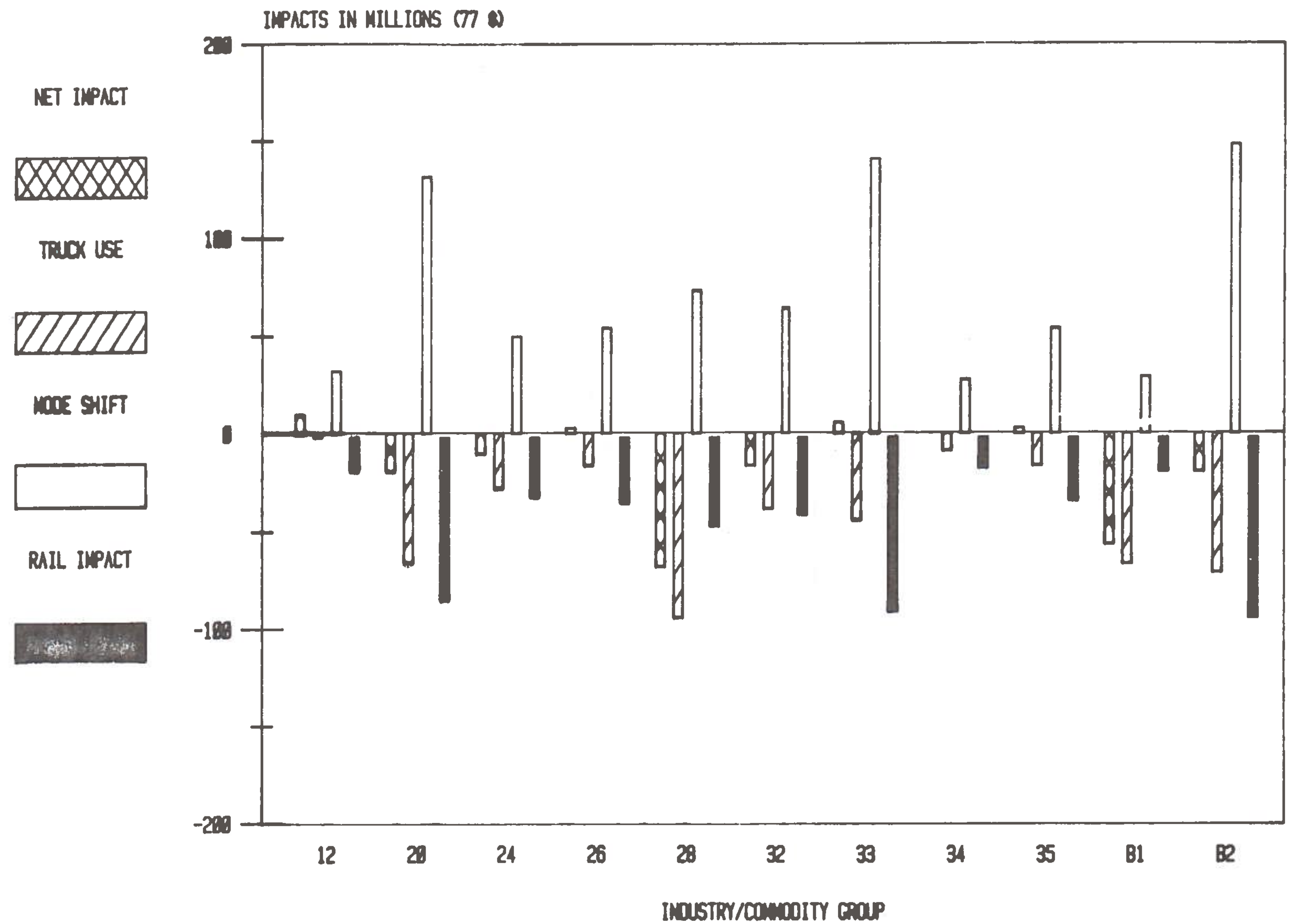

FIGURE 2.19 INDUSTRY/COMMODITY GROUP COST IMPACT (TRUCK & RAIL Δ) (4') ELIMINATING BARRIER STATE WEIGHT LIMITS

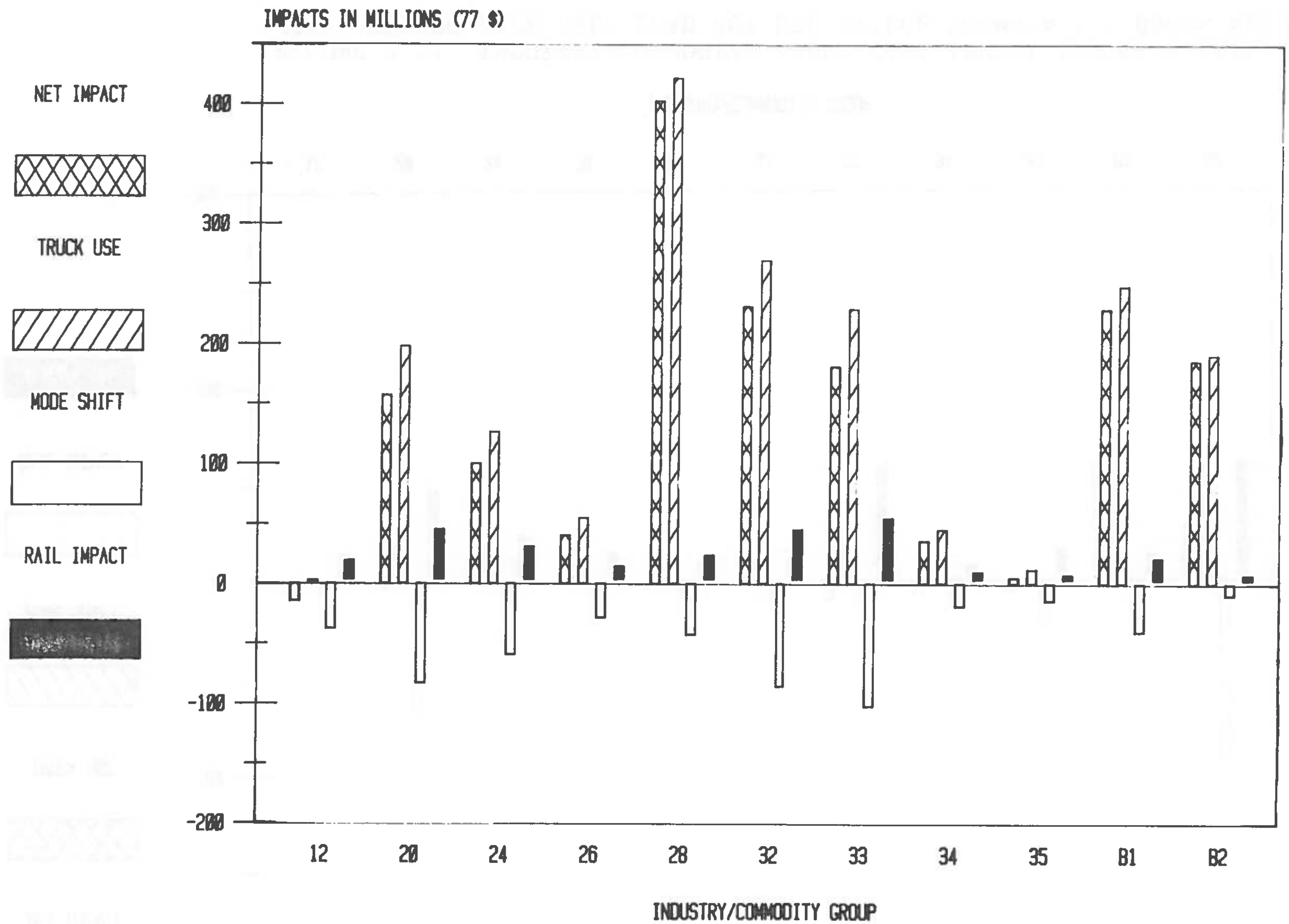

FIGURE 2.20 INDUSTRY/COMMODITY GROUP COST IMPACT (TRUCK & RAIL Δ)
(5) ROLLING BACK AXLE LOAD AND GROSS WEIGHT LIMITS

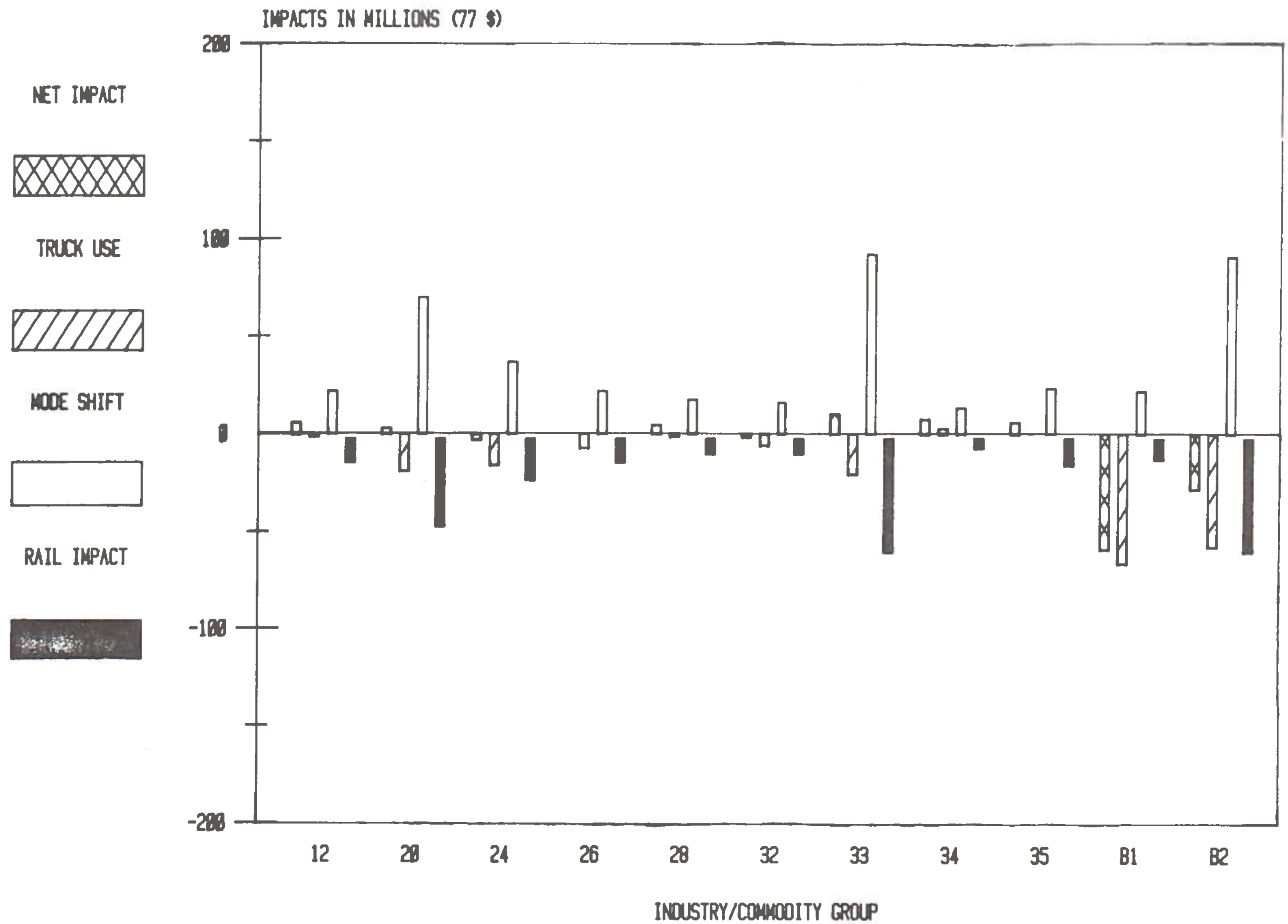

FIGURE 2.21 INDUSTRY/COMMODITY GROUP COST IMPACT (TRUCK & RAIL Δ) (8') ROLLING BACK AXLE LOAD BUT USE BRIDGE FORMULA 'A' GROSS WEIGHT

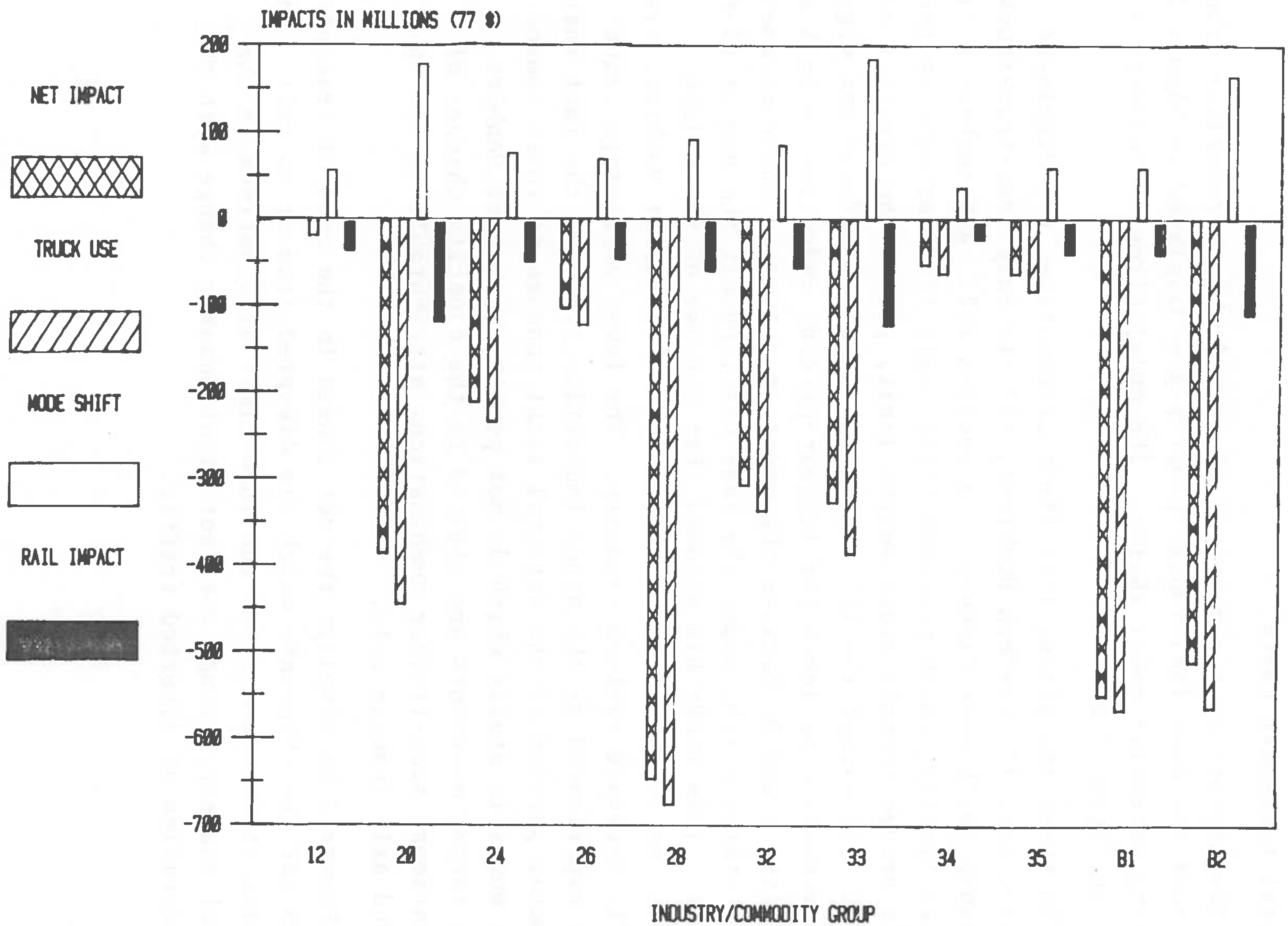

FIGURE 2.22 INDUSTRY/COMMODITY GROUP COST IMPACT (TRUCK & RAIL Δ)
(6) INCREASING AXLE LOAD AND USE BRIDGE FORMULA 'C' GROSS WEIGHT

the least impact of all these scenarios, with only grain and fresh fruit and vegetable movements showing significant net reductions in total transport costs.

The impacts as a percent of the total shipper/receiver transport cost for each individual industry are displayed in Figure 2.23, ignoring potential modal shifts. The modal diversion effects are shown in Figure 2.24.

In these two plots, five limit alternatives are displayed but the last one, 4" (Eastern Doubles), effects only less-than-truckload shipments which were discussed in section 2.2. Alternative 6 (increased limits), which provides higher axle loads as well as the use of the Bridge Formula gross weight limit, yields the greatest savings for all except the LTL shipments. Grain and fruit and vegetable movements experience the largest percent reduction in both alternatives 6 and 8' because the greatest volume of their movements are in states which, under the Base Case, permit the use of 65-foot Doubles. This study has assumed that the use of the Bridge Formula for gross weight, within states that permit Doubles, will greatly increase payload capacity. The lower percentage reductions experienced by the other industries reflects the fact that a greater portion of the national total tonnage of these commodities moves in states which do not permit the use of Doubles. These latter movements are limited to the capacity changes of conventional semi-trailer combinations attributable to the increased axle loading only.

Figure 2.24 displays the net change in the cost of transportation for the shipments which are diverted from or to rail. The relative attractiveness of the TS&W limit alternatives to the several industry groups does not significantly change with the consideration of diverted traffic.

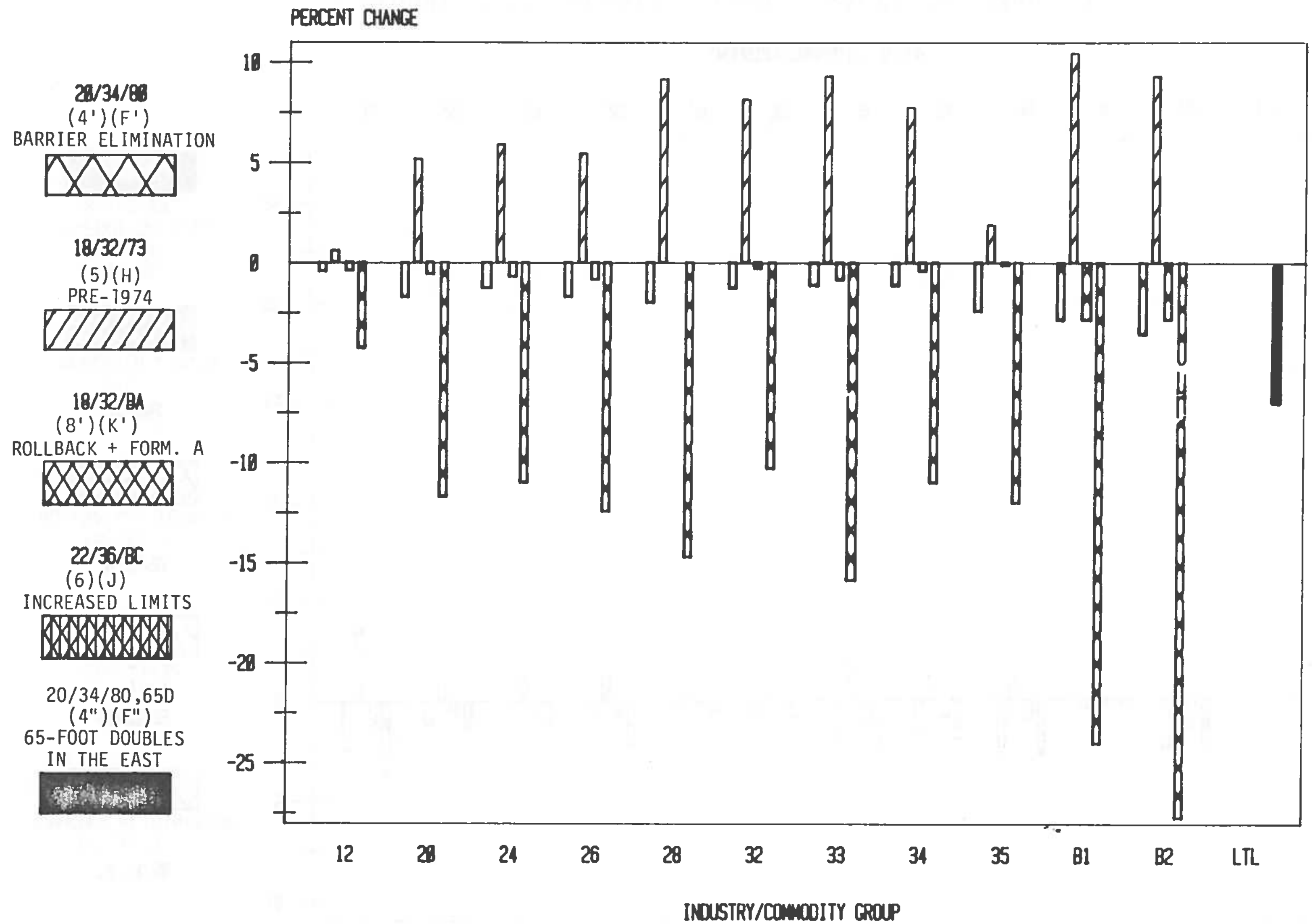

FIGURE 2.23 RELATIVE COST IMPACTS ON INDUSTRIES
NO MODE SHIFT (TRUCK Δ ONLY)

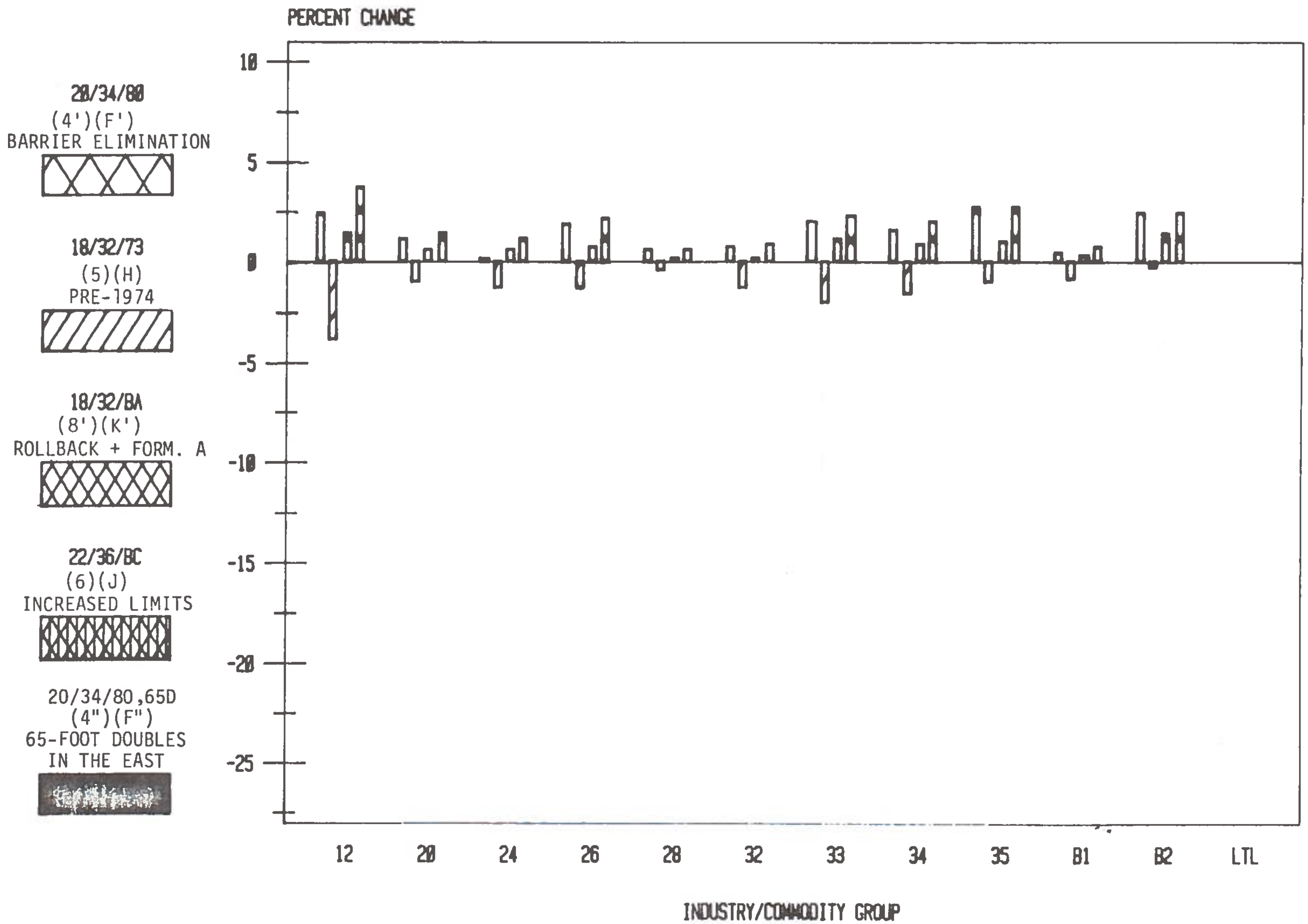

FIGURE 2.24 RELATIVE COST IMPACTS ON INDUSTRIES MODAL DIVERSIONS (TRUCK & RAIL Δ)

3. TRANSPORTATION DIRECT FUEL

This section examines the distribution of national aggregate fuel consumption impacts among geographical regions. No attempt has been made to disaggregate national aggregate fuel impacts among carrier services or industry groups or to develop regional level indirect energy impacts. Energy embedded in transportation rolling stock and materials and equipment in fixed facilities should be properly allocated to the regions which were the original sources of supply. The input/output models which were the basic sources for the national level indirect energy impacts given in the Final Report are much too crude to permit regional disaggregations.

Direct fuel consumption has been allocated to the region in which the truck miles were generated on the assumption that most of the fuel is consumed in the same region in which it is purchased. Obviously, this is not entirely accurate. Long haul traffic which travels through two or more regions on a regular basis could burn fuel in one region that was obtained in another. This assumption should not cause significant distortions in the regional distributions shown here because the regions tend to be large with respect to the average fuel range of the trucks involved. Unless there is a substantial price differential or supply difference among adjacent regions, the errors should tend to compensate.

The fuel conservation potential of alternative limits is probably best viewed at a regional level. The transportation fuel impacts are presented here in terms of the absolute value of the gallons consumed, providing there is no distinction between diesel or gasoline. However, diesel powered vehicles and gasoline powered vehicles were segregated in the analysis, and the impacts on each fuel type are tabulated in Table D-1 for each scenario.

The study regions are defined in Figure 2.0, and the selected limit alternatives are defined in Table 2.1. The effect of potential modal shifts has also been isolated here from the effects of truck use shifts in all cases. The fuel impacts of the modal diversions are the algebraic sum of increases in fuel for the mode receiving the diverted traffic and the decreases in fuel for the mode losing the diverted traffic. Table 3.1 shows the national aggregate fuel impact of the limit alternatives and Table 3.2 shows the 1985 Status Quo Base Case regional fuel consumption for all truck activity.

Figures 3.1 through 3.6 display the impacts in gallons of fuel for each region for each of the six limit alternatives. A scan of these plots shows that the impacts are far from uniformly distributed among the regions in each alternative. In fact, the signs of the impacts are reversed for some regions in alternative 8' (Rollback + Formula A) where large decreases in the Barrier regions are offset by increases in the other regions. In general, the pattern is very predictable with the alternatives which reduce limits resulting in increased fuel and alternatives which increase limits resulting in decreased fuel.

The Barrier states which are already at the lower limits experienced very little change in the alternatives 2A (Grandfather Elimination) and 5 (Pre-1974), but in alternative 8' where the tandem-axle Doubles are encouraged by the use of the Bridge Formula limits, the Midwestern Barrier region shows the greatest decrease in fuel consumption. The eastern and western regions show increases in fuel consumption for all these alternatives which reduce limits (i.e., 2A, 5, and 8'). The Midwestern Barrier region is the greatest beneficiary of the alternative 4' which eliminates the barrier limits. It is also the greatest beneficiary in alternative 6 which increases axle loads and gross weight. Surprisingly, the Midwestern Barrier region is also the largest beneficiary of alternative 4" which permits Western Doubles operations in the eastern states. As expected regions 1, 3, 4 and 5 reduced their fuel consumption, but only about half as much as region 6.

TABLE 3.1 1985 NATIONAL AGGREGATE TRANSPORT FUEL CONSUMPTION IMPACTS (Millions of Gallons, Diesel Plus Gasoline)

STUDY CODE	2A	4'	5	8'	6	4"
FINAL REPORT CODE	C	F	H	K	J	F
SHORT TITLE	(Grand-father Elimina-tion)	(Barrier Elimina-tion)	(Pre-1974)	(Roll-back + Form A)	Increased Limits)	65-Ft. Doubles in East
NET IMPACT	+99	-102	+413	+22	-437	-189
TRUCK USE IMPACT*	+104	-151	+450	+5	-499	-189
MODE SHIFT IMPACT	-24	+174	-126	+76	+228	0
RAIL LOSS (GAIN) IMPACT	+19	-125	+89	-59	-166	0

*For all trucks greater than 10,000 lbs registered gross vehicle weight.

Source: Appendix Tables D-1 and D-8.

TABLE 3.2 1985 BASE CASE TRUCK TRANSPORT FUEL BY REGION

Region	Millions of Gallons
U.S. Total	22,094
1 Northeast	3,867
3 Southeast	3,683
4 Mideast	2,459
5 Southern Barrier	712
6 Midwestern Barrier	3,208
7 North Central	1,337
8 West Central	1,560
9 Southwest	4,216
10 Northwest	1,011
11 Alaska	22
12 Hawaii	19

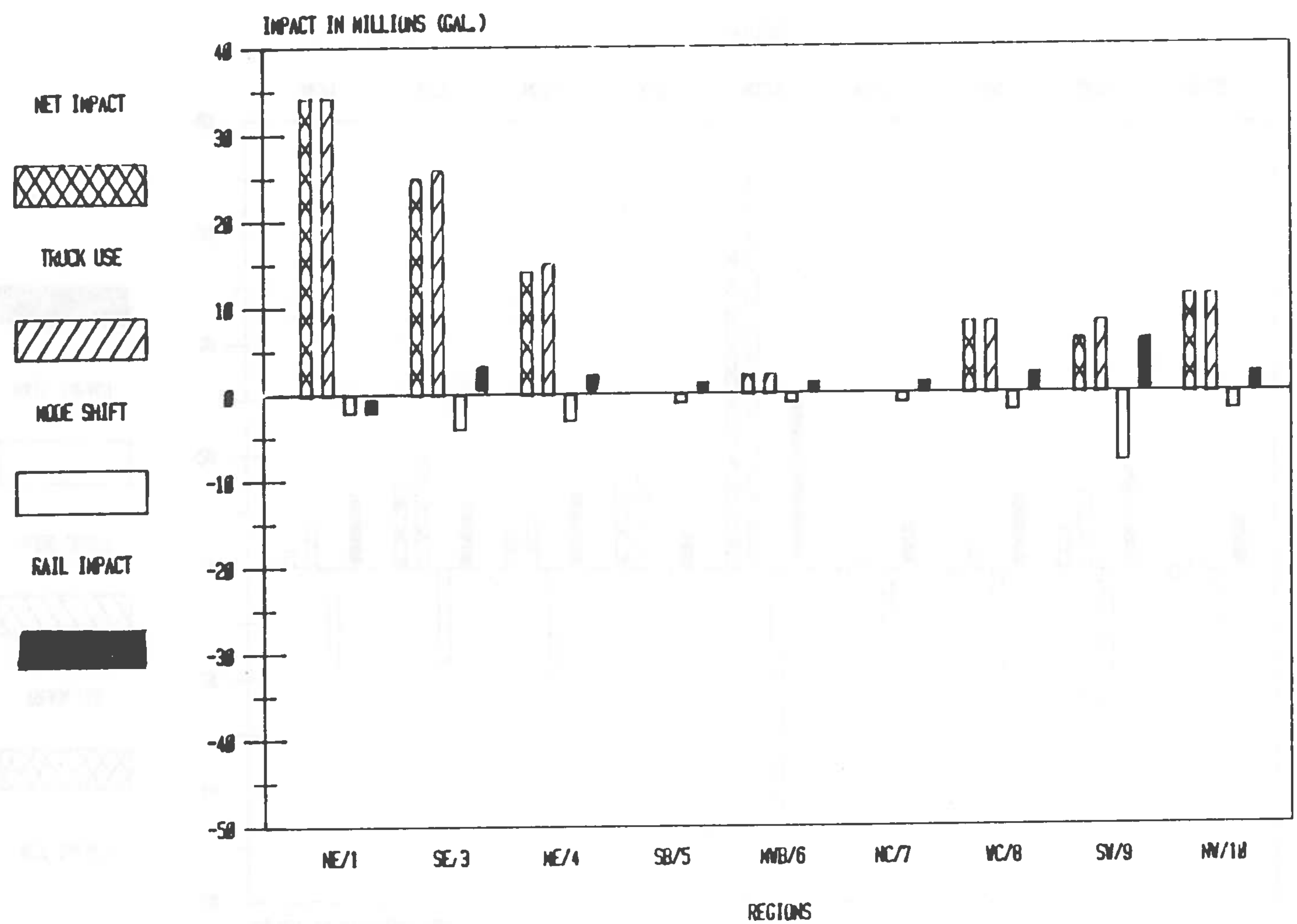

FIGURE 3.1 SYSTEM FUEL IMPACT BY REGION (TRUCK & RAIL Δ)
(2A) ELIMINATING HIGH GRANDFATHER AND PERMIT LIMITS

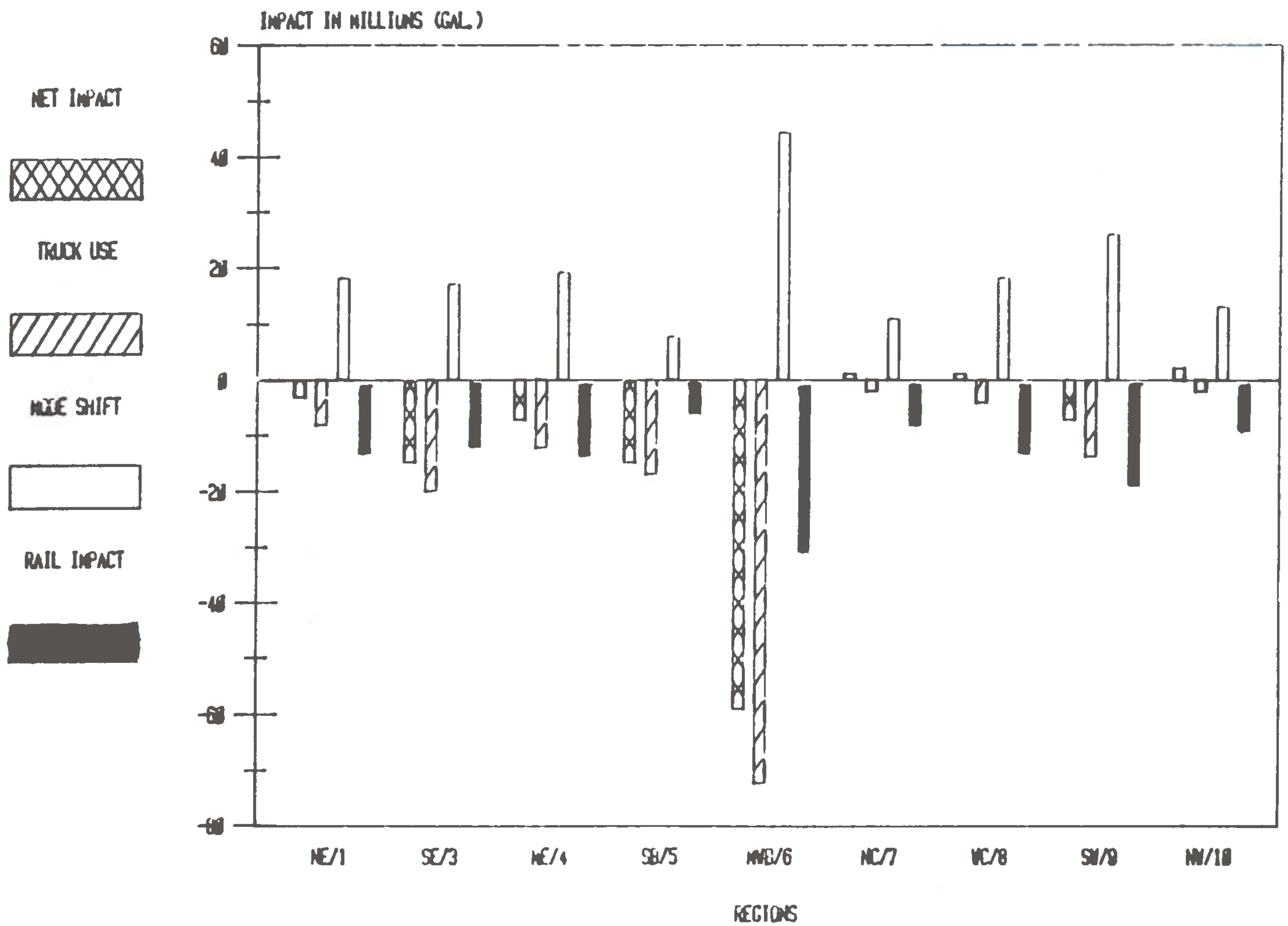

FIGURE 3.2 SYSTEM FUEL IMPACT BY REGION (TRUCK & RAIL Δ) (4') ELIMINATING BARRIER STATE WEIGHT LIMITS

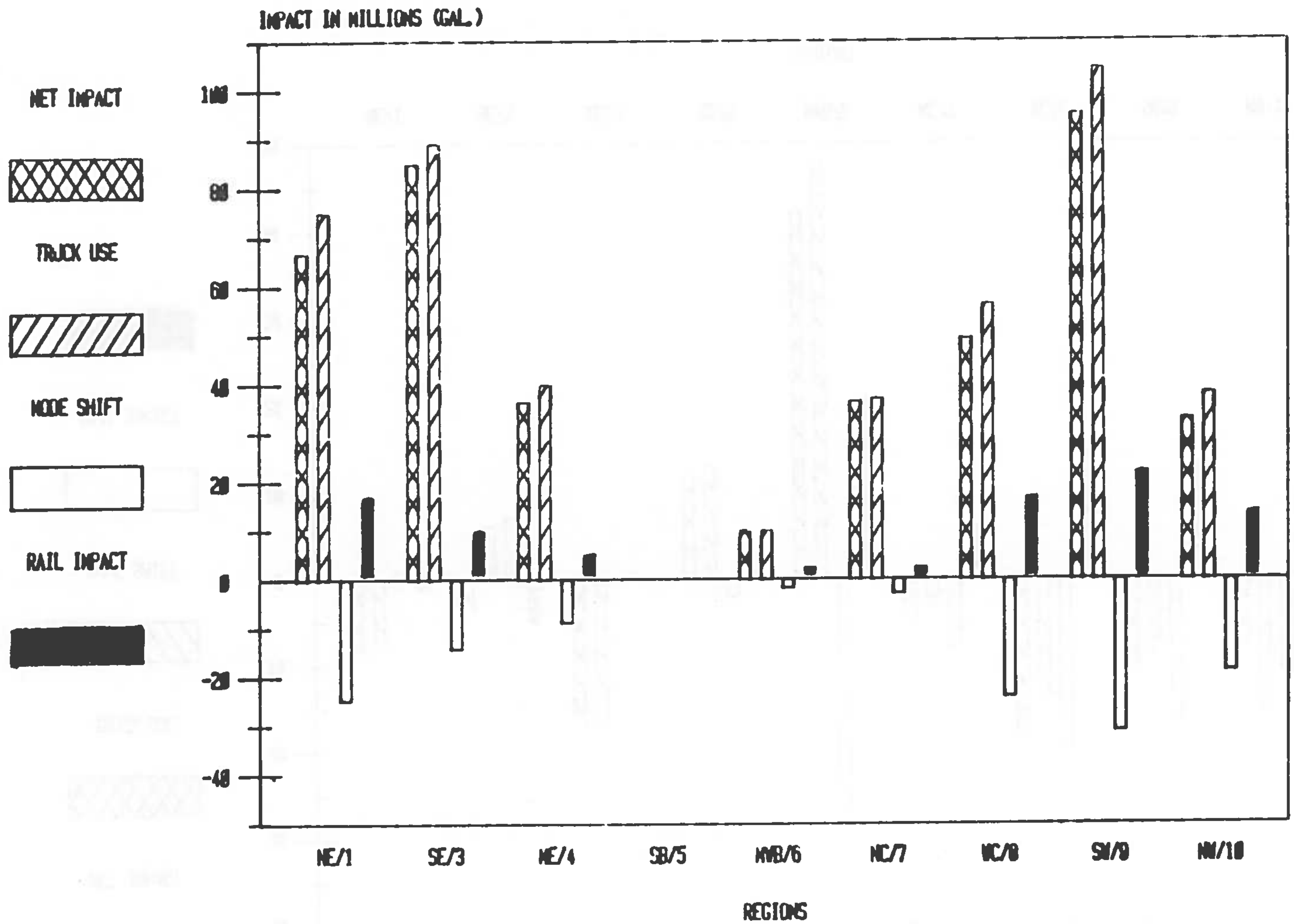

FIGURE 3.3 SYSTEM FUEL IMPACT BY REGION (TRUCK & RAIL Δ)
(5) ROLLING BACK AXLE LOAD AND GROSS WEIGHT LIMITS

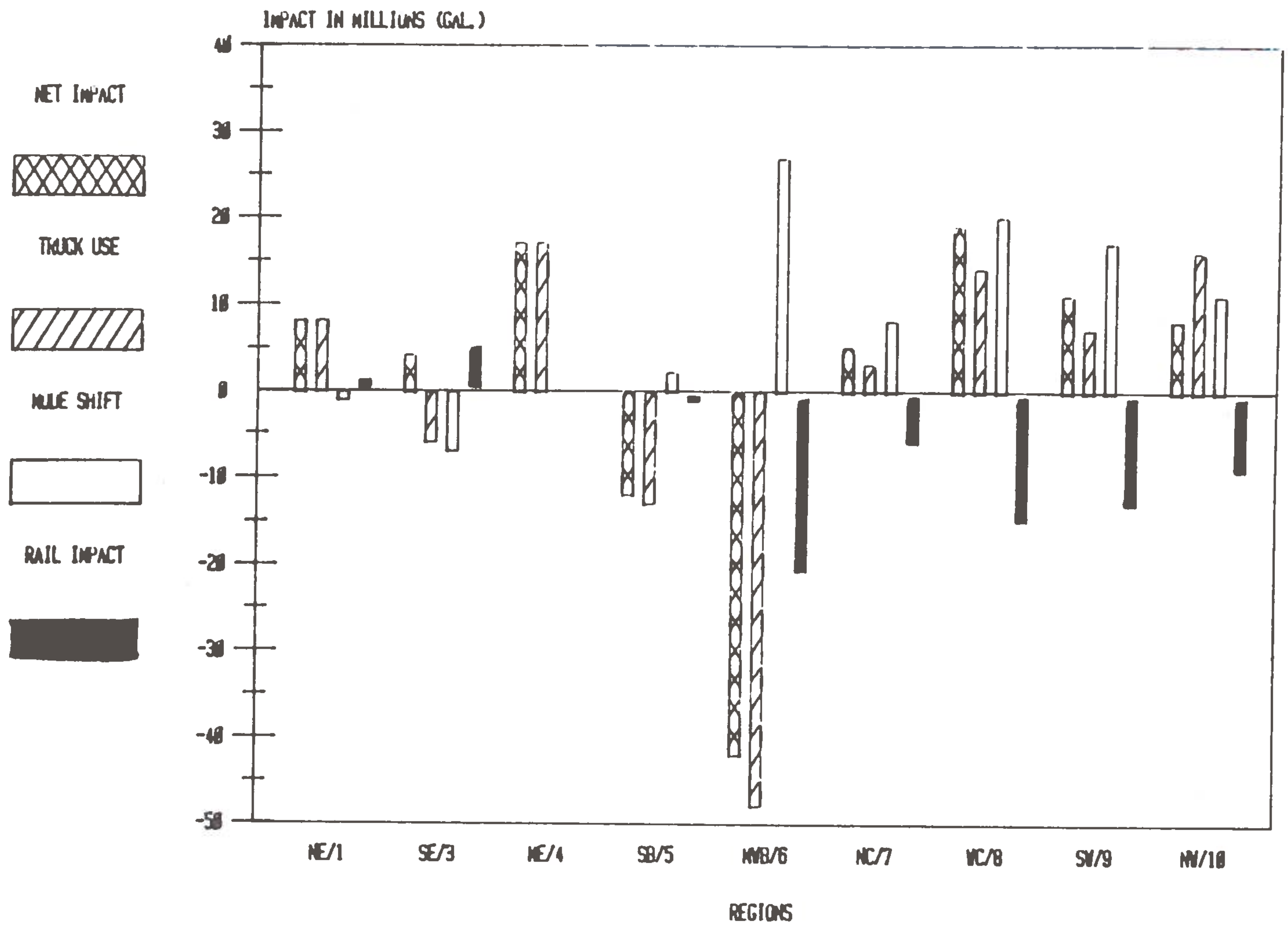

FIGURE 3.4 SYSTEM FUEL IMPACT BY REGION (TRUCK & RAIL Δ)
(8') ROLLING BACK AXLE LOAD BUT USE BRIDGE FORMULA 'A' GROSS WEIGHT

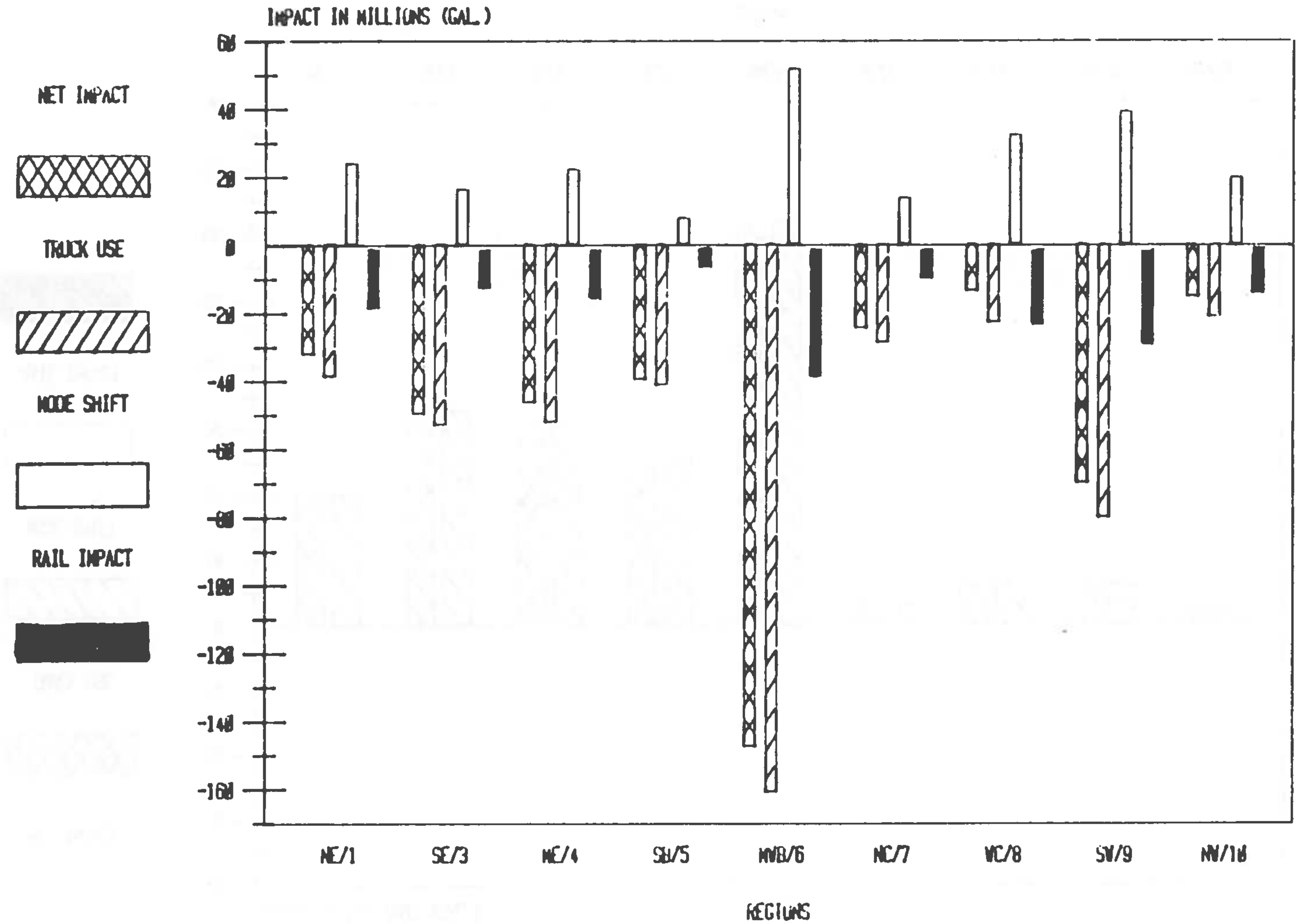

FIGURE 3.5 SYSTEM FUEL IMPACT BY REGION (TRUCKS & RAIL Δ)
(6) INCREASING AXLE LOAD AND USE BRIDGE FORMULA 'C' GROSS WEIGHT

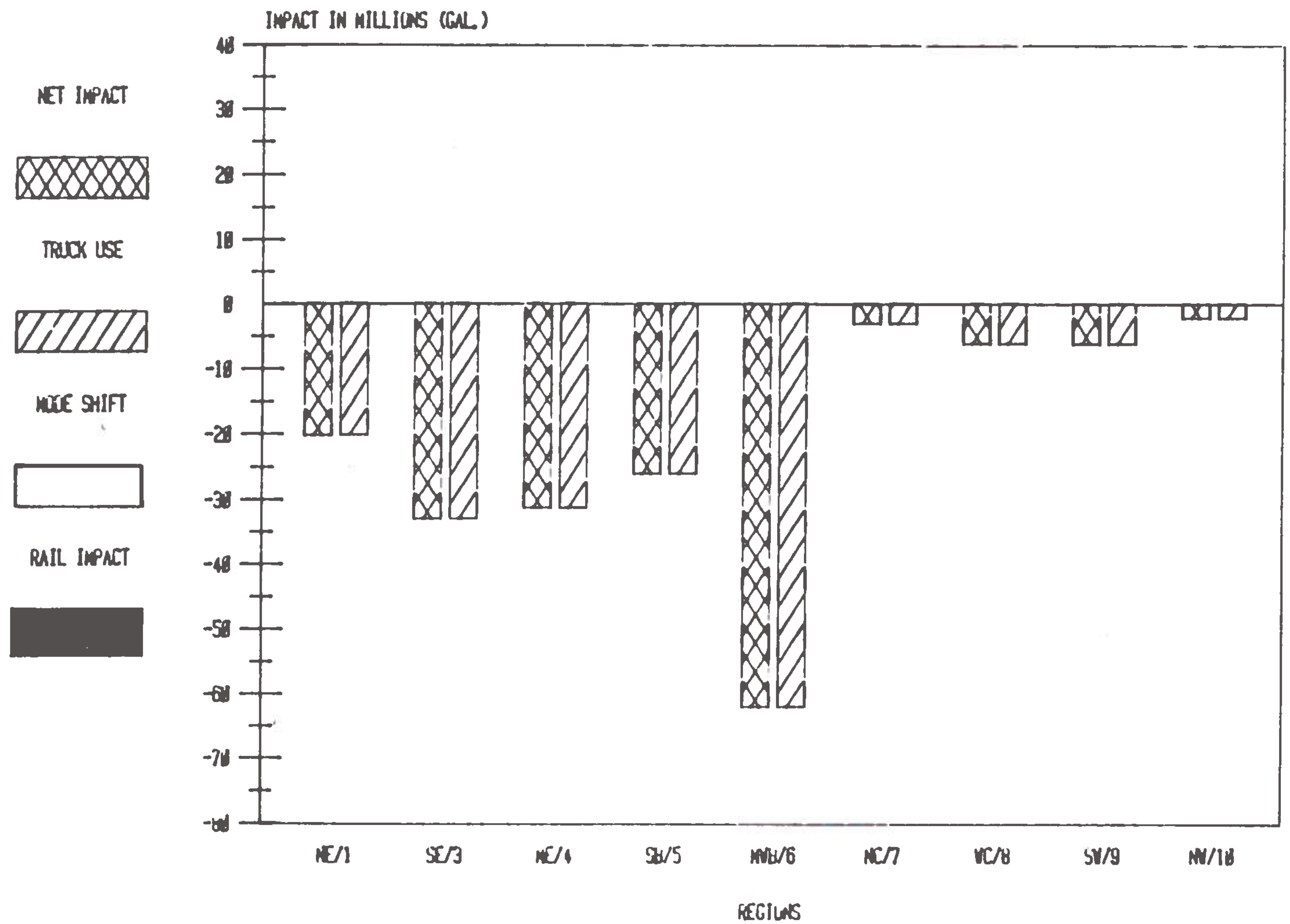

FIGURE 3.6 SYSTEM FUEL IMPACT BY REGION (TRUCK & RAIL Δ)
(4") ELIMINATING EASTERN STATES PROHIBITION OF SHORT DOUBLES

The net modal shift effect on total fuel in each region is small. Here, as in the cost comparison, the shift in modes may be of concern to some interests, but the net effect on the aggregate for the region is not sufficient to change the relative conservation attractiveness of the limit alternatives.

Decreasing axle load and gross weight limit obviously increases fuel consumption in all regions affected. However, use of the Bridge Formula to establish gross weight while at the same time decreasing axle loads reduces this adverse effect substantially as Figure 3.7 shows. The impact in terms of percent of regional total fuel for truck freight transport is not great. Elimination of the high grandfather limits increases the fuel consumption in each region less than 1 percent except in the northwest region in which the impact is slightly greater than 1 percent. Rolling back the axle load and gross weight limits to the pre- 74 Federal maximum increases fuel consumption in those regions affected by 2 percent to 4 percent. Rolling back the axle load limits, while using the Bridge Formula 'A' to determine gross weight limit, reduces the increase to a maximum of 1.6 percent and reduces fuel in several regions as much as 1.8 percent. Figure 3.8 shows that the net potential modal shift effects are negligible.

Increasing axle load and gross weight limits decreases fuel consumption. Figure 3.9 shows that the reductions are greatest for those alternatives and in those regions which increase truck capacity the most. The reductions range from 1 percent to 2 percent for all regions except the Barrier States regions, even for the alternative with the largest truck capacity increases. In the Barrier States where the truck capacity increase is greatest (about 14 percent), the decrease in fuel consumption is between 5.0 and 5.8 percent. The modal shift net fuel increase is again extremely small, as shown in Figure 3.10. There is no mode shift for limit alternative 4" which eliminates the prohibitions against the use of Western Doubles in the eastern states. The net effect of modal shift on the regional fuel for freight transportation is to increase it by considerably less than 1 percent.

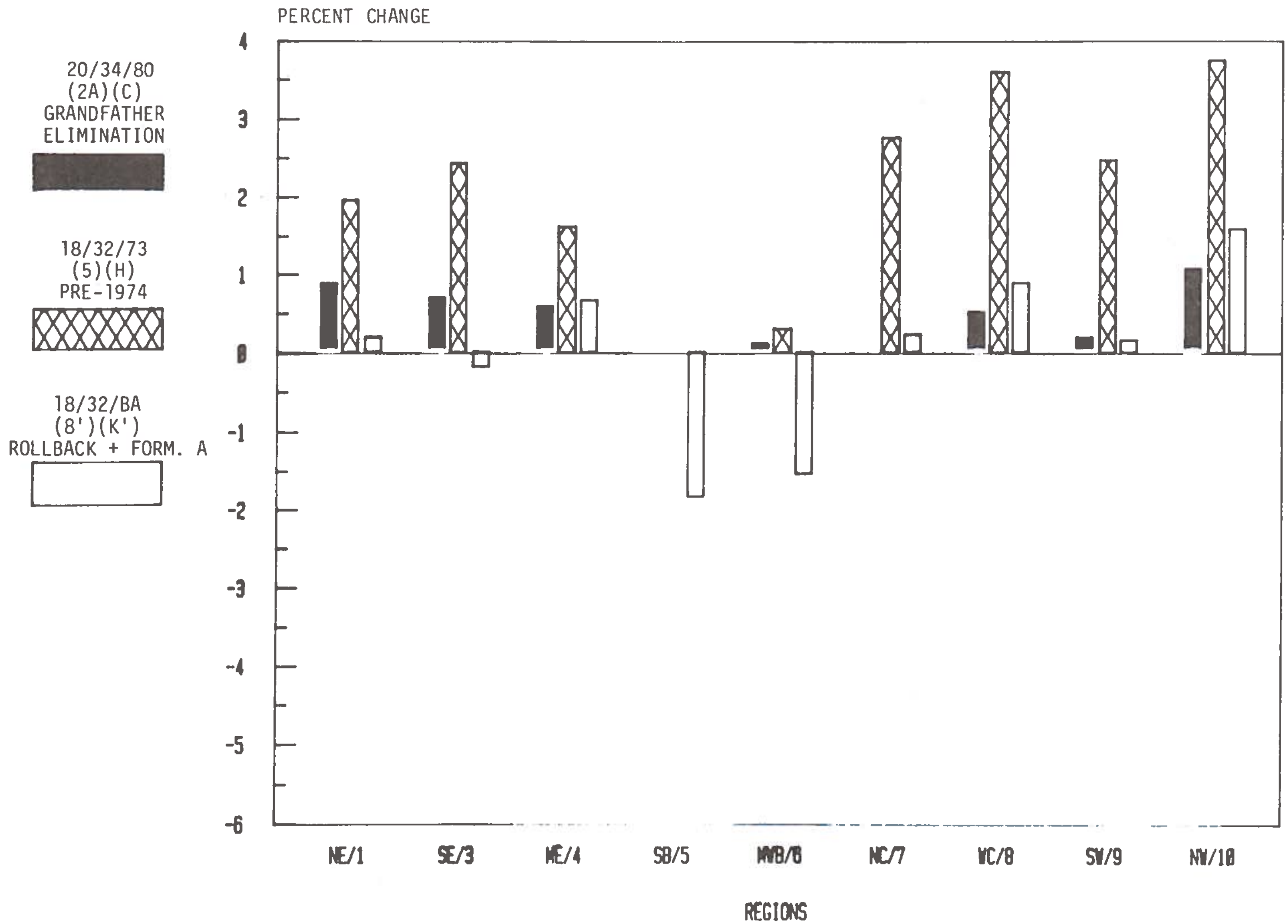

FIGURE 3.7 RELATIVE FUEL IMPACTS ON REGIONS - DECREASING LIMITS
NO MODE SHIFT (TRUCK Δ ONLY)

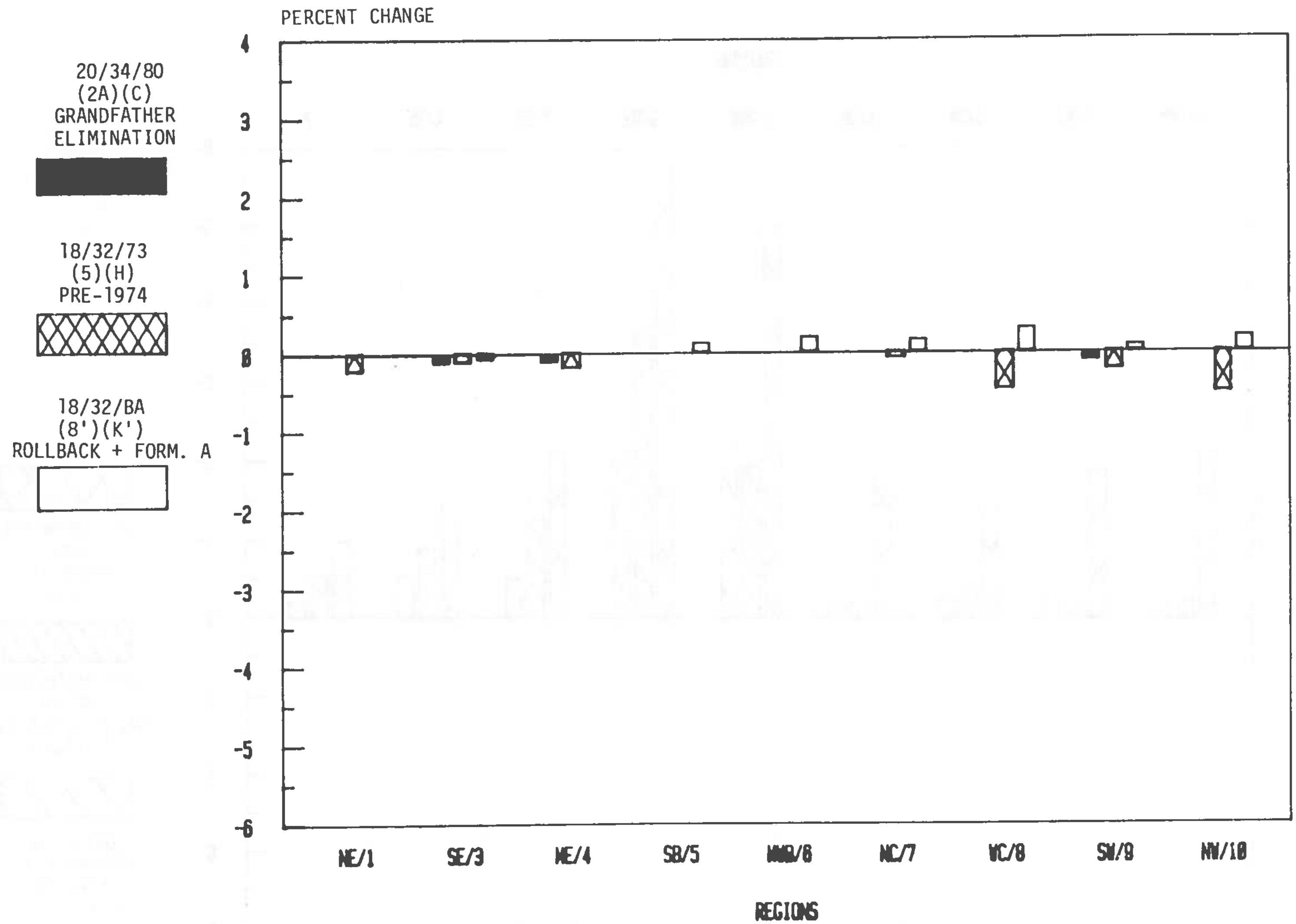

FIGURE 3.8 RELATIVE FUEL IMPACTS ON REGIONS - DECREASING LIMITS MODAL DIVERSIONS (TRUCK & RAIL Δ)

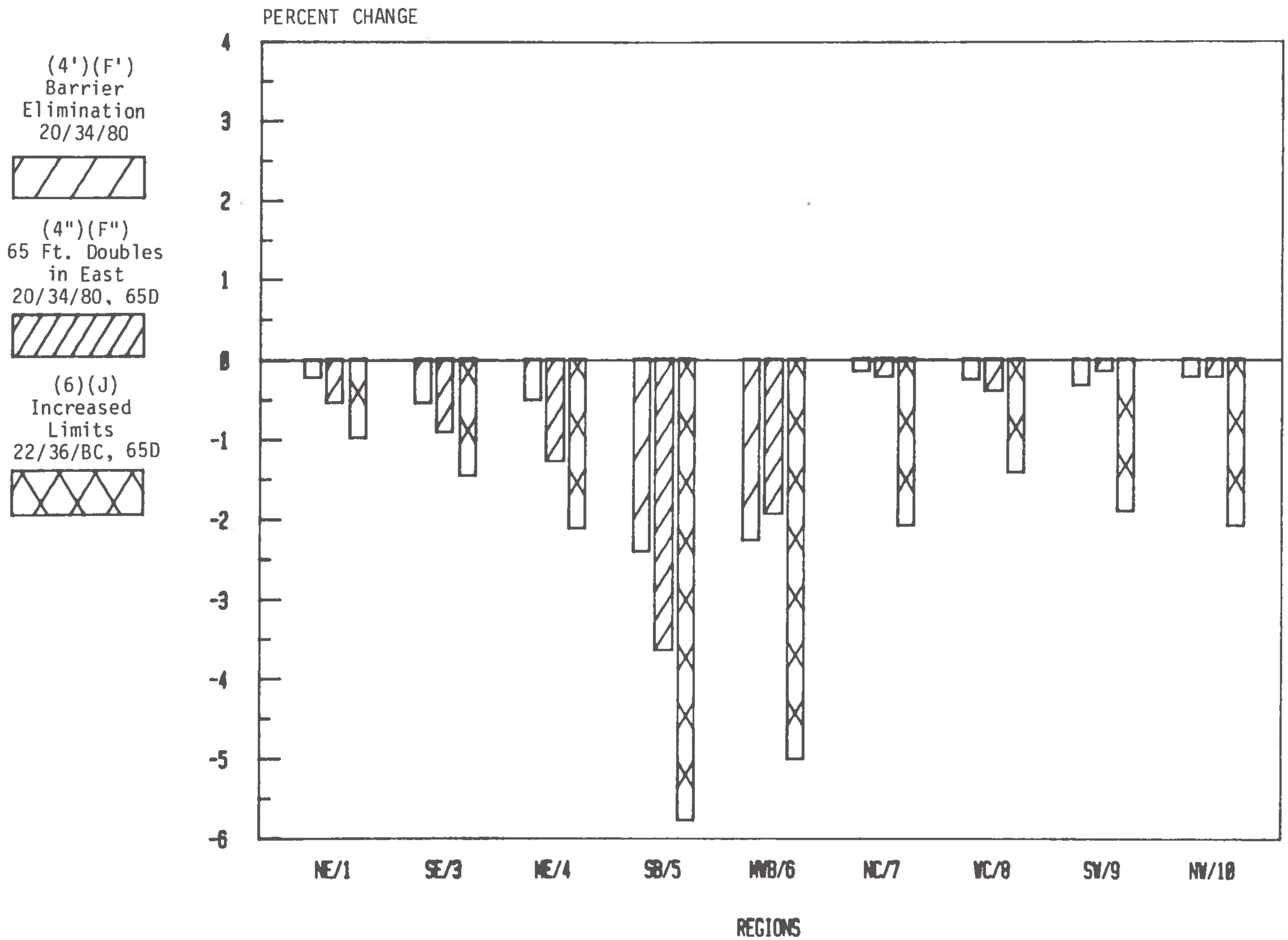

FIGURE 3.9 RELATIVE FUEL IMPACTS ON REGIONS - INCREASING LIMITS NO MODE SHIFT (TRUCK Δ ONLY)

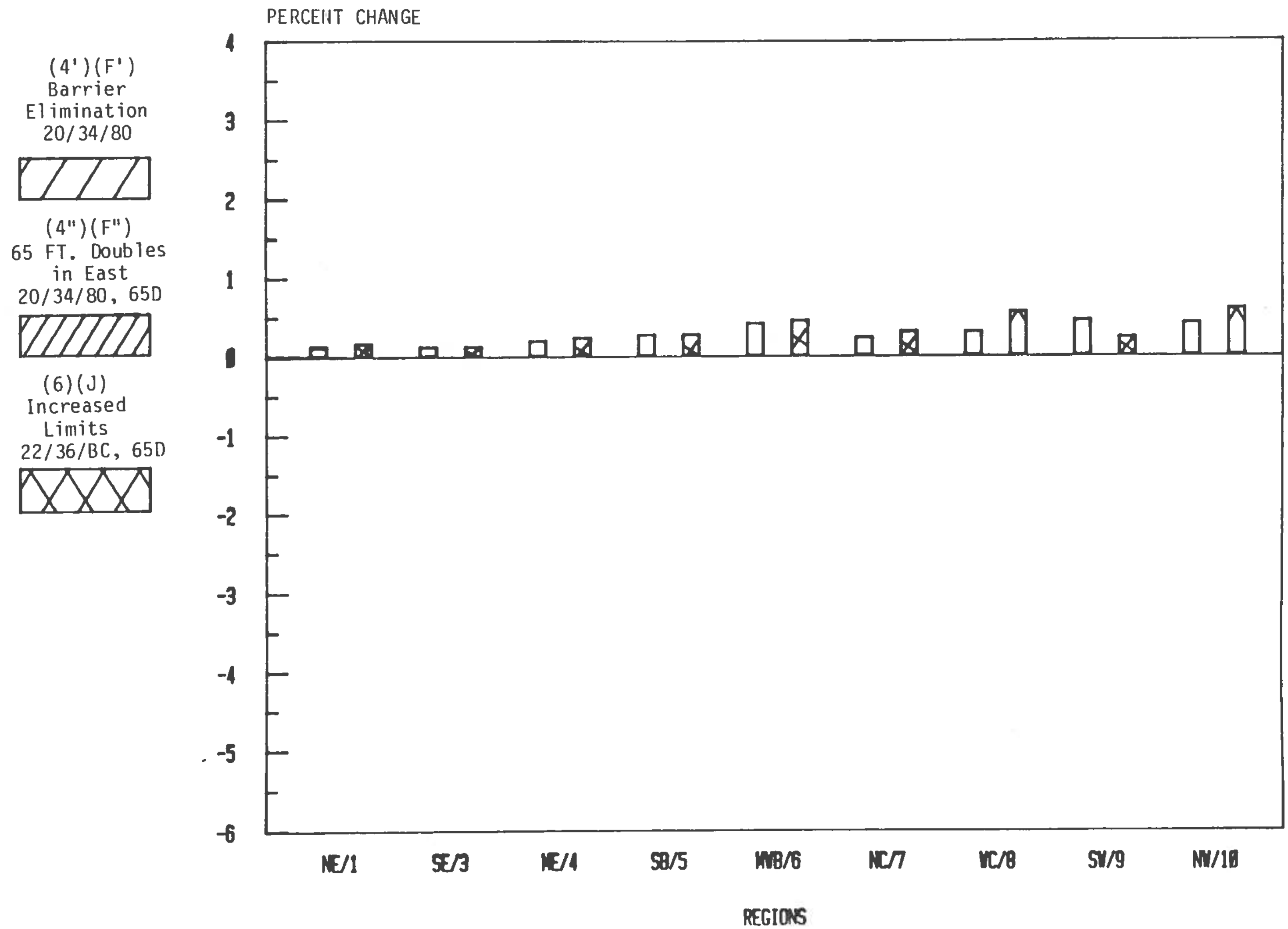

FIGURE 3.10 RELATIVE FUEL IMPACTS ON REGIONS - INCREASING LIMITS MODAL DIVERSIONS (TRUCK & RAIL Δ)

4. SENSITIVITY OF REPORTED IMPACTS TO INPUT UNCERTAINTIES

4.1 INTRODUCTION

It is evident that the specific impact values being reported, both absolute numbers and changes from the Base Case, are subject to considerable uncertainty. Many definite numerical assumptions had to be made where fairly broad ranges of values would have been more defensible. The point of this section is to show how the major qualitative conclusions of the study regarding transportation cost would have been changed if the set of numerical assumptions actually used had been replaced by some equally reasonable alternative.

The study as a whole evaluates alternative scenarios according to 10 dimensions (See Final Report, p. II-4): truck productivity, modal diversion, losses to particular industries from grandfather clause elimination, pavement damage, bridge damage, traffic safety, energy consumption, air quality, noise, and urban truck routing. As previously explained, (pp. 1-10 to 1-15), TSC was responsible for developing the detailed VMT data for the Base Case and each alternative, including that resulting from modal diversion, and for estimating the truck and rail cost, fuel consumption, and transit time impacts of each alternative. The other evaluation dimensions listed above are mostly dependent on the VMT changes among the truck configuration and gross weight categories.

Changes in transportation cost are the main outputs considered in this section, and the effects of "barrier" limits and national uniformity with a Federal standard as a minimum are of primary concern. Therefore, only changes due to truck type, weight, and mode shifts of Type 3 (long haul) traffic are considered in this section. Table 4.1 shows what these changes are for total traffic and for Type 3 traffic only in each of the alternatives presented in this volume. Because limit alternative 2A(C) (elimination of the grandfather limits) does not concern Type 3 traffic, it is not treated in this section. For the remaining alternatives, Type 3 traffic effects overwhelm the impacts on Type 2 traffic.

TABLE 4.1 TRANSPORT COST CHANGES - TYPE 3 TRAFFIC AND MODAL DIVERSION CONTRIBUTIONS

	TRUCK SIZE AND WEIGHT LIMIT ALTERNATIVES					
	BASE CASE	(Barrier Elimination)	(Pre-1974)	(Rollback + Formula A)	(Increased Limits)	(65 FT Doubles in East)
STUDY CODE	1	4'*	5	8'*	6	4"*
REPORT CODE	A	F'	H	K'	J	F"
TOTAL TRAFFIC						
Truck Transport Cost (In Millions '77 $) (No Mode Shift)	143,333	142,847	146,447	143,166	139,596	141,734
Δ From Base Case (In Millions '77 $)		-486	+3,114	-167	-3,737	-1,599
Δ From Base Case (Percent)		-0.3	+2.2	-0.1	-2.6	-1.1
MODAL DIVERSIONS:						
Rail Transit Cost Δ (In Millions '77 $)		-530	+380	-269	-759	-19
Truck Transport Cost Δ (In Millions '77 $)		+833	-715	+392	+1,134	+19
Net Diversions Δ (In Millions '77 $)		+303	-335	+123	-375	0
Δ Truck Cost + Net Diversion (In Millions $77 $)		-183	+2,779	-44	-3,362	-1,599
Δ From Base Case (Percent)		-0.1	+1.9	--	-2.3	-1.1
TYPE 3 TRAFFIC:						
Truck Transport Cost (In Millions '77 $) (No Mode Shift)	57,259	56,791	59,089	56,835	53,669	55,660
Δ From Base Case (In Millions '77 $)		-468	+1,830	-424	-3,590	-1,599
Δ From Base Case (Percent)		-0.8	+3.2	-0.7	-6.3	-2.8
Modal Diversions:						
Rail Transport Cost Δ (In Millions '77 $)		-530	+261	-257	-759	-19
Truck Transport Cost Δ (In Millions '77 $)		+833	-567	+445	+1,134	+19
Net Diversions Δ (In Millions '77 $)		+303	-306	+188	+375	0
Δ Truck Cost + Net Diversion (In Millions '77 $)		-165	+1,524	-236	-3,215	-1,599
Δ From Base Case (Percent)		-0.3	+2.7	-0.4	-5.6	-2.8
Type 3 Traffic Δ as % of Total Δ (No Mode Shift)		96	59	62	96	100
Type 3 Modal Diversions as % Total Diversions (Calculated on Basis of Truck Transportation Cost)		100	79	89	100	100

*See Section 2 for defintions of these alternatives.

Occasionally, results will also be shown in terms of the Type 3 VMT pattern, or in terms of tons or ton-miles. These numbers are to show why transport costs change in the way that they do. Effects on fuel consumption and transit time will not be discussed in this section.

Considering transportation cost alone, the limit alternatives can be compared as in Table 4.1 and ranked by the magnitude of the absolute difference from the Base Case. The most significant part of this would be the ranking, but the degree of difference from the Base Case, as measured by percentage change, is also important. Based on this, one can evaluate the significance of the changes in results associated with some input change. For example, suppose that under the reported assumptions Base Case costs were $100 billion, and became $90 billion in alternative X and $80 billion in scenario Y. A change in assumptions that made these numbers $50 billion, $45 billion, and $40 billion would be a mere scale change. (It might, however, color one's judgment of the truck size and weight issue.) A change in assumptions that left the Base Case costs at $100 billion, but changed the alternative costs to $96 billion and $92 billion, respectively, might well affect evaluations (e.g., trade-offs against increased pavement and bridge costs) even though it did not change rankings. If the reduced aggregate transport cost impacts resulted from similar uniform reductions in the detailed VMT impacts, then all detailed effects are likely to follow the aggregate pattern. Finally, changes that definitely reverse ranking by making alternative X cheaper than alternative Y are the most critical.

For the most part, the analysts believe that the conclusions about cost ranking cannot be shaken by reasonable and consistent variations of the input numbers. The absolute value of the cost changes, however, may be challenged.

In this section, the input uncertainties will be examined in turn under six headings — unit cost inputs, the pattern of VMT, shifts in truck type use, shifts in truck weight within types, mode shifts and definition of alternatives. Each of these areas of possible uncertainty is treated separately, but to provide an overview, the section immediately following presents the major results and conclusions of this section.

4.2 SUMMARY OF CONCLUSIONS

1. Truck and rail unit cost values are not of critical importance in determining the ranking of limit alternatives. A lower level of general commodity carrier costs relative to special commodity and exempt carrier and private truck costs would lead to a relative reduction of savings associated with alternative 4" (F") (extension of Doubles into the eastern states) compared to the savings associated with other alternatives. The most unpredictable components of truck costs – fuel costs and user taxes – are so small a fraction of total unit costs that reasonable ranges of variation in assumptions about them have no significant impact. Truck choice decisions are insensitive to fairly wide variations in the cost of Doubles (either single or tandem-axles) versus the cost of semi-trailers because, on the average, the former is superior for all classes of traffic. The mode choice method implicitly assumed rail rates were fixed. Insofar as truck rate decreases lead to competitive rail rate decreases, reported mode shift estimates would decrease as shown below for mode shift parameter decreases.

2. The Base Case VMT distribution among truck axle configuration types, weight blocks, carrier services, industries and body types is of critical and obvious importance in determining all of the reported impacts. Holding all other data and analytical methods constant, one could probably find a pattern of VMTs that would yield almost any set of conclusions about the relative size of cost impacts among alternatives, industries or regions. However, most of the major expressed uncertainties (by various TS&W study reviewers) about the traffic data base, such as whether 1977 base year activity was completely captured or whether the assumed 1977 to 1985 growth rates will be achieved, can be expected to affect

the VMT pattern in a mainly uniform way, perhaps with some unpredictable but minor distortions in the pattern. The two main exceptions to this both stem from having used the 1972 CTS for modal shares because the 1977 was not yet available. The private truck share of activity is underestimated, and the railroad share is overestimated (according to a special '72 compatible 1977 CTS file recently obtained by TSC from the Census Bureau). Because the methods used in the study assume that private trucking is somewhat more conservative with regard to truck shifts, an increase in the private trucking share would lead not only to a larger private truck share of the costs or benefits, but to a smaller total of costs or benefits. The effect of the falling rail share is ambiguous.

3. The methods used to predict truck use shifts (e.g., truck size and configuration choice) in response to the alternatives are the most critical inputs of the process, and is the place where future researchers would be best advised to concentrate their attention. Among the alternatives examined in this volume, alternative 4" (F") is dominated by a shift of traffic from conventional semis to 65-foot, light, five-axle Doubles (Western Doubles), while alternatives 6 (J) and 8' (K) are dominated by a shift to 65-foot, eight-axle Doubles. The magnitude of these shifts is very difficult to predict in advance, particularly in the latter case, and has a very large effect on the results.

4. The final weight distribution associated with each truck axle configuration type in each alternative was computed by Sydec from FHWA Loadometer data and the "Texas Load Shift" method,* although preliminary weight distributions had to be used by TSC.** Weight shift is a better understood and hence less controversial topic than truck configuration shift, and its significance for

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*Technical Supplement Volume 6.

**Technical Supplement Volume 4.

transport costs is smaller. Weight shift is not considered a critical assumption that could be reasonably manipulated to change the reported impacts.

5. Although mode shift estimates are always subject to a wide band of uncertainty, it has been shown that the ranking and relative magnitudes of alternatives change little with or without estimated mode shift. High mode shift estimates cause alternative 4" (F") (which permits 65-foot Doubles in the East) to look a little better in terms of truck and rail transport cost, since it involves few diversions in any case. Because the amount of mode shift is a study criterion in its own right, however, this is an area where both better data and models would always be welcome.

6. The last sensitivity considered is the broadest one — to what extent does the specific list of reported scenarios and their exact definitions, obscure the relationship between specific changes and resulting cost savings? On the basis of detailed analysis of these limit alternatives and some incomplete results from some unreported alternatives, the specific cost savings associated with each of the following can be shown: a) bringing all FAP highways to the 20/34/80 weight limit standard, b) permitting 65-foot Doubles on all FAP highways while retaining the 20/34/80 weight limits; c) permitting 65-foot Doubles on all FAP highways and adopting one of three sets of weight limits (18/32/Bridge Formula "A", 20/34/Bridge Formula "B", 22.4/36/Bridge Formula "C"; or d) 20/34/Bridge Formula "B", 65-foot Doubles on all FAP highways. Admittedly, the estimates get more and more uncertain as one goes down the list, but the effort provides a perspective of the range of alternatives available.

Table 4.2 restates this summary of conclusions in a representative quantitative way. The figures in the table are derived from the various tables in the rest of this section. The entries in the first column specify what input change is presented in the adjoining row. The second column defines the unit of change for the input being considered; this is intended to represent the largest reasonable divergence possible from the assumption used

TABLE 4.2 SUMMARY OF TRANSPORTATION COST SENSITIVITY, REPORTED RESULTS AND SEVERAL MAJOR VARIATIONS OF INPUTS FOR BASE CASE AND ALTERNATIVES 4" (F") AND 6 (J)
(In Millions of 1977 Dollars)

INPUT SPECIFICATION	UNIT OF CHANGE	BASE CASE TYPE 3 TRANSPORT COSTS	% Δ BASE CASE TRANSPORT COSTS	Δ IN 4" (F") FROM BC	Δ IN 6 (J) FROM BC	$\frac{\Delta 4"}{\Delta 6}$	INDEX OF DIVERGENCE**
Reported Resuts, no Mode Shift	-	57,259	-	-1599	-3590	.4454	-
Fuel Cost	1/2 x Reported Value	54,818	-4.3%	-1409	-3432	.4106	7.8
	5/2 x Reported Value	64,280	+12.3%	-1789	-4048	.4420	0.8
Relative Costs of Different Services	10% Drop in General Commodity Service Cost	53,881	-5.9%	-1439	-3478	.4137	7.1
Vehicle Miles	20% Drop in all VMT	45,807	-20.0%	-1279	-2872	.4454	0
Truck Size Shifts							
Use of 65 ft. Light Doubles	Specification "B" (see 4.5.1)	57,423	+0.3%	-1538	-3590	.4284	3.8
Use of 65 ft. Tandem Doubles	1/2 of Reported Shift	57,259	0	-1599	-2084	.7673	72.2
Alternative Specification***	Define Alt. 6 (J) to Permit Doubles in all FAP Highways	57,259	0	-1599	-5023	.3183	28.5
Reported Results, Mode Shift*	-	57,259	-	-1599	-3215	.4974	-
	25% Increase in All Mode Shift Parameters	57,259	0	-1599	-3189	.5014	0.8
	All Mode Shift Parameters = .05	57,259	0	-1599	-3343	.4783	3.8

NOTES: *Last three rows show transport costs, including mode shift effects, which are net of rail and truck cost changes.

**Index of Divergence = Δ ($\frac{\Delta 4"}{\Delta 6}$) from ($\frac{\Delta 4"}{\Delta 6}$) reported

***The indicated change makes 4" (F") itself, a subset of 6 (J). The Δ for 6 (J) used here is only the part exclusive of 4" (F") effects (i.e., the extension of light Western Doubles in LTL service).

in the reported results. The third column shows the total Type 3 Base Case costs that result from the particular assumption, and the next expresses this as a percentage change from the Base Case. The next two columns show the cost changes from the Base Case in scenarios 4" (F") (65-foot Doubles in the East) and 6 (J) (Increased Limits), respectively. These two alternatives were selected for presentation because they have very different sources of cost savings and produce the largest transport cost impacts. The next column shows the ratio between the cost changes in the scenarios while the last re-expresses this ratio as an index showing percent divergence from the reported value of the ratio. Note that all of the rows except the last three refer to results assuming no mode shifts. The index column shows the importance of the tandem-axle Doubles shift, and the eastern states' prohibition of Doubles, in affecting the relative attractiveness of the two alternatives.

4.3 UNIT COST INPUTS

The costing of truck and rail movements was thoroughly described in Technical Supplement Volume 2, and its implementation in the Type 3 traffic analysis was described in Volume 4 Appendix D and Appendix B of this volume. Line-haul costs were expressed as dollars per vehicle-mile, while terminal costs were given as dollars per ton. These unit costs vary by carrier service (general commodity service, special commodity service, private carriage*), ICC region, truck body type, and, for general commodity carriage only, by shipment size. Carrier service distinctions are only made for traffic in vans. Rail unit costs have analogous body type, shipment size, and regional distinctions.

*The traffic data for agricultural products makes no distinctions among truck haulers in the case of fresh produce, and essentially no distinction in the case of field crops. (Regulated and unregulated trucking are distinguished, but all agricultural products are exempt from regulation.) Agricultural trucking is assigned private truck costs for vans. On reefers and grain haulers no unit cost distinction by carrier group was made in the first place.

Unit costs had both an active and a passive role in the analysis. The passive role is that once VMTs were allocated to some category of activity associated with a definite unit cost, that unit cost converted the VMTs into transport costs. The active role is that cost comparisons were sometimes a determinant of the category into which VMTs were placed. The procedure for allocating truck VMTs to truck types was a constrained cost minimization. The procedure for shifing VMTs between rail and truck was cost-sensitive.

Table 4.3 shows the relative significance of different carrier services and different body types for Type 3 traffic.

The major uncertainties concerning unit costs are the following:

1) accuracy of the fuel component of unit cost
2) accuracy of the user charges component of unit cost
3) accuracy of the truck costing procedures, as they relate to fixing relative costs among carrier services and shipment sizes
4) accuracy of the assumption that rail prices do not change as a competitive response to truck price changes.

The last point will be deferred to the section on mode shift estimates. The others will be treated in turn here.

4.3.1 Fuel Unit Costs

Fuel unit costs (i.e., dollars per vehicle-mile) in 1977 dollars, were projected to double by 1985.* Given this doubling, fuel costs hover at about 10 percent of total per vehicle-mile costs, with some variation depending on shipment size, carrier group, body type, truck size, and region. If fuel costs were to be twice as high in 1985, therefore, all unit costs would go up

*Technical Supplement Volume 2.

TABLE 4.3 DISTRIBUTION OF TYPE 3 TRAFFIC VMT AND COST, BASE CASE, BY TRUCK BODY TYPE AND BY CARRIER SERVICE

	% SHARE OF VMT	% OF TRANSPORT COSTS
CARRIER SERVICE		
General Commodity	43	59
Special Commodity	25	19
Exempt	11	7
Private	21	15
	100	100
BODY TYPE		
Van	54	66
Flat/Platform	25	17
Refrigerator Van	12	8
Tank	5	4
Auto Carrier	3	4
Dump	1	1
	100	100

approximately 9 to 13 percent and total costs would increase by the same amount in all scenarios. This is all that needs to be said about the passive role of fuel costs.

Is it possible that increased or decreased fuel unit costs would change the truck choice for some significant category of traffic, and hence affect different scenarios in significantly different ways? The key choice that might be so affected is that between conventional semis and Doubles. The choice is between semis and light, 65-foot Doubles for low-density traffic in alternative 4" (F") (65-foot Doubles in East), and between semis and tandem-axle, 65-foot Doubles for high-density traffic in alternatives 6 (J) (Increased Limits) and 8' (K') (Rollback + Formula A). The possible influence of fuel costs on truck choice between singles and Doubles, and on the relative magnitudes of the outcomes, was examined for the Base Case and 65-foot Doubles and the Increased Limits alternatives.

For vans used in LTL service, fuel costs under the standard assumption are 9.4 percent of total unit costs for conventional semis and 9.2 percent for light Doubles. (These are weighted averages of the regional figures.) For all other truck services, fuel costs are a higher percentage of unit costs, and the percentage is still higher for tandem-axle Doubles. (11.9 percent for semis and 12.7 percent for tandem-axle Doubles are the figures for vans in general commodity truckload services.) Two alternative assumptions about 1985 fuel costs were examined: in the first, 1985 fuel costs were equal to the 1977 level, in the second, 1985 fuel costs ballooned to five times the 1977 level. Table 4.4 shows the Base Case total Type 3 traffic cost level and the percentage cost reductions for alternatives 4" (F") and 6 (J) change as we go from the reported assumption to the optimistic assumption or to the pessimistic assumption.

According to the reported Type 3 traffic methods, the changes in unit costs are not sufficient to shift any VMTs between singles and Doubles. To indicate what a more continuous method would have produced, there is an extra column in Table 4.4, under both alternative assumptions, that shows the results based on allowing the

TABLE 4.4 EFFECT OF FUEL UNIT COST - NO MODE SHIFT

STUDY CODE*	REPORT CODE	REPORTED EFFECTS WITH PROJECTED FUEL COST		EFFECTS WITH LOWER FUEL COST				EFFECTS WITH HIGHER FUEL COST			
		'85 FUEL $ = 2 X '77 FUEL $		'85 FUEL $ = '77 FUEL $				'85 FUEL $ = 5 X '77 FUEL $			
		A		A		B		A		B	
		Millions	%Δ	Millions	%Δ	Millions	%Δ	Millions	%Δ	Millions	%Δ
1	A	57,259		54,818		54,818		64,280		64,280	
4"	F"	55,660	-2.8	53,409	-2.6	53,419	-2.6	62,491	-2.8	62,470	-2.8
6	J	53,669	-6.3	51,386	-6.3	51,243	-6.5	60,232	-6.3	60,354	-6.1

A Based on reported VMT distribution between conventional semis and 65-foot Doubles.

B Based on an estimated shift in VMT between conventional semis and 65-foot Doubles in proportion to the change in relative cost attributable to the fuel cost change.

* 1 = Base Case
4"= 65-Foot Doubles in East
6 = Increased Limits

VMT shifts from the Base Case to change in proportion to the changes in relative costs.

Table 4.4 clearly shows that in no case does the fuel cost change significantly distort the ranking of the scenarios, nor was the percent change from the Base Case significantly altered. This test, using alternatives 4" (F") and 6 (J), was the best chance for finding such a distortion because 4" (F") derives its cost savings from a shift of LTL to 65-foot, light Western Doubles, whereas 6 (J) depends mainly on a shift of truckload shipments to tandem-axle, 65-foot Doubles, and these two categories, as was shown above, have opposite fuel cost intensities.

4.3.2 Highway User Charges

Highway user charge unit cost (i.e., dollars per VMT), in 1977 dollars, were projected to double by 1985 in real terms from the '77 base level, for the kind of heavy trucking activity covered by the Type 3 data. What will really happen, of course, depends on the outcome of the ongoing debate concerning the allocation of Federal highway user charges. Thus, this was necessarily a very uncertain assumption.

The importance of Federal and state user charges in total per VMT costs is indicated by the following examples. For van LTL services, user charges are 2.8 percent of unit costs for both singles and Doubles. For platform/flat trucks, user charges are 5.9 percent of unit costs for single, and 6.3 percent for Doubles. For refrigerated vans, these charges are 8.0 percent for singles and 8.2 percent for Doubles. These figures are typical.

Note that: 1) user charges under the reported assumption are a smaller component of costs than are fuel costs; and 2) the spread in this percentage between singles and Doubles is smaller than in the case of fuel costs. In view of this, the evidence of Table 4.4, (i.e. that the study results are not sensitive to probable variations in fuel cost) apply even more strongly to probable variations in user charges.

4.3.3 Fuel Unit Costs and Rail Competition

One might wonder how different fuel unit cost assumptions would affect modal competition. For each of the major body types involved in mode shifts, the average percentage of total costs accounted for by fuel costs is shown in Table 4.5 for both rail and truck. Notice that rail is relatively more fuel cost intensive for every body type. Even though trucks use more fuel per ton-mile, they also use more labor per ton-mile to an even greater degree. There is no real paradox to finding that rail has a higher relative fuel cost intensity.

The mode share model assumes that in all scenarios railroads keep some implicit system of prices constant, while truck prices vary in response to TS&W law changes. The effect of a five-fold increase in fuel unit costs from 1977 to 1985, for example, would cause a certain increase in the Base Case price levels of both modes.* Truck price increases would average about 37.5 percent, while rail prices would go up about 45 percent. The effect of these increases on 1985 mode shares can be analyzed in two parts. One part is the consequence of the 5 percent increase in the truck price relative to the rail price. Such a change in relative prices causes a shift to the mode that has become relatively cheaper. This is called a "substitution effect." Mode shift models are designed to measure this effect. In the present instance, the magnitude of the "substitution effect" shift would be rather small, when compared with the shifts due to the limit alternatives.

The second part of the effect of the fuel price increases is the consequence of the large general rise in the cost of transportation. Firms would react to this in various ways. They might purchase less transportation by buying or selling nearer to home. Even if they do not buy less transportation, they may reduce transportation costs by buying more of the mode that is <u>absolutely</u>

*This example uses a five-fold increase in the fuel cost per vehicle-mile in constant dollars. This includes all fuel efficiency improvements and assumes all other factor inputs retain their relative price levels.

TABLE 4.5 RELATIVE SIGNIFICANCE OF FUEL UNIT COSTS IN RAIL AND TRUCK RATES (EXPRESSED AS PERCENTAGE OF PER TON-MILE COST)

MOTOR CARRIER SERVICES		RAIL CARRIER SERVICES	
General Commodity Van/T.L.	11.9	15.8	TOFC/T.L.
Special Commodity Van	17.1	19.7	Box Car
Platform/Flat	14.4	17.9	Flat/Rack
Refrigerated Van	21.7	22.7	Refrigerated Box Car
Tank	13.1	23.2	Tank

Notes: Where Technical Supplement Volume 2 has separate terminal costs, these are converted into per vehicle-mile costs, using the appropriate average length of haul and average load, in the case of truck, and using 500-mile trip length and 30-ton load for rail.

Costs are a weighted average of regional costs. The weighting is body-type specific.

Truck figures are for conventional semis.

cheaper. This is called an "income effect." There is no hard quantitative information as to its size. Because the individual mode price increases are an order of magnitude greater than the change in relative prices, it may well be that the income effect is dominant, and that in total the rail share would be higher after the fuel price increase.

4.3.4 Relative Cost of Different Trucking Services

The limit alternative ranking considered here is in terms of percentage change in transport cost from the Base Case. Different body types and different carrier services have widely different costs per VMT, as is implied in Table 4.3. Of the limit alternatives considered here, 4" (F") (65-foot Doubles in the East) has its effect concentrated in the general commodity/van area, whereas the others have their main effects in the special commodity areas. Table 4.6 summarizes the distribution of limit alternative cost changes among body types. Notice that the distributions are similar for 4' (F') (Barrier Elimination) and 5 (H) (Pre-1974). They are also similar for (J) (Increased Limits) and 8' (K') (Rollback + Formula A). Comparing these two groups, 4' and 5 have relatively more of this effect concentrated on refrigerated vans and relatively less on general commodity vans and flats than 6 and 8'. The information in Table 4.6 can be used to make fast and fairly accurate estimates of the consequences of changing the cost input assumptions for any of these services.

One important question concerning relative truck service costs is what the effect would be of a decline in general commodity service cost relative to other truck costs. The top row of Table 4.6 shows that 4" (F) (65-foot Doubles in the East) has all of its savings concentrated in the general commodity service, 4' (F') (Barrier Elimination) and 5 (H) (Pre-1974) have the least percentage of savings in that area, while 6 (J) (Increased Limits) and 8' (K') (Rollback + Formula A) fall in between. It therefore follows that a reduction in general commodity service unit costs, everything

TABLE 4.6 RELATIVE CONTRIBUTION OF BODY TYPE SERVICES TO COST CHANGES

BODY TYPE SERVICE		% SHARE OF TOTAL COST*	% SHARE OF Δ COST (NO MODE SHIFT)				
		BASE CASE	(Barrier Elimination)	(Pre-1974)	(Roll-back + Formula A)	(Increased Limits)	(65-Ft Doubles in East
	STUDY CODE	1	4'	5	8'	6	4"
	REPORT CODE	A	F'	H	K'	J	F"
General Commodity Van		59.0	22.2	18.2	29.8	31.2	100.0
Special Commodity Van		3.6	5.7	6.0	1.9	4.3	0
Private Truck Van		3.9	4.0	4.1	6.4	3.6	0
Refrigerated Van		8.2	33.4	34.8	12.1	16.3	0
Flat/Platform		16.6	26.3	28.2	37.0	33.6	0
Tank		4.3	7.5	7.9	11.0	9.8	0
Dump		0.6	0.9	0.8	1.8	1.2	0
Auto Carrier		3.8	0	0	0	0	0
Total		100.0	100.0	100.0	100.0	100.0	100.0
% Δ of Total from Base Case			-0.8	+3.2	-0.7	-6.3	-2.8

*Total Type 3 Traffic Transport Cost Only else held equal, will reduce the measured cost saving in 4" (F") by the full amount of that reduction, the cost saving in 6 (J) or 8' (K') by a fraction of that reduction, and the cost saving in 4' (F') or 5 (H) by a still smaller fraction of that reduction. Consequently, 4' (F') and 5 (H) will look relatively better than all the other limit alterations if the assumed general commodity service costs are reduced for the alternatives; and 4" (F") will look relatively worse.

4.4 TRUCK VMT PATTERN

The change in the amount of VMTs in any particular category can be the result of changes in the average vehicle load for a given level of shipments flowing between origins and destinations, a change in vehicle-miles due to a routing circuitry change, a change in ton-miles due to a shift of tons to or from some other truck category, or a change in ton-miles due to a shift of tons between modes. Of these, the truck routing circuity effect is the smallest and is significant only in the use of Western Doubles. There were few opportunities to avoid the low limits of the "barrier states" by taking a circuitous route in the Base Case.* Western Double traffic could use the eastern toll roads to reach major cities in the East from the Southwest along a circuitous route. Truck shift, load shift, and mode shift are discussed in subsections following. This subsection concerns the Base Case VMT pattern from which all the shifts are calculated.

Table 4.7 presents a summary picture of how the Base Case VMTs are distributed among traffic types and truck types. If the assumed Base Case VMTs are varied, the companion set of 45,000 detail numbers also must be changed. The various alternative limit scenarios have their effects concentrated in different cells of this table. Limit alternative 4' (F'), which addresses the barrier state problem, changes the VMT of high-density traffic

*The Base Case in the Final Report was based upon state limits in effect on January 1, 1981.

TABLE 4.7 BASE CASE TYPE 3 TRAFFIC VMT BY SIZE OF TRUCK AND TYPE OF TRAFFIC

(In Millions)

TRAFFIC TYPE	SINGLE-UNITS AND SEMI-TRAILERS	TRUCK-TRAILERS, DOUBLES, TRIPLES	TOTAL
General Commodity LTL	5,370	2,774	8,144
Other Low-Density Freight*	7,087	0	7,087
High-Density - Small Loads	6,033	0	6,033
High-Density - Subject to 18/32/73 Weight Limits	7,218	42	7,260
High-Density - Subject to 20/34/80 Weight Limits	5,533	340	5,873
Total	31,241	3,156	34,397

*e.g., motor vehicles, metal cans, plastic products, etc.

subject to the 18/32/73 limit. Limit alternative 4" (F"), which permits 65-foot Doubles in the East, shifts VMT from the LTL/single unit and semis cell to the LTL/Doubles cell. Limit alternative 5 (H) (Pre-1974) is the opposite of 4' (F') and affects the high-density traffic subject to the 20/34/80 limits. Limit alternatives 6 (J) (Increased Limits) and 8' (K') (Rollback + Formula A) affect both rows of high density weight limited traffic. The small-load traffic is relatively insulated from all size and weight law changes. The other low-density traffic category also was estimated to be relatively unaffected, although one can imagine alternatives sweeping enough that Doubles could penetrate this market as well.

The point here is that the methods used to determine Base Case VMT, chiefly the 1977 TI&U and the 1985 growth factors, and its distribution into the truck and traffic categories were of primary importance in determining the results. The way in which the transport costs results would change if Base Case VMT distributions were changed is sufficiently obvious that no numerical sensitivity example is needed.

4.5 TRUCK SIZE (CONFIGURATION) SHIFTS

The important shifts among truck types in the various limit alternatives are a shift of LTL traffic from conventional semis to 65-foot light Doubles in alternative 4" (F") (65-foot Doubles in East), and a shift of high-density traffic from conventional semis to 65-foot, tandem-axle Doubles in alternatives 6 (J) (Increased Limits) and 8' (K) (Rollback + Formula A). Each of these will be discussed separately.

4.5.1 Use of 65-Foot Light Doubles (Western Doubles)

Based on the contract study reported in Appendix E of Volume 7, the use of light Doubles was restricted to general commodity LTL traffic in all scenarios. The level of Base Case usage was further restricted in region 1, where Doubles are permitted only along the turnpike corridor to be roughly in line with the level of Doubles activity as identified by the TI&U data. Doubles may not be as popular in the East even if legalized because of tradition, carrier operational patterns, the geometry and traffic density of arterials and the location of terminals and pick-up/ delivery points in the older eastern cities (see Appendix E). Accordingly the specification of limit alternative 4" (F") (65-foot Doubles in the East) restricted the use of Doubles to 50 percent of otherwise qualified traffic in the case of traffic with one or more endpoints in study regions 1, 3 and 5, the regions generally prohibiting 65-foot Doubles in the Base Case. This is the same restriction used to calibrate the Base Case level of Doubles' use.

Table 4.8 shows the consequences for VMT and transport costs, of several, more conservative, alternate specifications of both the Base Case and alternative 4" (F"). Specification A, designated "Reported," describes the restrictions used in the Final Report. It is identical for both cases. Specification B for the Base Case eliminates light Doubles in region 1 entirely, while specification C assigns traffic to Doubles only if the trip begins or ends in region 9. For alternative 4 (F"), specification B restricts Doubles' usage to the interstates in those regions (1, 3 and 5) presently prohibiting them. Specification C is exactly the same in the Base Case and in alternative 4" (F"), although of course much more traffic is eligible for Doubles use in alternative 4" (F").

The first conclusion from this analysis is that when using corresponding specifications in the Base and the alternative, the resulting cost differences (Δ) are quite similar, whether one uses the reported specification, the specification that is pessimistic about Doubles use in the East, or the specification that emphasizes the western concentration of these Doubles. One might, of course, wish to combine unmatched pairs, perhaps accepting the reported specification for the Base Case while being pessimistic, as in specification B, about alterntive 4" (F"). The cost difference for this mixed specification is -1402, about 15 percent lower than the reported value.

TABLE 4.8 ALTERNATE SPECIFICATIONS OF DOUBLES USAGE BY LTL CARRIERS LIMIT ALTERNATIVES 1 (A) AND 4" (F")

(VMT and Costs in Millions of 1977 Constant $)

ALTERNATIVE 1 (A): BASE CASE	SINGLES VMT	DOUBLES VMT	SINGLES COST	DOUBLES COST	TOTAL COST Δ (From Corresponding Specification)
A. (Reported) Doubles Used Where Legal, Except 50% Restriction in Region 1, 3 and 5.	5,370	2,774	14,902	8,242	
B. Doubles Used Where Legal, Except Not at all in Region 1	5,956	2,282	16,528	6,780	
C. Doubles Used Only Where Legal and if a Trip End-point in Region 9 or 10	7,202	1,237	19,986	3,675	
ALTERNATIVE 4" (F"): DOUBLES LEGAL IN ALL STATES					
A. (Reported) 50% Restriction in Regions 1, 3, and 5	3,451	4,003	9,576	11,910	-1,658
B. Both 50% Restriction and a Restriction to Interstates in Regions 1, 3, and 5	4,360	3,241	12,099	9,642	-1,567
C. Doubles used Only if a Trip Endpoint in Region 9 or 10	5,320	2,436	14,763	7,247	-1,651

Note: These sensitivity runs were performed using a simplified approximating method, and are slightly different from the reported cost results for the scenarios.

4.5.2 Use of 65-Foot Tandem-Axle Doubles

In the Base Case, there is very little truck activity in the categories of the TI&U identified with tandem-axle Doubles either tractor-semi-trailer and full trailer or truck and full trailers. In the TI&U subfile corresponding to Type 3 traffic, there are about 500 million VMTs of such Doubles. These correspond to various kinds of unusual operations and rules – the turnpike Doubles in the Northeast, the short multi-axle Doubles of Michigan, and various kinds of rigs in the Southwest (region 9). These are hardly more than background noise in the Base Case.

The rules posited in scenarios 6 (J) (Increased Limits) and 8 (K) (Rollback + Formula A) do not impose a general gross weight limit on trucks, but determine the gross weight limit applicable to any configurations by means of a "Bridge Formula." Under these conditions, it appeared that in states permitting 65-foot Doubles, a 65-foot tandem-axle (3S2-3 or 3-3) combination could achieve increased payload capacity for full load high density shipments. The reported results in these limit alternatives estimate major shifts to such a truck type based on the assumption that the carriers will choose the most economical combination permitted consistent with their operational constraints. Estimation of this traffic was speculative because there was no empirical evidence available to apply to this shift. (The examples of the few states, such as Michigan, that do not limit gross-weight to an arbitrary number but permit multi-axled Doubles should indicate that some significant shift would occur and could be economically beneficial to shipping interests.

Table 4.9 brackets the effect of a shift to tandem-axle Doubles by showing the reported results for Type 3 traffic followed immediately by results for the same limit alternative, but assuming no voluntary shift to tandem-axle Doubles at all. Unlike most changes considered thus far in this section, this one has a dramatic effect; most of the cost savings in alternative 6 (J)

TABLE 4.9 CONCERNING SHIFTS TO TANDEM-AXLE DOUBLES: A COMPARISON OF THE RESULTS OF ALTERNATIVES 6 (J) AND 8 (K) WITH AND WITHOUT SUCH SHIFTS

(All Data in Millions, All Costs in 1977 Dollars)

	ALTERNATIVE 6 (J) Increased Limits	ALTERNATIVE 8 (K) Rollback + Formula A
REPORTED:		
VMTs of High-Density Shipments in Semis - Without Mode Shift	11,436	12,242
With Mode Shift	11,913	12,134
VMTs of High-Density Shipments in Doubles - Without Mode Shift	5,017	5,278
With Mode Shift	5,313	5,552
Total Scenario Truck Transportation Costs - Without Mode Shift	53,669	56,835
With Mode Shift	54,803	57,280
Δ From Base Case - Without Mode Shift	-3,590	-424
With Mode Shift	-2,456	-21
IF SHIFT TO TANDEM-AXLE DOUBLES DOES NOT MATERIALIZE:		
VMTs of High-Density Shipments in Semis - Without Mode Shift	17,662	18,879
With Mode Shift	18,382	18,661
VMTs of High-Density Shipments in Doubles -Without Mode Shift	377	380
With Mode Shift	380	381
Total Scenario Truck Transportation Costs - Without Mode Shift	56,681	58,995
With Mode Shift	57,628	58,515
Δ From Base Case - Without Mode Shift	-578	+1,736
With Mode Shift	+369	+1,256

(increased Limits) are in fact due to the shift to tandem-axle Doubles. Alternative 8 (K) (Rollback + Formula A) becomes a burden to the trucking industry and/or shippers without some shift to tandem-axle Doubles.

The truck operators' and manufacturers' primary interst is to maximize the load carrying capability of its vehicles consistent with all extant regulations. If faced with the trade-off between the continued use of existing axle configurations coupled with lower payloads and the alternative of relatively modest redesigns to obtain the maximum allowable payloads through the use of tandem-axle Doubles, some portion of the total industry will opt for the latter. The net result will probably be somewhere between the two results shown on Table 4.9. Most probably the change from the Base Case will fall somewhere between zero and the reported result. In either case, a substantial increase from the current use of tandem-axle Doubles would be likely under this limit alternative.

4.6 SHIFTS OF WEIGHT DISTRIBUTIONS

Changes in the weight distribution for a given truck type were extremely important in determining the scenario results. Table 4.10 shows the changes in average load among scenarios. This average is affected as much by truck type shifts as by weight shifts within a truck type. The last two lines show the actual cost differences and the cost differences that would have occurred if load shifts had not occurred. They are better indications of the significance of weight shifts. The tiny residual effects in scenarios 4' (F') and 5 (H) are entirely due to reduced circuity.

4.7 MODE SHARES AND MODE SHIFTS

This subsection brings together all discussions related to Base Case mode shares or to the induced shifts from these base figures. The first subsection is an overview of the use of mode shares and analysis of modal diversions. The next two treat the Base Case mode shares and the mode shift parameters, respectively. The last summarizes this section.

TABLE 4.10 IMPORTANCE OF LOAD SHIFTING

(All Numbers in Millions)
(All Assume No Mode Shift)
(All Costs in 1977 Dollars)

TYPE 3 TRAFFIC	STUDY CODE	BASE CASE 1	(Barrier Elimination 4'	(Pre-1974) 5	(Rollback + Formula A) 8'	(Increased Limits) 6	(65-Foot Doubles in East) 4"
	REPORT CODE	A	F'	H	K'	J	F"
Ton-Miles*		518,402	518,373	518,318	518,071	518,017	517,825
Loaded Vehicle-Miles		34,397	33,825	34,899	33,446	32,379	33,707
Transport Cost		57,259	56,791	59,089	56,835	53,669	55,660
Average Load (Tons)		15.07	15.32	14.85	15.49	16.00	15.36
Δ Transport Cost		-	-468	+1,830	-424	-3,590	-1,599
Δ Transport Cost, Without Load Shift		-	-3	-9	-2,160	-3,012	-1,599

*Ton-mile differences reflect changes in routing circuity attributable to each alternative since the O/D tonnage flows remain unchanged from the Base Case.

4.7.1 Overview

The level of Base Case 1985 truck activity was determined by applying the forecast growth factors to the 1977 TI&U and did not depend on any actual or estimated mode share percentages. The level of relevant Base Case 1985 rail traffic was determined by the 1972 CTS; a comparison of 1972 and 1977 Rail Quarterly Commodity Statistics (QCS), to estimate what happened from 1972 to 1977; and projected growth factors comparable to those for truck from 1977 to 1985. Refer to Volume 4 Appendix C for details and explanation.

Figure 4.1 shows how the estimated rail diversions in the limit alternatives are winnowed from this presumed universe of 1985 rail flows. The 1.9 billion total 1985 rail tons is a rough estimate. The 760 million manufactured and agricultural products on the next row are the aggregate tonnage for that traffic. Certain kinds of rail traffic are not affected by the size and weight limit alternatives considered. These are small shipment traffic and low density traffic. The estimated volumes of these two types of rail traffic were isolated as traffic for which the competing truck services would be unaffected by the truck size and weight alternatives, thus leaving 637 million tons of rail freight conceivably relevant to truck size and weight issues. All of the 637 million tons consist of shipments of at least 15 tons of high-density goods for which the truck service option has become more or less attractive under the limit alternative. (As noted in the figure, there is also in alternative 4" (F"), a very small diversion from a very small category, rail "LTL" (assumed to be TOFC traffic by this study) which is not discussed further in this subsection.)

In each limit alternative, only a portion of the 637 million tons* is actually subject to diversion because of lowered truck

*As the figure shows, part of the 637 million tons is local (within a single BEA region) and is not considered Type 3 traffic equivalent. Such traffic was automatically excluded by the computer program but its volume was not recorded. Since most short rail movements are of bulks, which are mainly excluded from this data set, this local tonnage is probably very small.

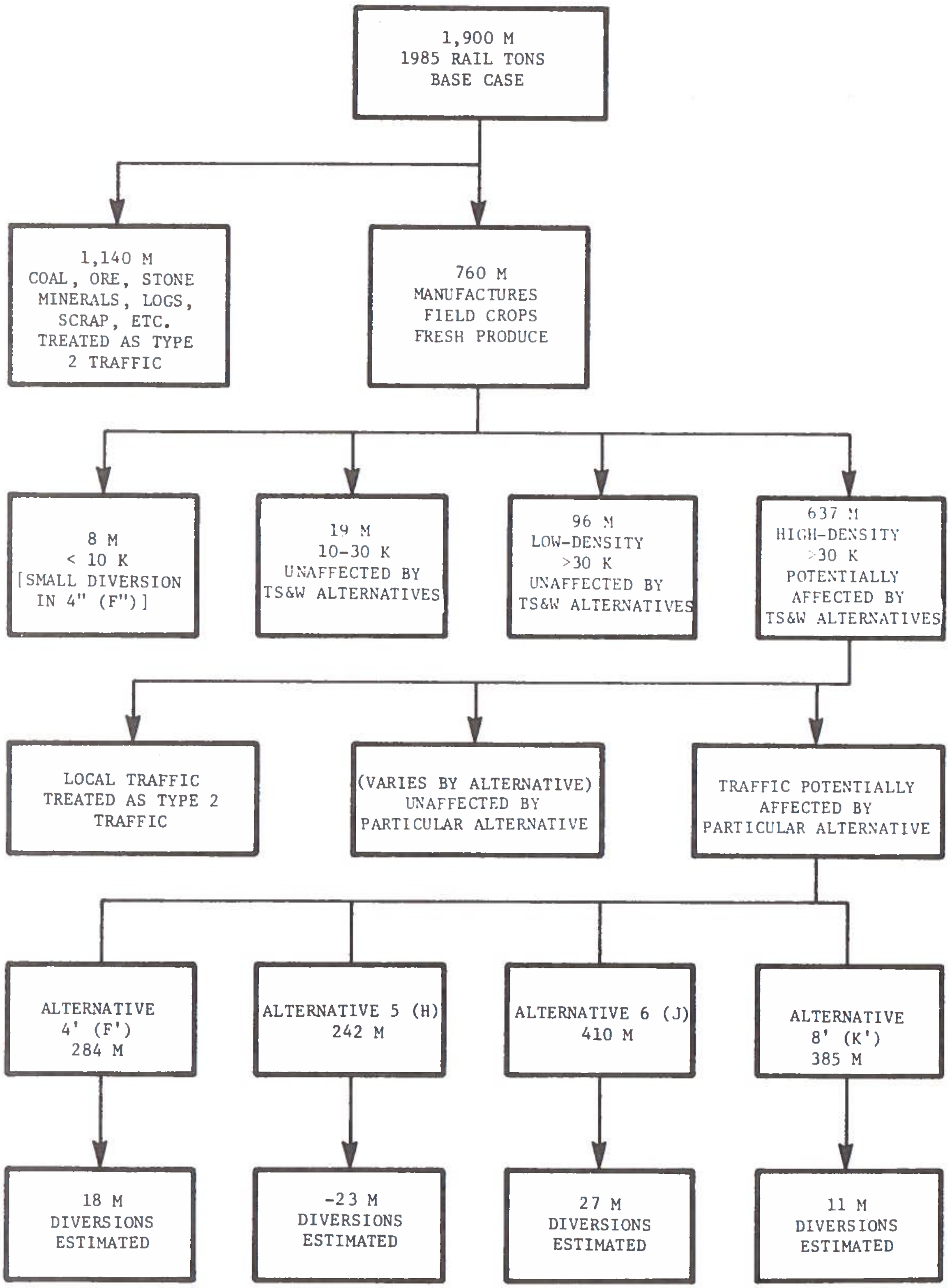

FIGURE 4.1 RAILROAD 1985 TONNAGE AND ANALYSIS OF TYPE 3 TRAFFIC DIVERSION DUE TO TS&W ALTERNATIVES

costs. The affected part ranges in size from 284 million tons in alternative 4' (F') (Barrier Elimination) to 410 million tons in alternative 6 (J) (Increased Limits). In alternative 4' (F'), this is traffic in or crossing the barrier state regions; in alternative 6 (J) it is western, midwestern, and turnpike corridor traffic.

Finally, out of this total of potentially divertible traffic, each alternative obtained its reported diversion estimate using the method described in Technical Supplement Volume 5. The exact estimate depends on the base year mode shares that were used, on the mode share parameters, and on the commodity composition of the potentially divertible traffic.

It should be remembered that some modal diversions from truck to rail were estimated for the bulk and local traffic in study scenarios 2B (G) (Grandfather Elimination), 5 (H) (Pre-1974) and 8 (K) (Rollback + Formula A), but are not shown in Figure 4-1.

4.7.2 Mode Shares

The modal diversion analysis method required very detailed mode share information. Specifically, it used percentage shares specific to each of the 29 commodity groups, two shipment sizes (30-60K lbs, > 60K lbs) and seven distance blocks. The shares were used both in estimating the modal diversion parameters and in calculating appropriate elasticities from the parameters, for individual markets.

The share data used was from the 1972 CTS, except that the 1977 Department of Agriculture data was used for the two agricultural commodities. The 1977 CTS survey was not available in time for the Final Report. It later became available for this volume. Table 4.11 shows the modal division of ton-miles among regulated truck, private truck and rail for the 1972 CTS and for a 1972-equivalent subset of the 1977 CTS. A diminishing rail share is seen for every commodity group. In the aggregate, the rail share declined 13.3 percent. To check how much of this was due to a change in the relative importance of commodity groups, a

TABLE 4.11 MODE SHARES: 1972 VS. 1977

(Percentage of Ton-Miles)

COMMODITY (2-DIGIT STCC)	1972 RAIL	1972 REGULATED TRUCK	1972 PRIVATE TRUCK	1977* RAIL	1977* REGULATED TRUCK	1977* PRIVATE TRUCK
20	58	28	14	50	36	14
21	65	35	0	55	44	1
22	16	62	22	12	61	27
23	16	74	10	8	71	21
24	80	8	12	64	14	22
25	41	33	26	23	54	23
26	75	19	6	70	22	8
28	65	29	6	62	28	10
29	63	25	12	46	28	26
30	34	56	10	26	58	16
31	3	81	16	1	72	27
32	49	39	12	38	40	22
33	57	36	7	48	44	8
34	38	51	11	25	57	18
35	30	62	8	24	65	11
36	39	52	9	26	54	20
37	76	19	5	73	22	5
38	39	54	7	11	82	7
39	38	50	12	12	76	12
Total	60	30	10	52	34	14

*1972 Compatible File.

Source: Census of Transportation, Commodity Transportation Survey, 1972, 1977 "constant commodity weight" index was calculated using the individual 1972 commodity tonnages with the 1977 rail shares.* This "constant commodity weight" index declined 11.7 percent from 1972 to 1977, showing that the rail decline was quite real.

The effect that the 1977 CTS detailed mode share data would have on the modal diversion parameter calculation is unpredictable. The effect that such data would have had on the <u>elasticity</u> calculations, assuming the parameters unchanged, is complicated, but the partial issues are clear. Larger truck mode shares, everything else equal, would produce higher elasticities and larger diversions. Qualifying this is the fact that diversions are only calculated in non-dominated markets in which neither rail nor truck has 90 percent of the market.

This approach of calculating only non-dominated markets cuts both ways, as some formerly competitive markets may become truck-dominated, while other formerly rail-dominated markets become competitive. On the balance, it seems likely that the use of 1972 mode shares produced a downward bias in the mode shift estimate.

4.7.3 Modal Diversion Parameters

As explained in Technical Supplement Volume 5, parameters for logit equations were calculated for each of the 29 x 2 combinations of commodity and shipment size. These are listed in Table 4.12. These parameters indicate the importance of freight rate differences in explaining mode shares. When these parameters were being developed, several alternative possibilities were tested. The first of these applied a simple coefficient to all commodities and shipment sizes. The value used was .05, which is roughly consistent with the values statistically estimated for such a parameter

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*

$$\text{Constant Commodity Weight Index} = \frac{\sum_{i=1}^{N} (\text{rail share in '77})_i (\text{total ton-miles in '72})_i}{\sum_{i=1}^{N} (\text{total ton-miles in '72})_i}$$

TABLE 4.12 MODE SHIFT PARAMETERS

	COMMODITY	STCC CODES	TRUCK LOAD (30 > 60K LBS)	GREATER THAN TRUCK LOAD (> 60K LBS)
	LTL Shipments		0.1114*	
	Field Crops		-	0.0628
	Fresh Produce		-	0.1058
L-1	Motor Vehicles	371, 374	0.0845	0.0565
L-2	Metal Cans, Luggage	316 341	0.1188	0.2911
L-3	Electric Light	364	0.1013	0.0171
L-5	Furniture, etc.	251, 264, 379	0.0749	0.5016
L-6	Rubber & Plastic Products, etc.	306, 307, 363, 367	0.1813	0.9426
L-8	Containers, Tires, etc.	205, 227, 265, 301	0.0380	-0.1130
L-10	Ceramic Products, etc.	253, 326	0.1334	0.1622
H-12	Millwork, etc.		0.2913	0.0860
H-20	Food Products	20 less 205	0.0580	0.1550
H-21	Tobacco Products	21	0.3936	0.1491
H-22	Textiles	22 less 227	0.1676	0.4840
H-23	Apparel	23	2.8587	-0.6665
H-24	Lumber	24 less 244, plus 254	0.2251	0.2697
H-26	Paper & Pulp Products	26	0.1718	0.2405
H-28	Chemicals	28	0.0805	0.0669
H-29	Petroleum Products	29	0.1232	0.6902
H-32	Stone, Clay & Glass Products	32 less 326	0.2855	0.2403

*This is for shipments of all manufactured commodities at <10K lbs.

TABLE 4.12 MODE SHIFT PARAMETERS (CONT.)

COMMODITY	STCC CODES	TRUCK LOAD (30 > 60K LBS)	GREATER THAN TRUCK LOAD (> 60 K LBS)
H-34 Fabricated Metals	34 less 341	0.2682	0.3153
H-35 Machinery	35 less 357	0.2277	0.1718
H-36 Electrical Equipment	361, 362, 366, 369	0.1312	0.2869
H-37 Motor Vehicle Parts	371, 374	0.0845	0.0565
H-65 Miscellaneous	311, 382, 387, 394, 399	0.1907	0.0061

in single-equation models. The second alternative was simply to increase all the parameter values by 25 percent. Tables 4.13 and 4.14 compare the reported results with those of these two alternatives, for alternatives 4' (F') and 6 (J), respectively.

4.7.4 Conclusions Concerning Modal Diversions

Tables 4.13 and 4.14 show that neither alternative set of paremeters changes the relative ranking (by transportation costs) of the limit alternatives. The larger the value of the parameter, the greater the sensitivity to rate changes will be. This conclusion presumably will hold for the other alternatives, under other reasonable modifications of the parameter set. Furthermore, since these parameters are the things that most directly affect the diversion estimates, the same conclusion can be applied to the two other items already discussed that impinge on modal diversions, namely, the base year mode shares and the possible rail price reaction to truck price changes.

Because modal diversion is itself a study criterion, and because the subject is inherently controversial, it would be desirable to go beyond these conclusions. One would like to feel very confident about the specific levels of modal diversion associated with each scenario, and one might like to know the industries and specific railroads most affected. As is explained in Technical Supplement Volume 5, this diversion analysis is not accurate enough to satisfy either of these goals. More up-to-date and detailed data and perhaps improved models would be necessary for progress on this point.

4.8 SPECIFICATION OF ALTERNATIVE SCENARIOS

A crucial question raised by the study, which cannot be fully answered at the present time, is the following. What are the advantages and disadvantages of the different methods of permitting bigger truck payloads — longer truck size or higher truck axle weights? Much of the necessary information is, of course, byeond the scope of this volume, such as the question of

TABLE 4.13 HIGH AND LOW DIVERSION CALCULATIONS FOR ALTERNATIVE 4' (F')
(Millions of Tons Diverted)

COMMODITY GROUP	TABLE 4.12 PARAMETER VALUES*	USING TABLE 4.12 PARAMETER VALUES X 1.25	USING SINGLE PARAMETER VALUE = 0.05
H-20 Food Products	2.52	2.90	1.82
H-26 Paper Products	1.18	1.34	0.44
H-28 Chemicals	1.55	1.80	0.97
H-32 Stone, Clay & Glass Products	1.88	2.04	0.55
H-33 Primary Metals	3.84	4.10	1.42
H-35 Machinery	1.08	1.19	0.51
H-24 Lumber	1.05	1.15	0.43
B-1 Field Crops	1.14	1.42	0.90
B-2 Fresh Produce	1.27	1.29	1.49
All Others	2.81	3.15	1.14
Total	18.32	20.38	9.67
Δ Truck Transport Costs Due to Diversion	+833	+869	+507

*These Diversions were reported in the Final Report.

TABLE 4.14 HIGH AND LOW DIVERSION CALCULATIONS FOR LIMIT ALTERNATIVE 6 (J)

(Millions of Tons Diverted)

(Millions)

COMMODITY GROUPS	TABLE 4.12 PARAMETER VALUES*	USING TABLE 4.12 PARAMETER VALUES X 1.25	USING SINGLE PARAMETER VALUE = 0.05
H-20 Food Products	4.10	4.54	2.63
H-24 Lumber Products	2.43	2.75	0.80
H-26 Paper Products	1.95	2.16	0.78
H-28 Chemicals	2.35	2.62	1.46
H-32 Stone, Clay, & Glass Products	3.55	4.06	1.14
H-33 Primary Metals	6.10	6.58	2.78
H-35 Machinery	1.54	1.72	0.80
B-1 Field Crops	2.59	3.24	2.06
B-2 Fresh Produce	1.70	1.74	1.62
All Others	7.05	8.21	1.74
Total	33.36	37.62	15.81
Δ Truck Transport Costs due to Diversion	+1,134	+1,214	+748

*These Diversions were reported in the Final Report.

pavement damage due to high axle loads, the question of the safety of the long multiple-unit trucks, and the question of the ability of specific highways to accommodate longer truck combinations. The data presented here only refer to the relative consequences for transportation cost. For ease of exposition, cost changes due to mode shifts are omitted. Their inclusion would not substantially change the conclusions of this section. It should be remembered that, even with this limited scope, the results are approximate and are intended mainly to provide a perspective of limit alternative combinations not fully analyzed in the Final Report.

First consider what can happen as a result of axle and gross weight limit changes alone. This is Action #1 in Table 4-15. A reduction in weight limits to the pre-1974 limits (18/32/73.28) causes a transport cost increase of $1,830 million, measured in 1977 dollars on the base level truck traffic. Establishing uniformity at the current Federal level (20/34/80), on the other hand, yields a transport cost saving of $468 million. Beyond this, raising the axle weight limits to 22.4/36, while leaving the gross weight limit at 80 K, would approximate the "no truck shift" (i.e., no shift to tandem-axle Doubles) version of alternative 6(J) presented in Table 4.9. Transport cost savings would rise to $578 million. This seems to be the practical limit of what can happen under rules which encourage the continuation of the present dominant role of conventional semis, mostly 2S2 and 3S2, in intercity truck transportation.

Additional motor carrier productivity gains could be obtained by allowing gross weight to be determined by appropriate bridge formulas. For conventional semis, there is no gain at either the 20/34 or 22.4/36 axle load limits. The 18/32 axle load limits, combined with Bridge Formula A to govern gross weights, would reduce the transport cost increase shown in Table 4.15 for Action 1, at 18/32 limits, from $1.830 billion to $1.736 billion. (The latter figure is shown in Table 4.9). Under any axle load limits, the major gains from Bridge Formula-determined gross weights must

TABLE 4.15 1985 TRANSPORTATION COST EFFECTS OF SPECIFIC ALTERNATIVE LIMIT ACTIONS
(Type 3 Traffic, Without Mode Shift)

(MILLIONS OF '77 DOLLARS)

FIRST LIMIT ACTION - ESTABLISH UNIFORMITY OF AXLE AND GROSS WEIGHT LIMITS			
	@ 18/32/73	@ 20/34/80	@ 22.4/36/80
Action #1 Effect	+1,830	-468	-578
SECOND LIMIT ACTION - DETERMINE GROSS WEIGHT WITH BRIDGE FORMULA A, B AND C, RESPECTIVELY			
	@ 18/32/Formula A	@ 20/34/Formula B	@ 22.4/36/Formula C
Action #2 Effect	-2,254	-2,700	-3,012
Actions 1 & 2 Total Effect	-424	-3,168	-3,590
THIRD LIMIT ACTION - ALLOW 65-FT. DOUBLES ON ALL FAP HIGHWAYS			
	@ 18/32/Formula A	@ 20/34/Formula B	@ 22.4/36/Formula C
Action # 3 Effect on Low-Density Traffic	-1,599	-1,599	-1,599
Action #3 Effect on High Density Traffic	-1,028	-1,285	-1,433
Actions 1, 2 & 3 Total Effect	-3,051	-6,052	-6,622

come from increased use of tandem axle Doubles, as postulated under limit alternatives 6 and 8', or some other "new" rig capable of offering higher payload weights to high-density traffic. The Action #2 row in Table 4.15 lists the transport cost savings expected from such a shift separately and in combination with the establishment of uniform axle weight limits at each of the three levels. The figures for the 18/32 and 22.4/36 axle weight limits are taken from Table 4.10. The 20/34 axle weight limit figures are approximations, since no such alternative was completely analyzed.

The cost savings from Action #2, using bridge formulas to determine gross weights, came about from the increased use of tandem-axle Doubles to carry high-density traffic in regions presently permitting 65-foot Doubles. Action #3 is to allow 65-foot Doubles, single or tandem-axles, on all Federal Aid Primary highways. Alternative 4" (F") did this, but without also adopting Action #2, so that gross weights were still limited 80 K. Only low-density traffic benefits from this, using single-axle ("Western") Doubles. The savings in transport cost were estimated at $1599K, and would be independent of the axle weight limits. Incomplete results were available on alternatives combining Actions 1, 2 and 3 at various axle weight limits. These are the basis of the remainder of the estimated cost savings under Action 3. It should be reemphasized that these numbers are tentative and very sensitive to changes in method. (See Section 4.5.)

Table 4.15 shows both the individual and the combined effects of the various alternative limit actions on transportation costs. Not all the alternatives shown here were contained in the Final Report. However, it was deemed useful to include them here because they were examined and estimates were made of their relative transport cost impacts. It must be stressed again that the impact measure shown here (i.e., change in transport cost without mode shift) is a very incomplete measure of the total impacts of these alternative limit actions. Changes in highway pavement, bridge and safety costs are not included here but must be considered in evaluating the net benefits of any set of truck size weight limit actions.

APPENDIX A

DERIVING NATIONAL AGGREGATE TRUCK & RAIL FUEL CONSUMPTION IMPACT ESTIMATES

A.1 INTRODUCTION

This Appendix describes the procedures used to estimate national and regional aggregate truck and rail fuel consumption impacts attributable to truck size and weight limit study scenarios. The aggregate fuel consumption impacts are estimated by application of unit vehicle fuel consumption factors to truck activity VMT files for each scenario. Truck fuel impacts are calculated directly from the net changes in the truck VMT, including the effects of diversions between truck and rail. The changes in rail fuel consumption associated with the diversions are calculated by converting the diverted freight ton-miles into rail car-miles and applying rail unit vehicle fuel factors. Only the fuel for diverted rail traffic is estimated. No attempt is made to estimate the total rail fuel consumption.

The development of the unit vehicle fuel consumption factors is fully documented in Technical Supplement Volume 3; the development of the truck activity VMT files is documented in Volume 4. The procedure outlined here has been used to estimate the fuel consumption change in truck and rail freight systems, attributable to specific changes in truck size and weight limits. The procedure is believed adequate for that purpose. The first step of this procedure is to estimate the change in truck fuel consumption for each scenario, the second is to isolate the portion of this change associated with modal diversions, and the third is to add the effect of change in rail fuel consumption. These impacts are calculated first at the national level; they are then distributed among the study regions.

The fuel computer program was written to apply this procedure to any file of truck VMT's disaggregated by state, highway class, axle configuration and weight group, as defined in Technical Supplement Volume 4. The truck VMT files, adjusted for the pavement and bridge impact analyses by Sydec, were used as the base VMT files for all national and regional level truck fuel impact calculations. These scenario files contain the net results of all truck size, highway class, weight block and modal shifts. The modal shift portion of the total truck fuel impact was isolated by application of fuel factors to the diverted VMT and ton-miles obtained from disaggregate analyses of "Type 2 Traffic" and "Type 3 Traffic."* The modal diversions for Type 2 and Type 3 traffic are derived in each case from analysis of truck traffic only.** The diverted truck traffic is converted to rail ton-miles using a national average circuity factor. The study team consensus was that 25 percent should be used (i.e., truck ton-miles diverted x 1.25 = rail ton-miles).

Regional level total truck fuel impacts for each alternative study scenario were obtained directly from the Sydec VMT and the TSC fuel program. The required segregation of the modal diversion portion and the regional distribution of the rail fuel changes were obtained from the regional distributions of the diverted Type 2 ton-miles and the diverted Type 3 ton-miles separately.

The unit vehicle fuel factors are state, highway and truck axle type specific and represent the mix of "standard" and "fuel saver" technology thought to prevail in the base year (1977) and the forecast year (1985). They are based on the Cummins truck simulation model results for trucks of various axle types, body types, and load, operating over level, hilly or mountainous terrain and utilizing either "standard" or "fuel-saver" technology.***

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*All truck activity was divided into two components for analysis. Type 2 traffic included all local; shorthaul and certain other traffic adequately represented by the Census Bureau's TI&U data. Type 3 traffic included long haul truck activity whose origin to destination flow characteristics were not adequately represented by the TI&U data. Technical supplement Volume 4 documents the details of the development and analysis of these two traffic streams.

**Technical Supplement Volume 5 documents the procedures and models used for the modal diversion estimates.

***For more details see Technical Supplement Volume 3.

TABLE A-1 INTERCITY FREIGHT LINEHAUL FUEL CONSUMPTION COEFFICIENTS

BODY TYPE AND CONFIGURATION	STANDARD TECHNOLOGY						FUEL SAVER TECHNOLOGY					
	LEVEL		HILLY		MOUNTAINOUS		LEVEL		HILLY		MOUNTAINOUS	
HIGHWAY	FFC	VFC	FFC	VFC	FFC	VFC	FFC	VFC	FFC	VFC	FFC	VFC
VAN												
Single Unit	0.1546	0.0027	0.1551	0.0030	0.1537	0.0036	0.1172	0.0017	0.1178	0.0020	0.1158	0.0025
Conv. Semi Tr.	0.1776	0.0027	0.1776	0.0030	0.1746	0.0036	0.1346	0.0016	0.1349	0.0021	0.1290	0.0027
Turnpike Dbl.	0.2121	0.0025	0.2109	0.0031	0.2106	0.0037	0.1675	0.0017	0.1668	0.0024	0.1681	0.0029
27-Ft. Dbl.	0.1842	0.0026	0.1845	0.0028	0.1810	0.0034	0.1451	0.0016	0.1450	0.0020	0.1422	0.0025
27-Ft. Triples	0.2143	0.0025	0.2113	0.0031	0.2096	0.0037	0.1692	0.0017	0.1671	0.0024	0.1673	0.0029
REEFER												
Single Unit	0.1560	0.0027	0.1566	0.0030	0.1557	0.0036	0.1180	0.0017	0.1189	0.0020	0.1172	0.0027
Conv. Semi Tr.	0.1823	0.0027	0.1829	0.0030	0.1809	0.0036	0.1374	0.0016	0.1386	0.0021	0.1337	0.0027
Turnpike Dbl.	0.2204	0.0025	0.2211	0.0031	0.2228	0.0037	0.1731	0.0017	0.1747	0.0024	0.1777	0.0029
HOUSEHOLD GOODS VAN												
Singl Unit	0.1560	0.0027	0.1566	0.0030	0.1557	0.0036	0.1180	0.0017	0.1189	0.0020	0.1172	0.0025
Conv. Semi-Tr.	0.1803	0.0027	0.1806	0.0030	0.1782	0.0036	0.1362	0.0016	0.1370	0.0021	0.1317	0.0027
Turnpike Dbl.	0.2152	0.0025	0.2148	0.0031	0.2152	0.0037	0.1696	0.0017	0.1698	0.0024	0.1717	0.0029
AUTO TRANSPORTER												
Conv. Semi-Tr.	0.2140	0.0025	0.2102	0.0026	0.2067	0.0031	0.1622	0.0016	0.1597	0.0018	0.1527	0.0023
TANK												
Single Unit	0.1399	0.0026	0.1401	0.0027	0.1397	0.0032	0.1192	0.0017	0.1202	0.0020	0.1188	0.0025
Conv. Semi Tr.	0.1512	0.0028	0.1527	0.0032	0.1510	0.0037	0.1288	0.0018	0.1310	0.0024	0.1314	0.0029
Turnpike Dbl.	0.1661	0.0028	0.1684	0.0031	0.1672	0.0037	0.1429	0.0019	0.1442	0.0026	0.1469	0.0031
FLAT/RACK/LOG												
Single Unit	0.1510	0.0027	0.1511	0.0030	0.1508	0.0036	0.1150	0.0017	0.1150	0.0020	0.1124	0.0025
Conv. Semi. Tr.	0.1512	0.0028	0.1527	0.0032	0.1510	0.0037	0.1288	0.0018	0.1310	0.0024	0.1314	0.0029
Turnpike Dbl.	0.1667	0.0028	0.1690	0.0031	0.1679	0.0037	0.1433	0.0019	0.1447	0.0026	0.1475	0.0031
DUMP												
Single Unit 3Axle	0.1148	0.0020	0.1163	0.0023	0.1142	0.0027	0.0870	0.0012	0.0883	0.0016	0.0844	0.0020
Single Unit 4Axle	0.1189	0.0019	0.1200	0.0024	0.1190	0.0029	0.0901	0.0012	0.9113	0.0017	0.0879	0.0022
Conv. Semi Tr.	0.1276	0.0021	0.1297	0.0028	0.1305	0.0033	0.0967	0.0013	0.0985	0.0020	0.0964	0.0025
Turnpike Dbl.	0.1565	0.0020	0.1639	0.0027	0.1702	0.0032	0.1233	0.0014	0.1296	0.0021	0.1357	0.0025

FCC = Fixed Fuel Coefficient
VFC = Variable Fuel Coefficient
Values are based on the Cummins Truck Simulation Model. They are for Interstate or equivalent roads, average driving conditions, and assume compliance with the 55 mph speed limit.

TABLE A-2 FUEL CONSUMPTION COEFFICIENTS FOR SELECTED TRUCK AXLE TYPES

STANDARD TECHNOLOGY

	Level Terrain		Hilly Terrain		Mountainous Terrain	
	FFC	VFC	FFC	VFC	FFC	VFC
3-Axle Single Unit	.1497	.0027	.1410	.0029	.1507	.0035
Conventional Semi-trailer	.1749	.0026	.1694	.0030	.1675	.0036
Turnpike Double	.1979	.0026	.1983	.0031	.1984	.0037
Double 27	.1842	.0026	.1845	.0028	.1810	.0034
Triple 27	.2143	.0025	.2113	.0031	.2096	.0037

FUEL SAVER TECHNOLOGY

	Level Terrain		Hilly Terrain		Mountainous Terrain	
	FFC	VFC	FFC	VFC	FFC	VFC
3-Axle Single Unit	.1112	.0017	.1164	.0020	.1142	.0025
Conventional Semi-Trailer	.1322	.0016	.1332	.0022	.1294	.0027
Turnpike Double	.1594	.0017	.1601	.0024	.1623	.0029
Double 27	.1451	.0016	.1450	.0020	.1422	.0025
Triple 27	.1692	.0017	.1671	.0024	.1673	.0029

TABLE A-3 FUEL CONSUMPTION COEFFICIENTS FOR 1977 AND 1985 TECHNOLOGY MIXES

1977 TECHNOLOGY MIX (80% Standard, 20% Fuel Saver)

	Level Terrain		Hilly Terrain		Mountainous Terrain	
	FFC	VFC	FFC	VFC	FFC	VFC
3-Axle Single Unit	.1420	.0025	.1361	.0027	.1434	.0033
Conventional Semi-Trailer	.1664	.0024	.1622	.0028	.1539	.0034
Turnpike Double	.1902	.0024	.1907	.0030	.1912	.0035
Double 27	.1764	.0024	.1766	.0026	.1732	.0032
Triple 27	.2053	.0023	.2025	.0030	.2011	.0035

1985 TECHNOLOGY MIX (30% Standard, 70% Fuel Saver)

	Level Terrain		Hilly Terrain		Mountainous Terrain	
	FFC	VFC	FFC	VFC	FFC	VFC
3-Axle Single Unit	.1228	.0020	.1238	.0023	.1252	.0028
Conventional Semi-Trailer	.1450	.0019	.1441	.0024	.1408	.0030
Turnpike Double	.1752	.0020	.1716	.0026	.1732	.0031
Double 27	.1568	.0019	.1569	.0022	.1538	.0028
Triple 27	.1827	.0019	.1803	.0024	.1780	.0031

The resulting factors were then weighted by the highway type/ terrain mix for each state indicated in Table A-4 and adjusted to reflect the difference in fuel use on secondary roads vs. interstate and primary roads* to yield the line-haul fuel factors of Tables A-5 and A-6. The 1977 and 1985 fuel factors by state, highway type, and major truck type are of a form compatible with the format of the basic truck activity VMT files for the 1985 Status Quo Base Case and all the alternative limit scenarios. It should be noted that these factors only account for direct line-haul fuel consumption. The following section explains the allowances for access fuel as well as empty mileage and the differentiation of diesel and gasoline consumption.

A.2.1.1.2 Development of Regional Level Fuel Consumption Estimates - Gasoline and diesel fuel consumption was calculated for each state, major highway type and selected truck-type categories using the equations indicated in Table A-7. The final reporting of fuel consumption is at the regional level in order to be compatible with other types of results, such as costs reported in the study. Note that the total fuel consumed for a particular state, truck type and highway type is the sum of the fuel consumed for empty miles, loaded miles and LTL terminal area miles, (if any) for that particular state, truck and highway type.

The equations are based on those presented by Knapton*, modified to account for empty and loaded distributions, diesel fuel and gasoline distributions, and LTL and truck-load distributions by major truck category and by state.

The correspondence between the major truck axle configurations aggregated from the TI&U data and the truck categories for which

*Knapton, David A., Technical Supplement Volume 3.

TABLE A-4 APPROXIMATE PERCENT DISTRIBUTION OF TERRAIN TYPES ALONG CORRIDORS SERVED BY THE PRINCIPAL HIGHWAY SYSTEMS[a]

State	Highway system and terrain type[b]								
	Interstate			F-A Primary			F-A Secondary		
	M	R	F	M	R	F	M	R	F
Alabama	0	20	80	0	20	80	0	20	80
Alaska	-	-	-	40	60	0	40	60	0
Arizona	15	85	0	60	40	0	60	40	0
Arkansas	0	40	60	20	20	60	20	20	60
California	30	30	40	60	20	20	60	20	20
Colorado	30	30	40	60	20	20	60	20	20
Connecticut	0	40	60	20	20	60	20	20	60
Delaware	0	0	100	0	0	100	0	0	100
D. C.	0	5	95	0	5	95	0	5	95
Florida	0	0	100	0	0	100	0	0	100
Georgia	0	20	80	0	20	80	0	20	80
Hawaii	-	-	-	40	60	0	40	60	0
Idaho	25	25	50	60	10	30	60	10	30
Illinois	0	10	90	0	10	90	0	10	90
Indiana	0	10	90	0	10	90	0	10	90
Iowa	0	15	85	0	30	70	0	30	70
Kansas	0	10	90	0	10	90	0	10	90
Kentucky	0	40	60	20	20	60	20	20	60
Louisiana	0	10	90	0	10	90	0	10	90
Maine	0	10	90	0	10	90	0	10	90
Maryland	20	20	60	10	55	35	10	55	35
Massachusetts	0	40	60	20	20	60	20	20	60
Michigan	0	15	85	0	30	70	0	30	70
Minnesota	0	20	80	0	20	80	0	20	80
Mississippi	0	5	95	0	5	95	0	5	95
Missouri	0	10	90	0	10	90	0	10	90
Montana	50	50	0	80	20	0	80	20	0
Nebraska	0	10	90	0	10	90	0	10	90
Nevada	0	10	90	0	10	90	0	10	90
N. H.	20	20	60	10	55	35	10	55	35
N. J.	20	20	60	10	55	35	10	55	35
N. Mex.	10	50	40	10	60	30	10	60	30
N. Y.	20	20	60	10	55	35	10	55	35

TABLE A-4 APPROXIMATE PERCENT DISTRIBUTION OF TERRAIN TYPES ALONG CORRIDORS SERVED BY THE PRINCIPAL HIGHWAY SYSTEMS[a] (CONTINUED)

State	Highway system and terrain type[b]								
	Interstate			F-A Primary			F-A Secondary		
	M	R	F	M	R	F	M	R	F
N. C.	10	20	70	10	20	70	10	20	70
N. Dak.	10	20	70	10	20	70	10	20	70
Ohio	0	40	60	20	20	60	20	20	60
Oklahoma	0	15	85	0	15	85	0	15	85
Oregon	50	50	0	80	20	0	80	20	0
Pa.	25	75	0	30	70	0	30	70	0
R. I.	0	5	95	0	5	95	0	5	95
S. C.	0	20	80	0	20	80	0	20	80
S. Dak.	0	40	60	20	20	60	20	20	60
Tenn.	0	40	60	20	20	60	20	20	60
Texas	10	50	40	10	60	30	10	60	30
Utah	50	50	0	80	20	0	80	20	0
Vermont	50	50	0	80	20	0	80	20	0
Virginia	50	0	50	40	0	60	40	0	60
Wash.	25	25	50	60	10	30	60	10	30
W. Va.	50	0	50	40	0	60	30	60	10
Wisconsin	0	15	85	0	15	85	0	15	85
Wyoming	15	85	0	60	40	0	60	40	0

[a] Source: Data from Statewide National Topographic Maps (1:250,000 scale series) and other topographic maps published by the U. S. Geological Survey, Washington, D.C.

[b] Terrain types along routes of highways are designated by letter. Letter M designates mountainous terrain, R, rolling terrain and F, flat terrain.

SOURCE: Claffey, P. J., Travel Estimates From Fuel Consumption Information, Report No. DOT-FH-11-7833, prepared for Office of Highway Planning, Federal Highway Administration, Washington, DC, September 1972.

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
ALABAMA						
3 AXLE SINGLE UNIT	.1408	.0025	.1408	.0025	.1400	.0026
CONVENTIONAL SEMI	.1656	.0025	.1656	.0025	.1646	.0025
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1892	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1753	.0024
TRIPLE 27	.2047	.0024	.2047	.0024	.2035	.0024
ALASKA						
3 AXLE SINGLE UNIT	-	-	.1390	.0029	.1465	.0031
CONVENTIONAL SEMI	-	-	.1613	.0030	.1700	.0032
TURNPIKE DOUBLE	-	-	.1909	.0032	.2012	.0034
DOUBLE 27	-	-	.1785	.0031	.1921	.0033
TRIPLE 27	-	-	.2060	.0034	.2216	.0037
ARIZONA						
3 AXLE SINGLE UNIT	.1372	.0028	.1405	.0031	.1512	.0033
CONVENTIONAL SEMI	.1619	.0029	.1608	.0032	.1730	.0034
TURNPIKE DOUBLE	.1408	.0031	.1910	.0033	.2055	.0036
DOUBLE 27	.1761	.0027	.1752	.0028	.1885	.0030
TRIPLE 27	.2023	.0031	.2019	.0032	.2172	.0034
ARKANSAS						
3 AXLE SINGLE UNIT	.1396	.0026	.1411	.0027	.1439	.0028
CONVENTIONAL SEMI	.1647	.0026	.1643	.0027	.1676	.0028
TURNPIKE DOUBLE	.1904	.0026	.1905	.0027	.1943	.0027
DOUBLE 27	.1765	.0025	.1758	.0026	.1821	.0026
TRIPLE 27	.0026	.2039	.0027	.2080	.0027	.2080

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX) (CONTINUED)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
CALIFORNIA						
3 AXLE SINGLE UNIT	.1407	.0028	.1417	.0030	.1519	.0032
CONVENTIONAL SEMI	.1632	.0028	.1617	.0031	.1733	.0033
TURNPIKE DOUBLE	.1907	.0029	.1909	.0032	.2046	.0034
DOUBLE 27	.1755	.0027	.1745	.0029	.1871	.0031
TRIPLE 27	.2032	.0029	.2022	.0032	.2168	.0034
COLORADO						
3 AXLE SINGLE UNIT	.1407	.0028	.1417	.0030	.1519	.0032
CONVENTIONAL SEMI	.1632	.0028	.1617	.0031	.1733	.0033
TURNPIKE DOUBLE	.1907	.0029	.1909	.0032	.2046	.0034
DOUBLE 27	.1755	.0027	.1745	.0029	.1871	.0031
TRIPLE 27	.2032	.0029	.2022	.0032	.2168	.0034
CONNECTICUT						
3 AXLE SINGLE UNIT	.1396	.0026	.1411	.0027	.1439	.0028
CONVENTIONAL SEMI	.1647	.0026	.1643	.0027	.1676	.0028
TURNPIKE DOUBLE	.1904	.0026	.1905	.0026	.1943	.0027
DOUBLE 27	.1765	.0025	.1758	.0026	.1821	.0026
TRIPLE 27	.2041	.0026	.2039	.0027	.2080	.0027
DELAWARE						
3 AXLE SINGLE UNIT	.1420	.0025	.1420	.0025	.1406	.0025
CONVENTIONAL SEMI	.1664	.0024	.1664	.0024	.1647	.0024
TURNPIKE DOUBLE	.1902	.0024	.1902	.0024	.1883	.0024
DOUBLE 27	.1764	.0024	.1764	.0024	.1746	.0024
TRIPLE 27	.2053	.0023	.2053	.0023	.2032	.0023

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX) (CONTINUED)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
D.C.						
3 AXLE SINGLE UNIT	.1417	.0025	.1417	.0025	.1404	.0025
CONVENTIONAL SEMI	.1662	.0024	.1662	.0024	.1647	.0024
TURNPIKE DOUBLE	.1902	.0024	.1902	.0024	.1888	.0024
DOUBLE 27	.1764	.0024	.1764	.0024	.1748	.0024
TRIPLE 27	.2052	.0023	.2052	.0023	.2034	.0023
FLORIDA						
3 AXLE SINGLE UNIT	.1420	.0025	.1420	.0025	.1406	.0025
CONVENTIONAL SEMI	.1664	.0024	.1664	.0024	.1647	.0024
TURNPIKE DOUBLE	.1902	.0024	.1902	.0024	.1883	.0024
DOUBLE 27	.1764	.0024	.1764	.0024	.1746	.0024
TRIPLE 27	.2053	.0023	.2053	.0023	.2032	.0023
GEORGIA						
3 AXLE SINGLE UNIT	.1408	.0025	.1408	.0025	.1400	.0025
CONVENTIONAL SEMI	.1656	.0025	.1656	.0025	.1646	.0025
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1753	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1753	.0024
TRIPLE 27	.2047	.0024	.2047	.0024	.2035	.0024
HAWAII						
3 AXLE SINGLE UNIT	.1390	.0029	.1390	.0029	.1465	.0031
CONVENTIONAL SEMI	.1613	.0030	.1613	.0030	.1700	.0032
TURNPIKE DOUBLE	.1909	.0032	.1909	.0032	.2012	.0034
DOUBLE 27	.1785	.0031	.1785	.0031	.1921	.0033
TRIPLE 27	.2060	.0034	.2060	.0034	.2216	.0037

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX) (CONTINUED)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
IDAHO						
3 AXLE SINGLE UNIT	.1409	.0025	.1423	.0030	.1523	.0032
CONVENTIONAL SEMI	.1637	.0028	.1621	.0030	.1734	.0032
TURNPIKE DOUBLE	.1906	.0028	.1909	.0031	.2043	.0033
DOUBLE 27	.1757	.0027	.1745	.0029	.1867	.0031
TRIPLE 27	.2036	.0028	.2025	.0031	.2167	.0033
ILLINOIS						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1660	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024
INDIANA						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1660	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024
IOWA						
3 AXLE SINGLE UNIT	.1411	.0025	.1402	.0026	.1414	.0026
CONVENTIONAL SEMI	.1658	.0025	.1651	.0025	.1644	.0025
TURNPIKE DOUBLE	.1903	.0025	.1904	.0026	.1896	.0026
DOUBLE 27	.1764	.0024	.1765	.0025	.1758	.0025
TRIPLE 27	.2049	.0024	.2045	.0025	.2037	.0025

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX) (CONTINUED)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
KANSAS						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1660	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1704	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024
KENTUCKY						
3 AXLE SINGLE UNIT	.1316	.0026	.1411	.0027	.1439	.0028
CONVENTIONAL SEMI	.1647	.0026	.1643	.0027	.1676	.0028
TURNPIKE DOUBLE	.1904	.0026	.1905	.0026	.1943	.0027
DOUBLE 27	.1765	.0025	.1758	.0026	.1821	.0026
TRIPLE 27	.2041	.0026	.2034	.0027	.2080	.0027
LOUISIANA						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1660	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024
MAINE						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1660	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX) (CONTINUED)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
MARYLAND						
3 AXLE SINGLE UNIT	.1411	.0027	.1389	.0027	.1408	.0027
CONVENTIONAL SEMI	.1643	.0027	.1634	.0027	.1657	.0027
TURNPIKE DOUBLE	.1905	.0027	.1906	.0027	.1933	.0027
DOUBLE 27	.1758	.0026	.1762	.0026	.1787	.0026
TRIPLE 27	.2039	.0027	.2033	.0028	.2061	.0028
MASSACHUSETTS						
3 AXLE SINGLE UNIT	.1396	.0026	.1411	.0027	.1439	.0028
CONVENTIONAL SEMI	.1647	.0026	.1643	.0027	.1676	.0028
TURNPIKE DOUBLE	.1904	.0026	.1905	.0026	.1943	.0027
DOUBLE 27	.1765	.0025	.1758	.0026	.1821	.0026
TRIPLE 27	.2041	.0026	.2039	.0027	.2080	.0027
MICHIGAN						
3 AXLE SINGLE UNIT	.1411	.0025	.1402	.0026	.1414	.0026
CONVENTIONAL SEMI	.1658	.0025	.1651	.0025	.1644	.0025
TURNPIKE DOUBLE	.1903	.0025	.1904	.0026	.1896	.0026
DOUBLE 27	.1764	.0024	.1765	.0025	.1758	.0025
TRIPLE 27	.2049	.0024	.2045	.0025	.2037	.0025
MINNESOTA						
3 AXLE SINGLE UNIT	.1408	.0025	.1408	.0025	.1400	.0025
CONVENTIONAL SEMI	.1656	.0025	.1656	.0025	.1646	.0025
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1892	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1753	.0024
TRIPLE 27	.2047	.0024	.2047	.0024	.2035	.0024

TABLE A-5 FUEL FACTORS BY STATE, HIGHWAY TYPE AND SELECTED TRUCK TYPE (1977 TECHNOLOGY MIX) (CONTINUED)

	INTERSTATE		PRIMARY		SECONDARY & OTHER	
	FFC	VFC	FFC	VFC	FFC	VFC
MISSISSIPPI						
3 AXLE SINGLE UNIT	.1417	.0025	.1417	.0025	.1404	.0025
CONVENTIONAL SEMI	.1662	.0024	.1002	.0024	.1647	.0024
TURNPIKE DOUBLE	.1902	.0024	.1902	.0024	.1885	.0024
DOUBLE 27	.1764	.0024	.1764	.0024	.1748	.0024
TRIPLE 27	.2052	.0023	.2052	.0023	.2034	.0023
MISSOURI						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1680	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024
MONTANA						
3 AXLE SINGLE UNIT	.1398	.0030	.1419	.0032	.1558	.0035
CONVENTIONAL SEMI	.1611	.0031	.1604	.0033	.1761	.0036
TURNPIKE DOUBLE	.1910	.0033	.1911	.0034	.2098	.0037
DOUBLE 27	.1749	.0029	.1739	.0031	.1909	.0034
TRIPLE 27	.2018	.0033	.2014	.0034	.2211	.0037
NEBRASKA						
3 AXLE SINGLE UNIT	.1414	.0025	.1414	.0025	.1403	.0025
CONVENTIONAL SEMI	.1660	.0024	.1660	.0024	.1647	.0024
TURNPIKE DOUBLE	.1903	.0025	.1903	.0025	.1888	.0025
DOUBLE 27	.1764	.0024	.1764	.0024	.1750	.0024
TRIPLE 27	.2100	.0024	.2100	.0024	.2083	.0024