Federal Truck Size and Weight Study

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The report to Congress that has recently been prepared in response to a directive by the Congress to examine the need for, and desirability of, uniformity in maximum truck length and weight limits throughout the United States is summarized. Several alternative changes to federal limits on truck length and weight are investigated, and the impacts that these changes would have on truck productivity, modal diversion, freight costs, pavement and bridge costs, safety, energy, air quality, and noise are estimated. Also estimated was the present value of forecast cumulative changes in transportation and highway system costs. It was found that increases in truck length and weight limits within a substantial range provide sufficient transportation cost savings to pay for damage done to the highway system under changes in the limits. However, if limits are increased without a corresponding increase in highway system expenditures, then the condition of pavements and bridges in the United States would deteriorate, which would, in turn, affect the motor vehicle operating costs, travel speeds, and circuity experienced by highway users.

The federal government has been involved in the regulation of truck size and weight limits on the Interstate system since the passage of the Federal-Aid Highway Act of 1956. In the Federal-Aid Highway Amendments of 1974 the Congress set limits to truck size and weight by providing for 20,000 lb on a single axle, 34,000 lb on a tandem axle, and 80,000 lb for the gross vehicle weight (GVW); these limits are further controlled by a formula that limits the total weight in accordance with axle spacing.

As of January 1, 1981, six Mississippi Valley states (generally called the barrier states) had gross weight limits for the Interstate system at the lower levels provided for in federal legislation before 1974 (i.e., 73,280 lb). Five Mississippi Valley states plus Montana had axle limits less than the current federal limits of 20,000 lb for single axles and 34,000 lb for tandem axles on the Interstate system.

A much greater number of states have limits greater than the current federal Interstate standards under a grandfather clause provision of federal highway law. Most of the northeastern and southeastern states have higher axle limits, which are often even higher off the Interstate system. Higher gross limits are common among western states, particularly off the Interstate system. In addition, only 36 states allow the operation of "doubles" (tractor-semitrailer-trailer or truck-trailer) on some or all of their highways, 4 allow only a 60-ft length, and 2 permit only 55 ft.

This disparity in size and weight limits makes it difficult for truckers engaged in interstate hauling to operate efficiently. A trucker whose operations cross several state borders must either configure his rig to comply with the lightest axle or gross weight limits (and thus reduce payload) or route his trips to avoid states that have lower limits (and thus add time and mileage); either alternative results in higher costs per ton of cargo. A third alternative is to run illegally in states that have lower limits and accept the risks of detection and consequent delays and fines. Some truckers choose this alternative.

In response to these and other related problems, Section 161 of the Surface Transportation Assistance Act of 1978 directed the Secretary of Transportation to examine the need for, and desirability of, uniformity in maximum truck size and weight limits throughout the United States. A summary of the report to Congress (1,2) that was prepared in response to this directive is presented in this paper.

APPROACH

The federal truck size and weight (TS&W) study analyzes the impacts of changes to federal limits on truck length and weight under 10 alternatives, or scenarios, that specify truck size configurations and weight limits to be evaluated, as well as the extent of the highway system to which the limits would apply and the degree of required conformity by the states. These 10 scenarios consist of a base case and 5 categories of changes in current federal truck length and weight limits.

The base case is an extrapolation to 1985 of recent trends in truck activity, with no changes in the federal or state limits that were in effect on January 1, 1981. It serves as a benchmark against which benefits and costs for the various scenarios are compared. The five categories of changes in limits are

1. Grandfather clause elimination,
2. Barrier elimination,
3. Uniformity (eliminate barriers and grandfather clause),
4. Rollback to pre-1974 limits (retain grandfather clause), and
5. Increases in limits (eliminate barriers and retain grandfather clause).

The data in Table 1 describe the scenarios. January 1, 1981, truck width limits are assumed to remain in effect for all scenarios because proposals to increase truck width were not under active consideration when this study was initiated.

All impacts are expressed in terms of changes from the base case. They have been estimated as annual costs for 1985 for all impacts, except for costs for reconstruction of existing bridges, which are one-time costs.

In order to provide a uniform basis for comparing scenarios to the base case the present value of forecast cumulative changes in costs has been calculated for each scenario. These present values have been calculated by summing all projected future impacts (cost changes from the base case for all future years) and discounting them by 10 percent/year in real terms.

Findings are reported at the national level for all impact areas. In addition, regional results are reported for some of the most significant impacts. The regions are mapped and defined by name in Figure 1. The regions have been defined so as to group contiguous states with relatively similar current TS&W limits. This has been done in order to facilitate the analysis and reporting of impacts of possible changes in federal limits, including the impacts of achieving greater uniformity.

The state TS&W limits as of January 1, 1981, can be characterized by region as follows (federal limits apply unless otherwise indicated):

1. Northeast--high axle limits; 65-ft doubles are not permitted (except in Delaware and Maryland);
2. Southeast--high axle limits (except in Virginia and West Virginia); 65-ft doubles are not permitted (except in Florida);
3. Mideast--65-ft doubles are permitted; Michigan has very high GVW limits;

Table 1. Definitions of TS&W scenarios.

Scenario	Short Title	Affected Highway System	Definition
A	Base case		Current federal TS&W limits and current state limits
B	Grandfather clause elimination	Interstate	Elimination of all grandfathered limits on the Interstate system
C	Grandfather clause elimination	Interstate and primary	Elimination of all grandfathered limits on the Interstate and primary systems
D	Barrier (weight only) elimination	Interstate	Elimination of all weight barrier limits on the Interstate system
E	Barrier (weight and length) elimination	Interstate	Same as for D, but also includes elimination of all length limits of less than 65 ft for all combinations permitted by a state on the Interstate system
F	Barrier elimination	Interstate and primary	Strengthens E by extending federal limits to primary system and by eliminating states' power to prohibit doubles of up to 65 ft
G	Uniformity	Interstate and primary	Elimination of all grandfathered limits and all limits below those specified in Section 127 (the barrier limits) on the Interstate and primary systems; also, length limits must be at least 65 ft on all combinations permitted by a state
H	Rollback	Interstate and primary	Reduces all federal limits to pre-1974 levels and extends applicability to primary system
J	Increased weights	Interstate and primary	Increases federal axle weight limits to higher levels prevailing in several states; removes GVW limits, but substitutes higher bridge formula C for current formula B; prohibits barrier limits; and extends applicability to primary system
K	Low axle, formula A	Interstate and primary	Eliminates GVW limit to permit heavier trucks, but limits these trucks by the lower pre-1974 axle limits and bridge formula A; prohibits length limits for combinations of less than 65 ft; prohibits barrier limits; and extends applicability to primary system

Figure 1. Regions used in TS&W study.

4. Southern barrier--lower axle limits and GVW limits (73,280 lb); 65-ft doubles are not permitted;
5. Midwestern barrier--lower GVW limits (73,280 lb) and lower axle limits (except in Illinois); 65-ft doubles are permitted;
6. North Central--65-ft doubles are permitted;
7. West Central--65-ft doubles are permitted; higher GVW limits on other primary highways; Nebraska has low axle limits, low GVW limits on the Interstate, but allows high GVW on the Interstate by permit; Wyoming and Colorado have high axle limits for tandems;
8. Southwest--65-ft doubles are permitted; New Mexico has high axle limits and GVW limits;
9. Northwest--65-ft doubles are permitted; high GVW limits on other primary highways and by permit on Interstate;
10. Alaska--65-ft doubles are permitted; high GVW limit; and
11. Hawaii--65-ft doubles are permitted; high single-axle limit; high GVW limit on other primary highways.

DISCUSSION OF SCENARIOS

Truck Productivity

From the perspective of users of trucks there is great economic value in having the flexibility to choose vehicles and vehicle loadings that will meet their needs effectively and at a lowest cost. Increases in TS&W limits will increase the allowable tonnage and volume of freight (per trip) that can be carried. Under these circumstances fewer trips and vehicle miles of travel (VMT) will be required to carry the same amount of freight. This improvement in truck productivity reduces truck costs. Conversely, decreases in TS&W limits will increase trips and VMT and result in an increase in truck costs. The cost savings or cost increases will accrue to truckers, shippers, receivers, and consumers. The portion of cost savings or increase that each group receives depends primarily on the competitiveness of the affected markets.

The effects of the TS&W scenarios on truck productivity, as measured by the impact on the truck freight cost per ton-mile, are shown in Figure 2.

Elimination of the grandfather clause in scenarios B and C results in a worsening of truck productivity in those states with limits that currently exceed the federal standard.

The elimination of barrier limits in the six Mississippi Valley states with limits lower than the federal standard results in truck productivity improvements for shipments into, within, and through these states. Extending the elimination of barrier limits from just the Interstate system (as in scenarios D and E) to both the Interstate and primary systems (as in scenario F) results in substantially larger improvements in truck productivity.

Scenario G (the establishment of uniform TS&W limits by eliminating both the grandfather clause and barrier limits on both the Interstate and primary systems) results in improved productivity for shipments into, within, and through the barrier states, and worsened productivity for shipments in states with grandfather clause limits. The net effect of these changes is a modest improvement in truck productivity.

Scenario H (the rollback of truck size and weight limits to pre-1974 levels) results in a worsening of truck productivity, primarily because the payloads carried by many trucks would have to be reduced. This decrease in payloads in turn results in more vehicle miles being required to carry the same amount of freight and correspondingly higher truck freight costs.

Scenario J (increased weight limits) results in a substantial decrease in truck cost per ton-mile because it allows carriers to load existing trucks more heavily and, in some cases, to shift to different truck configurations that have higher average payloads. The shaded portion of the bar for scenario J in Figure 2 (and in later figures) represents the range of impacts for two variations of scenario J. These two variations differ only moderately in impacts to truck productivity and transport cost. They differ substantially in terms of pavement costs, however, and are discussed in the section on Pavement Impacts.

Scenario K also assumes the elimination of gross weight limits to permit heavier overall loads. Nevertheless, the lower pre-1974 axle limits and lower bridge formula A would be applied to these heavier trucks in order to reduce their impacts on pavements and bridges. This scenario results in cost savings due to productivity improvements about one-tenth the size of those for scenario J.

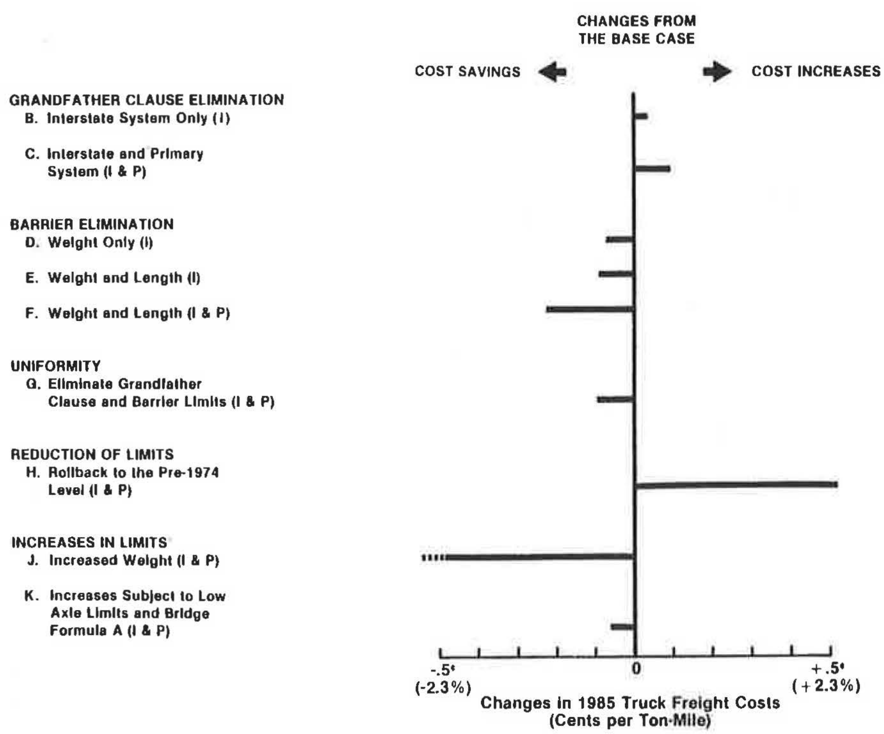
Modal Diversion

Choice of mode is only moderately sensitive to shipping costs and rates compared with other components of overall distribution costs and quality of service (including handling costs, reliability, security, and inventory costs). However, changes in TS&W limits will have little effect on these other components of distribution cost and quality of service because shipping costs and rates are the principal modal-choice factors that would be affected by TS&W limit changes.

Changes in truck costs and rates result in some change in the selection of transport mode for some shipments. The most significant effect would be on competition between rail and truck. Higher truck rates would result in the diversion of some shipments to rail whereas lower truck rates would have the reverse effect. Changes in truck costs and rates could also have some slight effect on barge traffic (by affecting the competitiveness of truck and barge transport with rail transport) and on air traffic, but these effects on modal competition are considered to be minor, and they have not been analyzed in this study.

The effects of the alternative scenarios on rail traffic (billions of short-line ton-miles) are shown in Figure 3. The data in the figure indicate that the six scenarios that would reduce truck transport costs will also result in moderate diversion of traffic from rail to truck. The greatest effect would occur in scenario J, in which it is estimated

Figure 2. Scenario impacts on truck productivity.



that rail traffic would decline by about 27 billion ton-miles, or about 2 percent of 1985 base case rail traffic. Only a small amount of diversion from truck to rail will occur in the case of the grandfather clause elimination scenarios, and a moderate amount of diversion (about 13 billion ton-miles) will occur in the case of reduced weight limits.

Total Freight Costs

The effects of the scenarios studied on total (truck and rail) freight costs are shown in Figure 4. The impacts shown are the net effect of changes in truck productivity and diversion to or from rail.

The scenarios that improve truck productivity (D,

Figure 3. Scenario impacts on modal diversion.

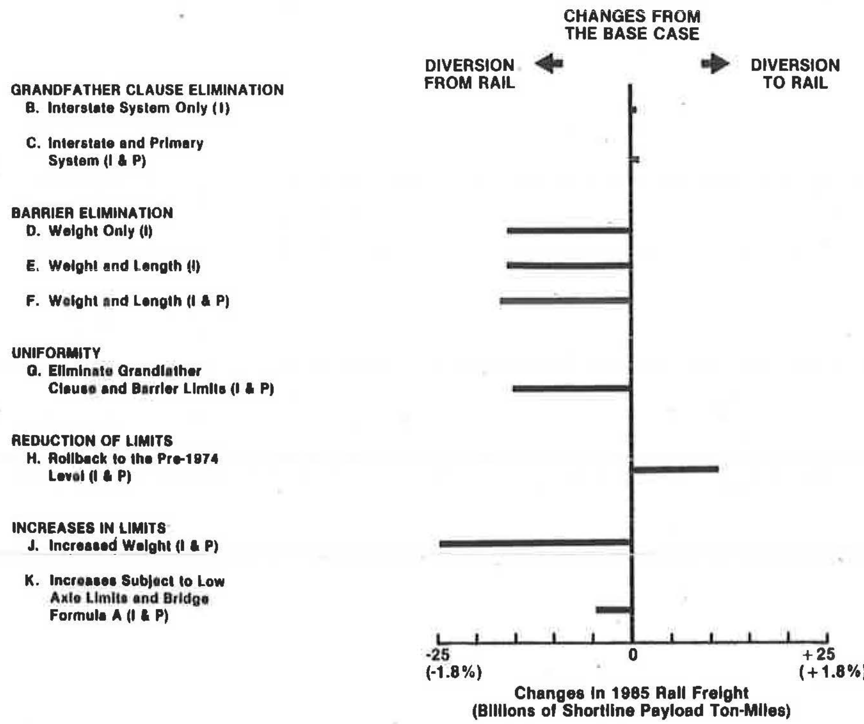
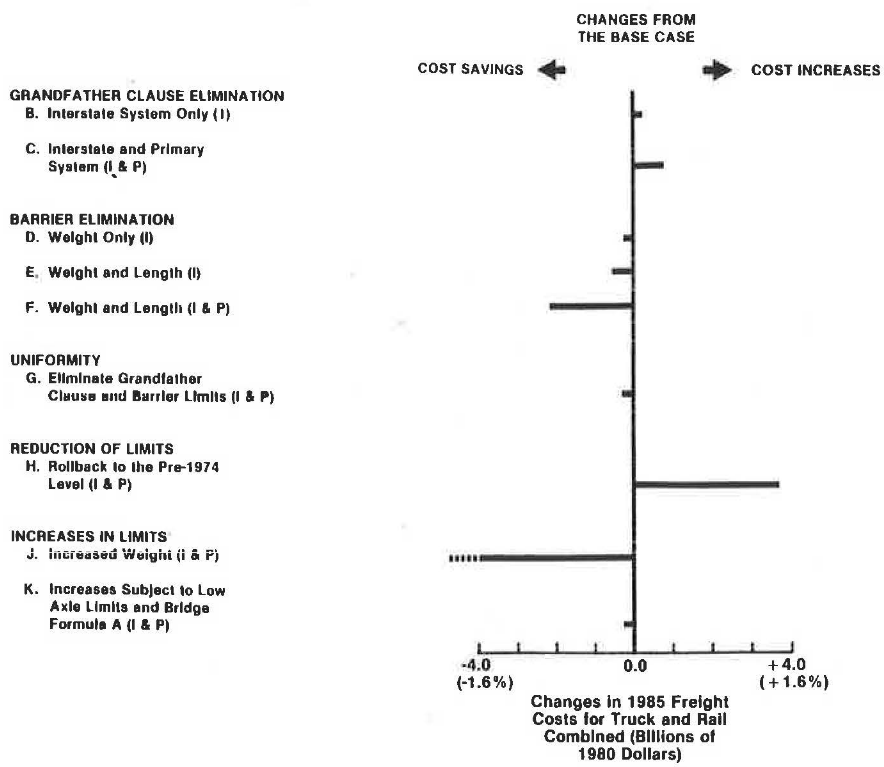


Figure 4. Scenario impacts on total freight costs.



E, F, G, J, and K) result in lower total freight costs for truck and rail combined. The scenarios that worsen truck productivity (B, C, and H) result in higher total freight costs for truck and rail combined. However, in both cases the magnitude of the changes in total freight costs is less than that due to changes in truck productivity alone.

For those scenarios that improve truck productivity, some of the cost savings due to improved productivity will be offset by cost increases due to diversion from rail to truck. Many shippers who shift from rail to truck may do so even though the shift results in increased shipping costs. Many shippers are willing to shift despite increases in their freight costs because truck offers shorter shipment times and more reliable delivery dates than rail. Conversely, for those scenarios that worsen truck productivity, some of the cost increases due to worsened truck productivity are offset by cost savings due to diversion from truck to rail. However, those shippers who shift from truck to rail lose the shorter shipment times and more reliable delivery dates associated with truck transport. In balance, the effect of scenarios B, C, and H on those shippers who shift to rail is negative because they would choose to ship by truck in the base case and would shift to rail only when truck weight limits are decreased. The data in Figure 4 present only the net effects of all these factors.

Pavement Impacts

Highway pavements are affected by changes in the number of trucks and truck axle weights. Pavement wear increases sharply with increases in axle weights. Thus higher axle weight limits tend to accelerate pavement wear, even though they reduce truck miles by allowing higher average payloads.

Accelerated pavement wear affects the expenditure levels required by highway agencies to maintain the condition of the highways, primarily as a result of increased pavement maintenance costs and requirements for more frequent or costly pavement overlays.

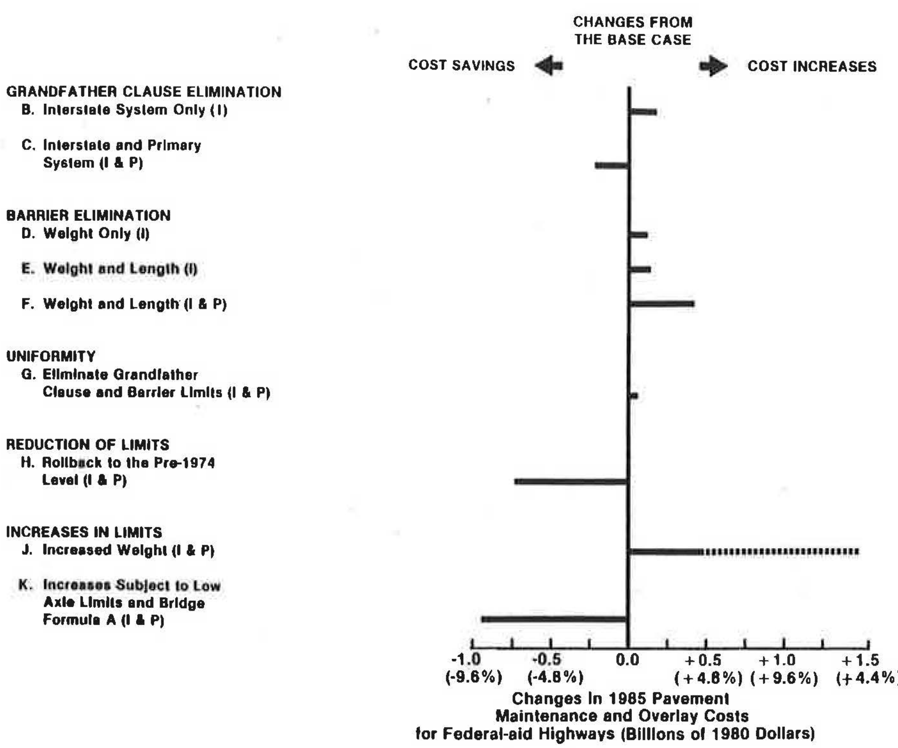
Although relatively little factual data exist regarding recent trends in national average pavement conditions, the general consensus is that states have not been able to meet requirements to hold average conditions constant. For those scenarios that would involve substantial additional requirements, doubt exists as to the ability of the states to respond adequately. Inability to meet these requirements would result in greater long-term pavement resurfacing costs and increased vehicle operating costs.

The impacts of the TS&W scenarios on the pavement maintenance and overlay requirements in 1985 are shown in Figure 5. These estimates are based on the amount of work required to maintain the current conditions of the Federal-Aid highways. No analysis of impacts has been conducted for non-Federal-Aid highways, principally because both data and theory are lacking for many of them. Because non-Federal-Aid highways are typically low-volume roads, the pavements for these highways often reflect standard minimum designs; these pavements usually provide greater load-carrying capacity than the traffic that uses the highway requires. These minimum pavement designs are constructed principally to withstand non-traffic-related damage (e.g., environmental effects), and modest changes in truck traffic should have little effect on most of these highways. Nevertheless, because non-Federal-Aid highways comprise most (80 percent) of the highways in the United States, modest incremental cost changes can amount to significant costs. In a small proportion of these highways that carry high-volume heavy truck traffic (e.g., coal-haul roads), weight increases can cause major pavement cost increases, particularly on routes that have low-quality pavements.

In summary, the overall national effect of limiting pavement impacts to Federal-Aid highways is probably a fairly small underestimate of national costs, but the effects on a small proportion of the routes may be quite significant.

Generally, those scenarios that allow higher axle weights result in more pavement costs. The excep-

Figure 5. Scenario impacts on pavement costs.



tion is the elimination of the grandfather clause on the Interstate system. Under this scenario some trucks would divert from the Interstate system to other Federal-Aid primary highways so that they could continue to take advantage of grandfather clause limits. Thus, although truck weights on the Interstate system would decrease (producing a reduction in Interstate system pavement costs), truck weights on other primary highways would increase, thereby producing an increase in pavement requirements on these highways. The net result is a small increase in pavement costs.

Scenario F, which eliminates barrier limits on both the Interstate and primary systems, produces a large increase in pavement requirements. Under this scenario pavement maintenance and overlay costs would be about 4 percent higher than under the base case. In the barrier states pavement maintenance and overlay requirements would increase by about 14 percent over the base case.

Scenario J, which would allow the largest increases in axle weights, results in the largest increase in pavement requirements. Two variations of scenario J were analyzed: the increase in pavement requirements might be as little as that shown by the solid bar in Figure 5 or as great as that shown by the shaded bar.

In the first variation a substantial amount of freight traffic would shift from tractor-semitrailers to short heavyweight doubles, which have more axles than tractor-semitrailers (doubles with short trailers that have tandem axles). Although a fully loaded short heavyweight double weighs more than a fully loaded tractor-semitrailer, its weight is spread over more axles; therefore, it does less damage to pavements than the tractor-semitrailer. Under this variation pavement cost increases would be about $350 million.

If the projected shift to short heavyweight doubles does not materialize, the impacts of scenario J on pavement requirements could be substantially worse. To quantify this effect, a second variation on scenario J was analyzed for pavement impacts. In this variation there is no shift of freight movement between truck types. The only effects are that trucks run heavier to take advantage of the more permissive weight limits, and some traffic will shift from rail to truck. In this variation, the impact of scenario J on 1985 pavement maintenance and overlay requirements jumps to about $1.5 billion, almost 14 percent higher than would be required to maintain and overlay pavements to the constant average condition in the 1985 base case.

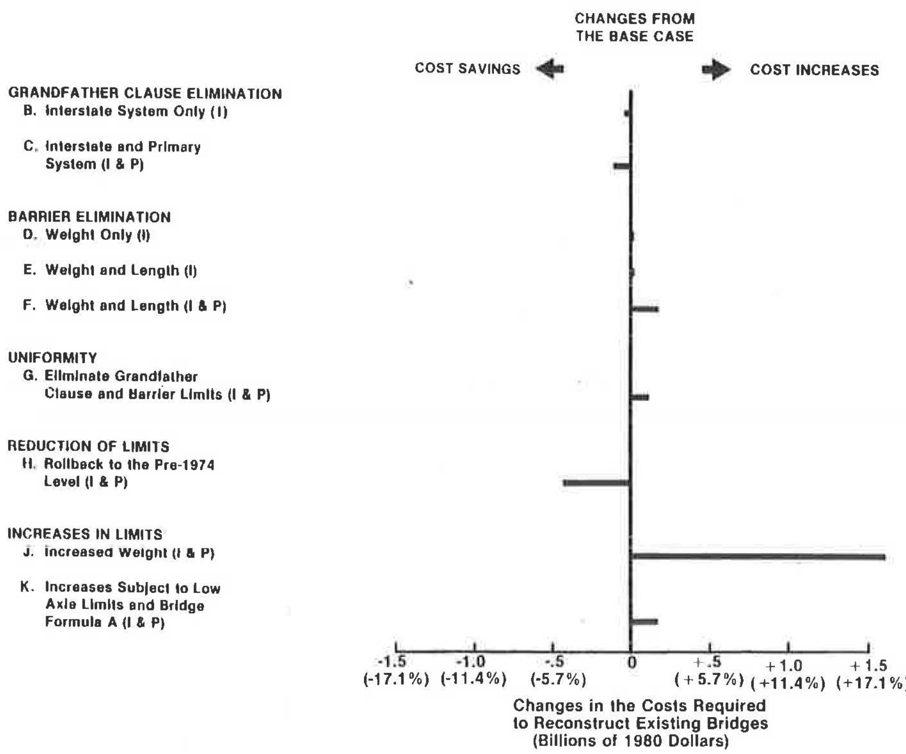
Bridge Impacts

The structural members of bridges are affected by GVW and axle spacings. Bridges are designed to withstand overstresses, but repeated applications of loads beyond those assumed in bridge design will produce adverse cumulative effects that may require that the bridge be rebuilt or posted to prohibit heavier trucks.

The impacts of each TS&W scenario on costs required to reconstruct those existing bridges that would have inadequate load-bearing capacities under each scenario are shown in Figure 6. The cost impacts for existing bridges have been calculated based on the assumption that all bridges that cannot carry legal loads (within permissible overstress criteria) under each scenario would be reconstructed. The costs for reconstruction of existing bridges are one-time costs. However, several years would transpire before the full impacts would be experienced, and several years would be required to finance and obligate these expenditures. Accordingly, it was assumed that these expenditures would be spread evenly over the 5-year period from 1981 to 1985.

The percentages given in Figure 6 indicate the bridge cost impacts as a percentage of projected capital outlay for bridges on state-administered highways over this period. However, note that states may choose to post bridges (or otherwise re-

Figure 6. Scenario impacts on bridge costs.



strict use to lighter vehicles) as an alternative to reconstruction. Through posting, states can save, or at least postpone, bridge reconstruction costs. The disadvantages of posting (as an alternative to reconstruction) are difficulty of enforcement and added circuity of truck travel, which results in higher goods movement costs and higher fuel consumption.

Scenario J results in the largest increase in bridge costs for any of the scenarios analyzed. Bridge costs would increase in all regions under this scenario. The largest increases would occur in barrier states and in those states that currently allow doubles but restrict gross weights to levels at or below the federal limit of 80,000 lb. Under scenario J short heavyweight doubles that weigh about 105,000 lb would become legal. This type of truck would exceed permissible overstress criteria for many long span bridges with low design loads.

The largest savings in bridge costs would occur under scenario H, under which TS&W limits are rolled back to pre-1974 levels. Bridge costs under this scenario would be reduced in all regions except the barrier states, where the GVW limit is currently 73,280 lb, as it was before 1974.

The impacts of TS&W scenarios on costs required to construct new bridges so that they can handle projected traffic loadings have also been estimated. These impacts tend to parallel cost impacts for existing bridges in terms of the relations among scenarios, but they are far smaller in magnitude.

Safety Impacts

Safety impacts of changes in TS&W limits result from changes in the number of truck trips and the types of trucks used. Increases in TS&W limits tend to increase truck payloads and allow a given volume of freight to be moved with fewer trips. This effect tends to decrease the highway users' exposure to truck accidents. However, improvements in truck productivity associated with increases in TS&W limits create the potential for diversion of freight to trucks from other modes. In many cases the amount of freight diverted is of sufficient magnitude to produce a net increase in accidents.

One of the most contested issues in analyzing the safety impacts associated with TS&W limits is whether accident rates for double trailer trucks are higher than the rates for tractor-semitrailers. Recent safety studies produce conflicting results on this issue: some indicate substantially higher accident rates for doubles, and others indicate no appreciable difference in the accident rates of doubles and tractor-semitrailers.

An intensive examination of truck safety conducted by Bio Technology, Inc. (3) has recently provided evidence from selected highway test sections indicating that accident rates for double trailer trucks are appreciably higher than the rates for tractor-semitrailers. This study, and in particular this conclusion, has been highly criticized by the trucking industry, which has alleged that there are a number of flaws in the study methodology and that the results cannot be used to draw general conclusions regarding the comparative rates of different truck configurations.

The changes in total accidents under each scenario are shown in Figure 7. Two sets of impacts are shown because wide disagreement exists regarding the relative safety records of different types of combinations. The most significant difference in the assumptions of the two results shown in Figure 7 is that the first set of results (the striped bars) assumes that doubles have substantially higher accident rates, and the second set of results (the solid bars) assumes that doubles have the same accident rates as tractor-semitrailers. There are studies that support both assumptions.

Energy Impacts

An increase in the size and weight limits would permit trucks to transport more freight with only a slight increase in fuel consumption. Total freight transported per gallon of fuel would thus rise.

Figure 7. Scenario impacts on safety.

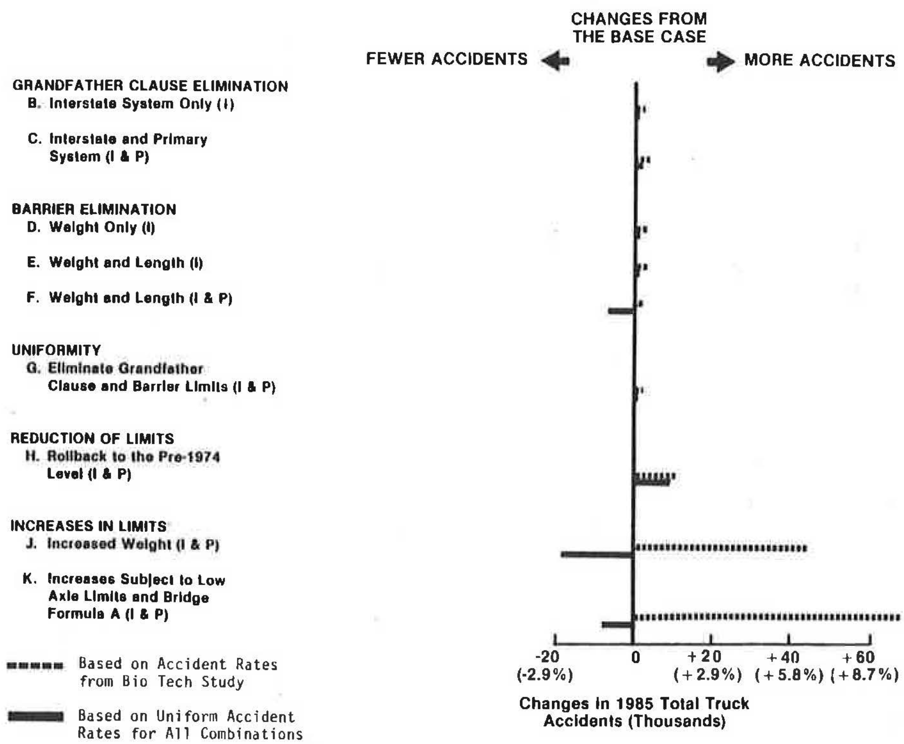


Figure 8. Scenario impacts on energy consumption.

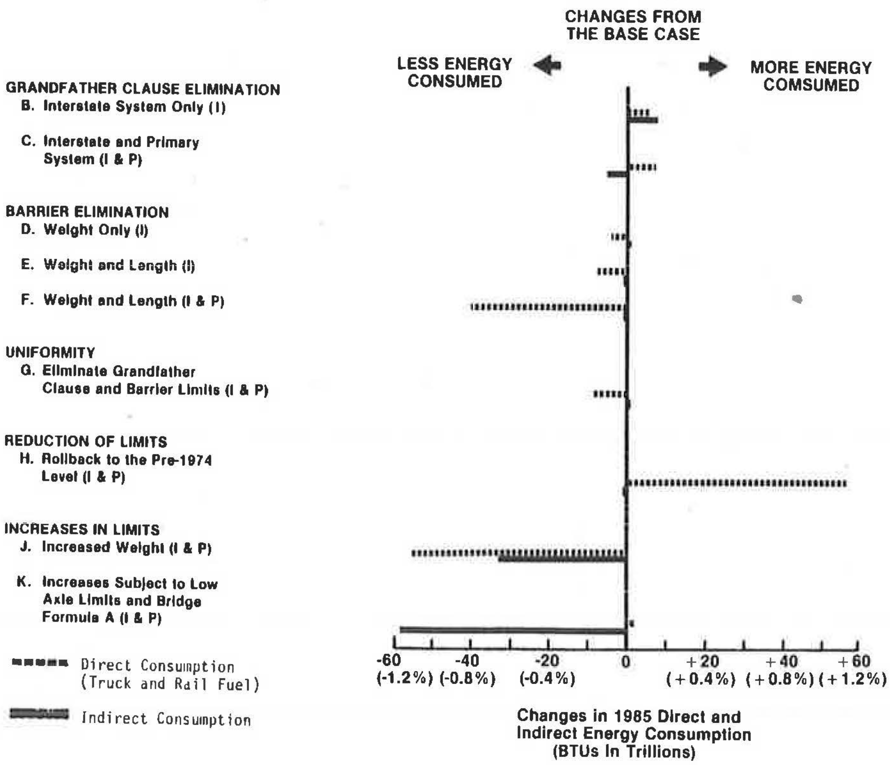


Table 2. Scenario impacts on air quality.

Scenario	Change in Emissions from Heavy-Duty Vehicles and Rail Freight Operations (%) Hydrocarbons	Nitrogen Oxides	Carbon Monoxide	Particulates
B	+0.17	+0.15	+0.17	+0.15
C	+0.34	+0.38	+0.41	+0.37
D	-0.68	-0.32	+0.25	-0.29
E	-0.71	-0.37	+0.13	-0.34
F	-1.27	-1.18	-1.00	-1.13
G	-0.63	-0.39	-0.06	-0.32
H	+1.34	+1.44	+1.56	+1.46
J	-2.30	-2.68	-3.12	-2.62
K	-1.03	-1.23	-1.49	-1.20

This improvement in fuel efficiency, however, would be offset somewhat by diversion of traffic to trucks from the more fuel-efficient rail mode. Higher weight limits may also result in increases in energy consumed in paving and maintaining the highway system.

The impacts of the scenarios analyzed on direct energy consumption (truck and rail fuel) and on indirect energy consumption are shown in Figure 8. Indirect energy is primarily the energy required for pavement overlays, but it also includes energy consumed in road maintenance, bridge construction and repair, and production of fuel, as well as energy embodied in vehicles and parts. (In the case of scenario J the bars shown in Figure 8 represent the impacts expected for the variation involving a major shift of payload to short heavyweight doubles. Each of the two bars would be slightly shorter--perhaps about 10 percent shorter--but in the same direction for the variation that involves no shift of truck payload to short heavyweight doubles.)

The data in Figure 8 indicate that the gains in truck fuel efficiency due to increases in TS&W limits are generally dominant by comparison with the offsetting effects of rail-to-truck loss of fuel efficiency and added pavement requirements.

Air Quality Impacts

The impact of each TS&W scenario on hydrocarbon, nitrogen oxide, carbon monoxide, and particulate emissions from heavy-duty trucks and rail freight operations is given in Table 2. Increases in TS&W limits would generally reduce emissions slightly, and decreases in TS&W limits would increase emissions slightly, because emissions are closely correlated with changes in truck miles.

The largest increases in emissions for heavy-duty vehicles and rail freight operations would result from scenario H (the rollback scenario), ranging from 1.34 percent for hydrocarbons to 1.56 percent for carbon monoxide.

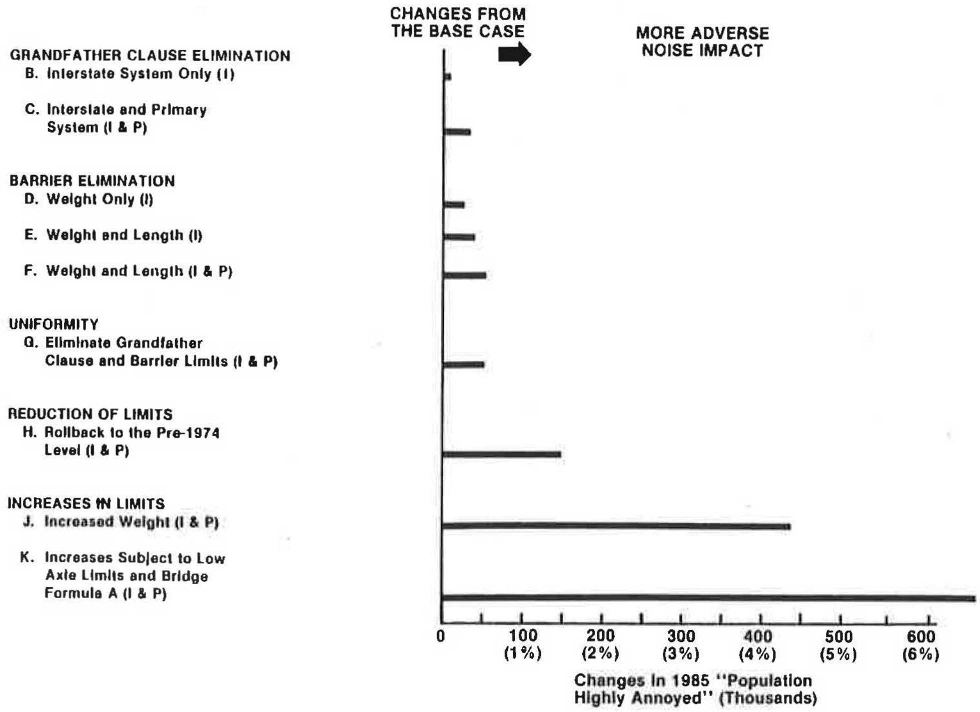
The largest decreases would result from increases in TS&W limits in scenario J, ranging from 2.30 percent for hydrocarbons to 3.12 percent for carbon monoxide.

Noise Impacts

Noise impacts of each TS&W scenario have been estimated based on an analysis of vehicle and traffic conditions for typical road segments and an empirical relation developed by the U.S. Environmental Protection Agency (EPA), which relates noise levels to the fraction of residents who describe their reaction to noise as highly annoyed. Community response to noise is difficult to capture in a single measure, so "population highly annoyed" should be regarded as a somewhat abstract index of the relative community noise impact.

Some adverse noise impacts relative to the base case are expected for all scenarios, as shown in Figure 9. For those scenarios that decrease TS&W

Figure 9. Scenario noise impacts.



limits, the adverse effects would be due to an increase in truck miles. For those scenarios that increase TS&W limits, the adverse effects occur because, even though total truck travel decreases, large increases in average load and number of axles significantly increase noise exposure. Due to the predominance of this effect, scenarios J and K result in more adverse noise impacts than other scenarios.

Economic Impacts of Grandfather Clause Elimination

The grandfather clause is a provision of federal highway law that permits all states to retain any limits above the federal limits if such limits were in force before the effective date of the federal limits (July 1, 1956). As of January 1, 1981, 15 states still had Interstate system single-axle limits greater than 20,000 lb, 17 states had Interstate tandem-axle limits greater than 34,000 lb, and 12 states had Interstate gross limits greater than 80,000 lb.

Elimination of the grandfather clause would result in a worsening of truck productivity (as shown in Figure 2) and an increase in overall transport costs (as shown in Figure 3). These cost impacts, which are small in percentage terms when spread over all commodities and industries, may actually involve substantial impacts on particular industries. For this reason a special investigation was conducted to determine which specific industries would be affected and by how much.

In most instances the increased costs will be small in relation to the value of the goods transported. These increased costs will result in a slight price increase to consumers or a slight decline in receipts of affected producers or shippers. In the case of industries that ship commodities with a low value per ton (e.g., agriculture, logging, construction), increased truck transport costs would represent a higher percentage of commodity value (perhaps 1 or 2 percent, and in a few instances as much as 10 percent).

Discernible economic effects due to reduced weight limits on the Federal-Aid primary system are most likely to be observed in the following areas.

1. In southern Idaho, Montana, and western North Dakota, farmers whose wheat is currently transported to Lewiston, Idaho, in double-bottom trucks (about 10 percent of total production) may have their receipts decline by up to 3 percent. Some additional dislocations might occur due to resulting adjustments in the grain marketing system.
2. In Michigan several commodities will be affected by a reduction of the current 164,000-lb effective GVW limit on designated highways to 80,000 lb. Sugar beets is likely to be the most affected commodity. Among the economically more important commodities, timber and to a lesser extent corn are likely to be the most affected. Increased transport costs for affected shipments of corn (about 10 percent of corn produced in Michigan) will average less than 1 percent of the price of corn.
3. In Nevada and Utah the current limits are 129,000 and 122,000 lb, respectively, and the existing rail network is limited. Reduction of these high limits could affect some mines, particularly those in remote locations.
4. In Alaska only one rail line and no Interstate highways exist; a 109,000-lb GVW limit applies to other roads.
5. In several eastern states particularly high limits exist for three- and four-axle single-unit trucks. In states where the highest of these limits exist overall costs for individual highway construction and maintenance projects that must be accessed by roads to which reduced weight limits apply are likely to increase by about 2 percent. The cost of highway projects that do not require such access will increase by less, if at all. (These changes do not reflect the savings in highway costs due to reduced requirements for pavement construction and maintenance reported for scenario C in Figures 5 and 6.) The cost of other affected construction projects in these states will be increased to a lesser extent.

If reduced weight limits are applied only to the Interstate system, fewer construction projects and minerals movements will be affected, and a number of states that do not have high limits on the Interstate system will be unaffected.

PRESENT VALUE OF CUMULATIVE COST CHANGES

All of the cost impacts discussed in the preceding sections are annual impacts for 1985, with the exception of the costs for existing bridges, which are a one-time cost for reconstruction of existing bridges on Federal-Aid highways.

Cost impacts for years before 1985, as well as future years, will not generally be at the same levels shown for 1985. For example, the increases in pavement costs shown in Figure 5 will not be sustained indefinitely. Once highway pavements have been adequately rehabilitated to accommodate heavier trucks, adverse pavement cost impacts will be reduced to a small fraction of those shown in Figure 5 for 1985.

The present value of forecast cumulative changes in highway costs for each scenario as compared with the base case is shown in Figure 10. The cumulative cost changes reflect pavement and bridge cost impacts in years before 1985 as well as in all future years. Scenario J, which would allow the largest increases in axle weights, results in the largest increase in the present value of highway cost impacts. The increase in highway costs in scenario J may be as little as \$2.6 billion if the shift to short heavyweight doubles materializes, or as large as \$6.4 billion if it does not.

The cumulative highway cost changes shown in Figure 10 would have to be borne by highway agencies, and presumably should be passed on to trucks through user charges in an equitable manner. These cost changes are calculated as the requirements for highway agency expenditures necessary to maintain current highway condition. If this expenditure does not occur (e.g., if expenditures by highway agencies remain the same under each scenario), then the condition of the pavements and bridges would deteriorate, which would in turn affect the motor vehicle operating costs, travel speeds, and circuity experienced by highway users.

The costs to highway users associated with a worsening of highway conditions can be substantial. For example, if highway agency expenditures for pavement overlays under scenario J are the same as those projected for the base case, then scenario J would produce a worsening of pavement condition. The present value of the cumulative changes in motor vehicle operating costs alone due to this worsening of pavement condition could be on the order of \$17 billion. Thus if highway agencies are unable to meet the expenditure levels to maintain highway conditions under each scenario, cumulative cost changes due to highway system damage could be considerably greater than those shown in Figure 10 for those scenarios that result in additional pavement requirements (i.e., B, D, E, F, G, and J). The distribution of these costs among the states are not uniform and vary according to the scenario.

The present value of forecast cumulative cost changes for freight transportation, including changes in expenditures for truck and rail freight transportation and property damage due to accidents is shown in Figure 11.

The present value of forecast cumulative cost changes for highways and transportation combined is shown in Figure 12. Freight transportation costs tend to be the dominant component. Scenarios D, E, F, and G, which would eliminate barrier limits, and scenarios J and K, which would increase limits, all show cost savings relative to the base case for highway and transportation costs combined. The practical implication of this finding is that elimination of barriers or increases in TS&W limits

Figure 10. Present value of highway cost impacts.

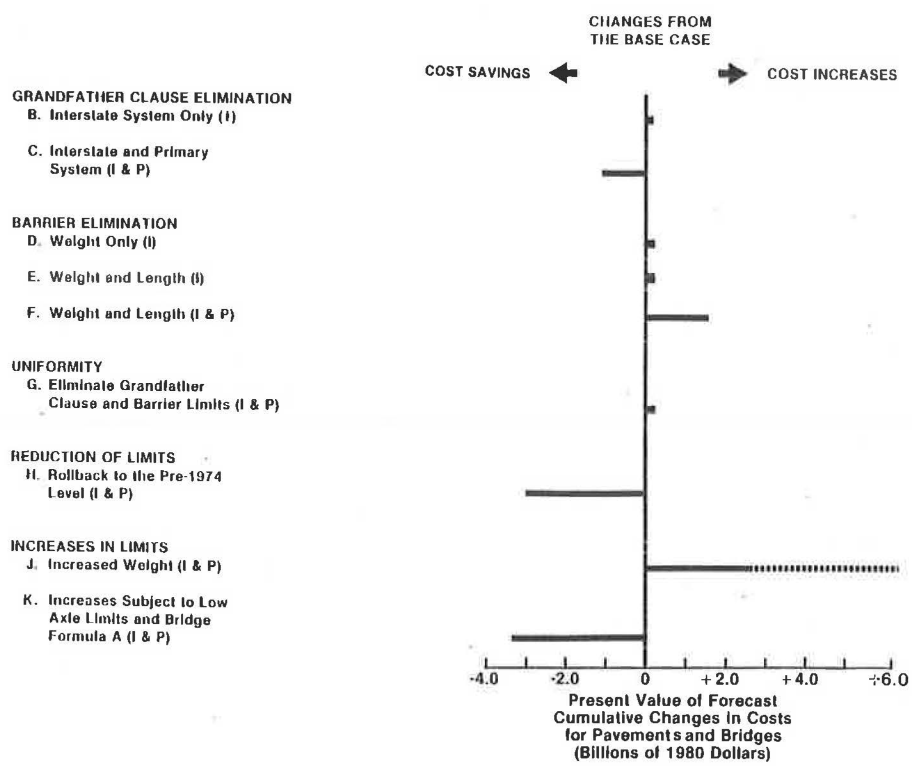


Figure 11. Present value of transportation cost impacts.

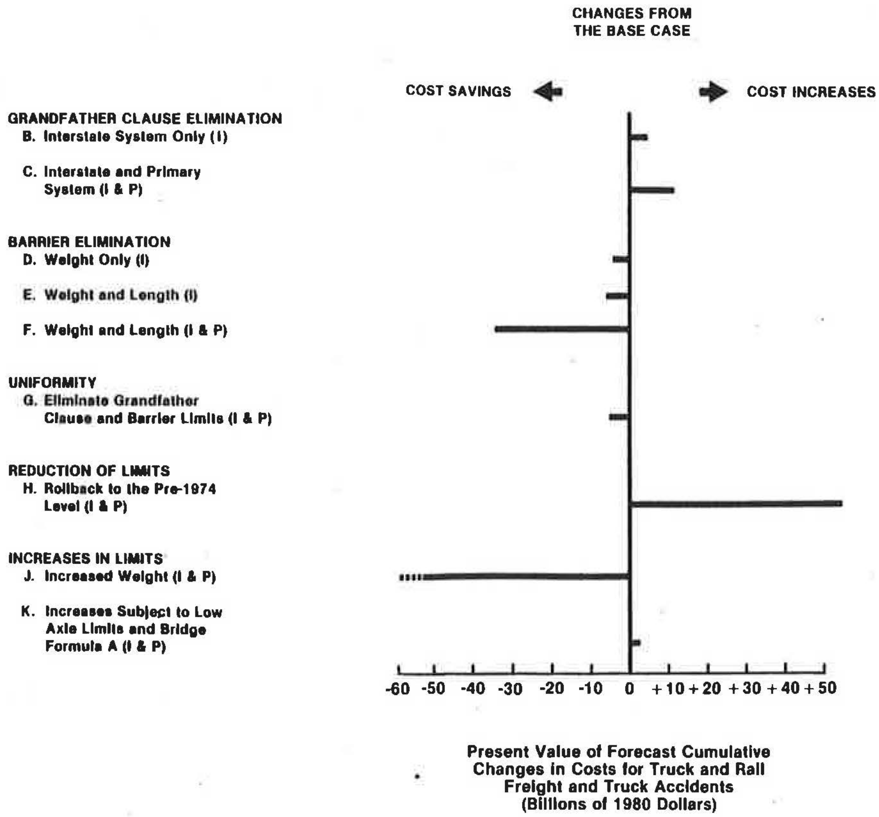
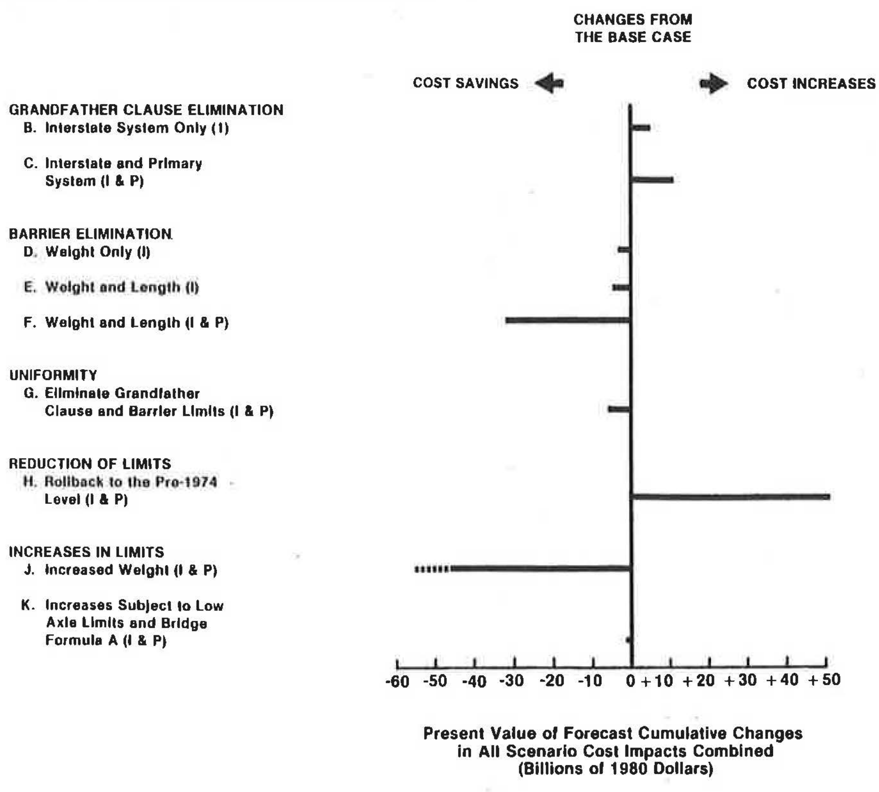


Figure 12. Present value of all scenario cost impacts.



provide sufficient transportation cost savings to pay for damage done to the highway system under these scenarios. However, if barriers are eliminated or limits are increased without a corresponding increase in expenditures to maintain highway conditions, the net impact of these actions could be a much lower decrease, or even an increase, in total cumulative costs.

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Truck Weight Study Sampling Plan in Wisconsin

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The procedures used by the Wisconsin Department of Transportation for determining the number and locations of sampling stations for its truck weight study are described. The purpose of the program is to collect representative trucking characteristic data for use in pavement design, highway cost allocation, motor carrier enforcement, and other planning and research activities. Previous weight studies have produced data of limited value due to inadequate road type and geographic coverage. In addition, stations are selected without statistical guidelines for sampling. The use of new weighing-in-motion technologies and the emphasis on the collection of basic weight data permit a more random selection of weigh stations and a more comprehensive sample of truck traffic. The sampling plan developed relies heavily on user needs and statistical criteria to help ensure a valid and meaningful sample. By using data from the 1980-1981 highway performance monitoring system Wisconsin truck weight case study, the number of required stations is calculated on the basis of the average variability of truck weights in the state. These stations are distributed across recommended road types in proportion to the size of the total population (truck vehicle miles of travel) on each road type. Stations by road type are assigned to counties by using a weighted random numbers procedure. Criteria are presented for selecting corridors and sites where stations should be established. This type of sampling approach can generate more representative and comprehensive data that better describe the truck population.

Most states, including Wisconsin, determine the number and location of their truck weight study stations on essentially a nonprobability, nonrandom basis. The number of stations operated may be a function of budget constraints. Station locations may be selected for convenience, to minimize travel expenses, or to provide perceived coverage of major truck routes. They may also be limited to certain permanent static scale locations.

The resulting data from the study may be representative, but there is no way of making such a determination. Only with some type of probability sample can definitive statements be made about the statistical validity of the sample. It may well be that cost or technological limitations will be the ultimate determinant of sample design. Within cost and operational constraints, though, it is critical to encourage the greatest possible use of statistical criteria. The flexibility and lower operating costs of new weighing-in-motion technology make such an approach more feasible.

The Division of Planning and Budget of the Wisconsin Department of Transportation (WisDOT) normally conducts a truck weight study every other year. The truck weight study collects a variety of trucking characteristic data by weighing and classifying trucks and interviewing the drivers of trucks on rural Interstate and rural state trunk highways. Wisconsin's truck weight study was suspended in 1981 so that it could be evaluated and restructured as necessary. Concerns about the high cost of the program, the accuracy and statistical reliability of the data collected, and the usefuleness of the data led to this evaluation project.

Several working papers and a final report that contained recommendations for a new truck weight study were developed during the project (1-4). Study phases included identifying and ranking the needs of data users, creating a sampling plan, and exploring options in weighing technology.

The focus of this paper is on the recommended sampling plan for Wisconsin. A methodology that uses statistical criteria in order to determine the number and general locations of sampling stations is described. In addition, some guidelines for selecting precise station sites are presented. The scheduling of operations is not addressed here.

SAMPLING POPULATION

Truck sampling in Wisconsin has been limited to rural Interstate and rural state trunk highways. The data in Table 1 illustrate the lack of adequate coverage by comparing the percentage of trucks sampled by road type in the 1979 truck weight study with the

Table 1. Comparison of Wisconsin truck weight study sample with truck VMT.

Highway Jurisdictional System	Percentage of Vehicles in Truck Weighting Study Sample	Percentage of Truck VMT
Rural		
Interstate	63	12
State trunk highways	37	37
County trunk highways	0	13
Town roads	0	6
Urban[a]		
Interstate	0	5
State trunk highways	0	16
City and village[b]	0	10
Other	0	1

[a]Includes areas inside incorporated municipalities.
[b]Includes urban county trunk highways.