IMPACT OF CHANGES IN TRUCK WEIGHT REGULATIONS ON MONTANA'S ECONOMY

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Executive Summary

This study investigated the impacts on Montana's economy of changes in the allowable gross weights of the vehicles that operate on the state's highway system. Four scenarios were considered with different maximum allowable gross vehicle weights (GVWs). Three scenarios, with maximum GVWs of 36,300; 39,900; and 47,900 kilograms (80,000; 88,000; and 105,500 lbs), represented reductions in GVWs in Montana. The fourth scenario consisted of an increase in allowable GVW to 58,100 kilograms (128,000 lbs).

Work on the study began with the estimation of the vehicle fleets that would evolve under each scenario, as users and providers of transportation services adjusted to the new GVW limits. Based on these estimated changes in the vehicle fleet and traffic streams, attendant changes in the demands on, and the performance of, the highway infrastructure were determined. Attention was focused on pavements and bridges, as these elements of the infrastructure were believed to be most sensitive to load related changes in vehicle demands. Only nominal changes in pavement demands were calculated across all scenarios relative to the present situation. Increased demands and costs were calculated for the 36,300; 39,900; and 58,100 kilogram (80,000; 88,000; and 128,000 lb) scenarios. The maximum cost increase was calculated for the 36,300 kilogram (80,000 lb) scenario, and it amounted to 1.2 percent (corresponding to 1.5 million dollars per year). A nominal decrease in pavement costs of 0.5 percent (corresponding to 0.7 million dollars per year) was determined for the 47,900 kilogram (105,500 lb) scenario. The bridge system was found to offer an acceptable level of safety and serviceability under the 36,300 kilogram (80,000 lb), 39,900 kilogram (88,000 lb), 47,900 kilogram (105,500 lb) and existing scenarios. Assuming an HS20 standard, significant additional bridge costs, above and beyond those that would be incurred under the existing weight limits, were found only for the 58,100 kilogram (128,000 lb) scenario. Bridge costs under the 58,100 kilogram (128,000 lb) limit were estimated to increase by 0.9 million dollars per year.

While the focus of the infrastructure investigation was on pavements and bridges, consideration was also given to possible effects that changes in allowable GVW would have on other aspects of system performance. In general, geometric and capacity requirements were found to be only nominally different between scenarios. Only allowable GVW was changed between scenarios, and gross weight is only one of several vehicle characteristics that drive geometry and capacity issues. A wide range of vehicle types and configurations are able to operate under all the scenarios considered. A simple safety analysis found little change in the number of fatalities and injuries expected across all scenarios.

The investigation subsequently focused on the economic impacts that would be experienced above and beyond changes in direct infrastructure costs. These impacts were first investigated by studying specific industries in the state. Case studies of the economic impact of changes in allowable GVW were done on industries from the agriculture, forestry and wood products, extractive industries, construction, and retail trade sectors of the economy. In general, for each industry, costs increased for scenarios involving reductions in GVW limits and decreased for the scenario involving an increase in GVW limits. Increased transportation costs of 3 to 54 percent were predicted for the 36,300 kilogram (80,000 lb) scenario, depending on the industry considered. These changes in transportation cost ranged from 0.2 to 4.2 percent of the value of the commodity produced. Typical reductions in transportation costs for the 58,100 kilogram (128,000 lb) scenario were on the order of magnitude of 1 to 2 percent (with a maximum predicted cost reduction of 6 percent). Greatest effects on transportation costs were predicted for industries that operated the heaviest trucks for most of their transportation activities (e.g., milk, sugar beets, talc, wood chips, cement, motor fuel). The lowest cost increases were predicted for industries that already extensively use trucks operating at or below 36,300 kilograms (80,000 lbs) in their operations (e.g., cattle, logging). Changes in transportation costs typically were at least an order of magnitude larger than changes in infrastructure costs.

Potential economic effects of these changes in transportation costs were expected to vary based on the nature of the industry under study. Industries serving local markets (e.g., sand and gravel, cement, retail food, retail fuel) were expected to raise their prices in response to increases in transportation costs. Businesses serving such markets would all be affected equally, allowing them to collectively increase their prices, and the magnitude of the required increases to cover costs were not large enough to suggest dramatic reductions in product demand. This situation would, none the less, result in a reduction in the disposable income of the consumers in the state. Industries competing in regional and/or national marketplaces (e.g., wheat, cattle, sugar beets/sugar, crude oil, talc, wood chips/liner board), would potentially have more difficulty passing on any cost increases to their customers, as their competitors may not be faced with similar increases in costs. Outcomes in this case could range from reductions in production to terminating operations in Montana. Note that, while informative, these case studies considered only direct impacts experienced by certain industries in the state under different GVW scenarios, and they ignored indirect and induced impacts that might be experienced across all the industries in the state.

A state wide economic model was used to obtain a broader indication than available from the case studies of both the direct and indirect economic impacts that would result from changes in maximum allowable GVW. An augmented input/output model developed by Regional Economic Modeling, Inc. (Amherst, Massachusetts) was used for this purpose. The effects of changes in GVW limits were introduced into the model based on changes in transportation productivity predicted on an industry-by-industry basis for each scenario. In general, reductions in the allowable gross weight of the vehicles operating on the state highway system were found to produce negative impacts on the state's economy, while an increase in allowable gross weight was found to produce a nominal positive impact on the state's economy. Under the 36,300 kilogram (80,000 lb) GVW limit, gross state product (GSP) reached a level 0.4 percent below that expected under existing regulations (baseline case), which translated into a 50 million dollar reduction in GSP, for example, in the fifth year after the new limits were introduced. Under a 58,100 kilogram (128,000 lb) GVW limit, GSP reached a level consistently 0.08 percent above that expected under existing regulations, which translated into approximately a 5 million dollar increase in GSP, for example, in the fifth year after the new limits were introduced. Long term reductions in overall state income and employment of approximately 0.2 percent were observed under the 36,300 kilogram (80,000 lb) scenario. A nominal increase in these parameters of 0.04 percent was observed in the 58,100 kilogram (128,000 lb) scenario. Note that as might be expected, changes in the trucking sector were in the opposite direction of other sectors' effects.

It was found in the results from both the case studies and the statewide economic model that in many instances the total economic impacts of changes in GVW limits exceeded the associated changes in infrastructure costs by an order of magnitude. This result reinforces the need to consider more than just infrastructure impacts in evaluating truck size and weight issues.

1. INTRODUCTION

1.1 GENERAL REMARKS

The high visibility of trucks on the highways and the low visibility of the importance of trucking to the overall economy leads to frequent calls for tighter regulation of truck weight limits. Commonly perceived benefits of lower truck weights include reduced infrastructure damage and improved highway safety. Whether these benefits will be realized by reducing the allowable gross weight of trucks, however, is not as obvious as it may seem, in that in using lighter trucks, more trips are required to move the same amount of freight as is presently hauled on the highway system. While this effect would possibly be mitigated to some extent by shifts of freight from truck to other modes of transportation, other modes are not expected to be viable alternatives in all cases for a variety of reasons (e.g., basic availability, timeliness, etc.). Furthermore, the demands vehicles place on the infrastructure and the safety of their operation is related to several factors in addition to their gross weight. For these reasons, whether improvements in infrastructure performance and safety will be realized under reduced gross vehicle weights (GVWs) can only be determined through engineering analyses.

While discussions of truck weight policies generally focus on infrastructure and safety issues, such policies can potentially have more far reaching impacts, notably on the economy. The productivity of the freight transportation sector of the economy can change as more/less trips are required to move freight or as different modes of transportation are used to move freight. Changes in trucking costs (e.g., equipment and labor costs) as trip requirements change under different size and weight limits have been shown to be significantly greater than associated changes in infrastructure costs (e.g., Transportation Research Board (TRB), 1990a). Additionally, any such changes in transportation productivity will directly result in attendant changes in the productivity of the industries that use transportation services. Such effects will further propagate to other sectors of the economy that provide services to, or rely on, the directly affected sectors.

In Montana, where 62 percent of the value of products originating in state is moved by truck (Bureau of Transportation Statistics (BTS), 1996) and an overwhelming majority of intrastate freight movements are accomplished by truck, any changes in trucking operations and costs could have a significant effect on the state's economy. In anticipation of future discussions of policy changes regarding allowable gross weights of vehicles that operate on the state's highways, policy makers need objective information on the impacts any such changes would have on the state's economy (as well as on the highway infrastructure). A review of both the economics and engineering literatures on truck weight limits shows that nearly all past studies have looked only at direct transportation and infrastructure impacts; they do not consider the broader economic effects such regulations might have (e.g., Transportation Research Board, 1990a). Studies that have included broad economic impacts are most often done with regards to a particular highway project (e.g., Weisbrod and Beckwith, 1992), rather than truck size and weight limits.

1.2 OBJECTIVES AND SCOPE

The objective of this study was to determine the broad impacts on the state economy that would result from changes in GVW limits on the state's highways. The allowable GVWs considered in this study were 36,300; 39,900; 47,900; and 58,100 kilograms (80,000; 88,000; 105,500; and 128,000 lbs). The lowest GVW scenario, the 36,300 kilogram (80,000 lb) scenario, represents approximately a 32 percent reduction in allowable GVW compared to existing weight limits, and it is consistent with the present Federal standard enacted across the United States in 1982 on the interstate system. The highest GVW scenario, the 58,100 kilogram (128,000 lb) scenario, corresponds to approximately a 10 percent increase in allowable GVW compared to existing limits, and it is consistent with a proposal put forth by Alberta for a north-south trucking corridor across the western United States. It was assumed under all scenarios that the maximum GVW limits would be adopted at least on a regional scale. In making this assumption, however, it was further assumed that in the 36,300; 39,900; and 47,900 kilogram (80,000; 88,000; and 105,500 lb) scenarios, any existing regulations in other states requiring lower GVWs than the maximum value allowed by the scenario took precedence over the scenario value. Thus, these scenarios were intended to represent the imposition of lower allowable GVWs in Montana and the surrounding area, not the liberalization of allowable GVWs in states that already have lower GVWs than Montana.

The research objective was met by performing the following tasks:

1) Projections were made of the traffic streams that would evolve under each GVW scenario based on the characteristics of the existing vehicle fleet and traffic streams in conjunction with information solicited from users and providers of trucking services.
2) Expected changes in highway infrastructure costs were calculated for the new traffic streams generated in step 1, with due consideration of pavements, bridges, geometrics, and safety.
3) Changes were determined in the total transportation costs that resulted from each policy scenario for the various sectors of the state's economy. Attention was focused on mining, agriculture, wood products, retail food, construction and retail gasoline.
4) The results from steps (2) and (3) were used in conjunction with other information to develop inputs for each scenario to a sectoral model of the entire state economy. These inputs were generally formulated based on changes in productivity due to changes in transportation operations.
5) Consolidated and sectoral economic impacts were predicted through time for each scenario in terms of changes in and absolute levels predicted for output (or gross state product), employment, and income.
6) The results of step (5) were reviewed to determine if the magnitude of the economic impacts was sufficiently large to suggest that the level of highway use would significantly change, necessitating a re-iteration of steps (2) through (6).

With regard to these tasks, note that in discharging Task 3, case studies were conducted on 11 selected industries representing major sectors of the state's economy. These case studies consisted of identifying a trucking operation within the industry in question, determining how this operation would be impacted in each GVW scenario, calculating the attendant changes in infrastructure impacts, and, finally, assessing the potential economic impacts that would be experienced by the industry. Also note that the decision was made in Task 6 that while the economic impacts predicted in Task 5 were significant, they were not so dramatic or immediate as to require a re-iteration of the analysis.

It is important to state at the outset that the impacts considered in this study revolved mainly around the infrastructure and the economy. Although an investigation of other effects (e.g. environmental and energy conservation effects) was undertaken, it was determined that the data and analysis procedures required to produce useful results from such an investigation were unavailable. Any impacts of changing truck weight limits beyond those directly addressed here that could be expressed in terms of the traffic stream could be combined with the effects demonstrated below to present a complete picture.

The organization of this report is as follows. Chapter 2 provides a brief introduction to the status quo of the state's economy and transportation infrastructure. Chapter 3 addresses Task 1 above, presenting the new traffic stream calculations for each scenario. Infrastructure impacts and costs (Task 2) are addressed in Chapter 4. Chapter 5 contains the case studies for industries in the sectors listed in Task 3. The statewide economic model is presented in Chapter 6, which includes both the derivation of model inputs (Task 4) and the analysis of the model results (Task 5). Summary and conclusions are reported in Chapter 7.

2. EXISTING CONDITIONS IN MONTANA

2.1 GENERAL REMARKS

Economic activity in the state of Montana has steadily increased over the past several years, with the Gross State Product (GSP) reaching approximately 17.7 billion dollars in 1995 (Census and Economic Information Center (CEIC), 1998). Economic activity in the state is centered on agriculture, forestry and wood products, mining, retail trade, tourism, and other services. As is often the case, while the transportation system initially developed to some extent to support these activities, once established, any new enterprises or changes in existing activities have to a large degree been implemented around the existing transportation infrastructure. With respect to the transportation of freight across and within Montana, the highway and rail systems are the primary elements of this infrastructure. While freight movements on the highway system were the focus of this study, such movements are better understood in the context of the manner in which all freight moves in and across the state.

2.2 STATE ECONOMY

The structure of the state's economy can probably best be understood by looking at the level of activity in its broad sectors. Two principal means of desegregating economic activity by sector are according to value added and employment. These breakdowns are shown in Figures 2.2-1 and 2.2-2, respectively. Although much of the land in the state is devoted to production in agriculture, forestry, mining and tourism, these sectors account directly for less than one third of the value added in the state. By understanding that the agriculture, forestry and fisheries services sector is limited to those industries that service these sectors, the seemingly low shares contributed by this sector are put in perspective. Lumber and wood products are considered part of the manufacturing sector. Tourism falls in the services category in these figures. On the other hand, these sectors account for more than half the employment in the state. These facts will be useful later in understanding the magnitude of the statewide economic impacts.

Projections of state economic growth are provided by the baseline forecast of the statewide economic model that is largely the subject of Chapter 6. Several indicators of the state's prospects over the ten year period from 1995 to 2005 give a generally positive view (1995 is taken as the first year of a ten year period as it is the latest year where gross state product by industry is available). Overall, the state's economy is predicted to grow at an annual rate of 1.6 percent over the period 1995 to 2005. Population is predicted to grow at an annual rate of one-tenth of one percent (slower than the national average), while employment is projected to grow at an annual rate of 0.8 percent over the same period. More Montanans will be a part of the labor force. At the same time, personal income is expected to increase at an annual rate of 4.3 percent. This rate is a nominal growth rate; if the inflation rate remains below this rate, then real personal incomes will rise. Over this ten year horizon, the competitive position of the state's economy relative to the national economy is not expected to change dramatically: in 1995, Montana's GSP represented 0.30 percent of the national gross domestic product (GDP), and is projected to represent 0.29% of the national economy in 2005.

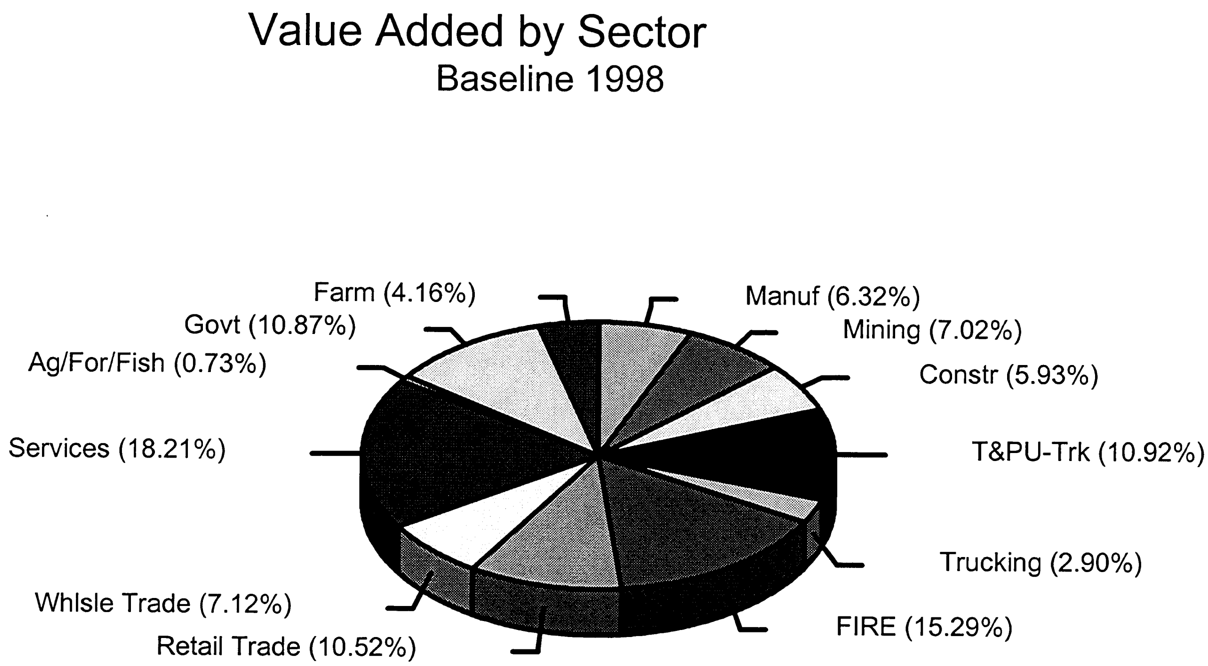

Figure 2.2-1. Value Added by Sector, 1998 Baseline
(based on REMI model, see Section 6)

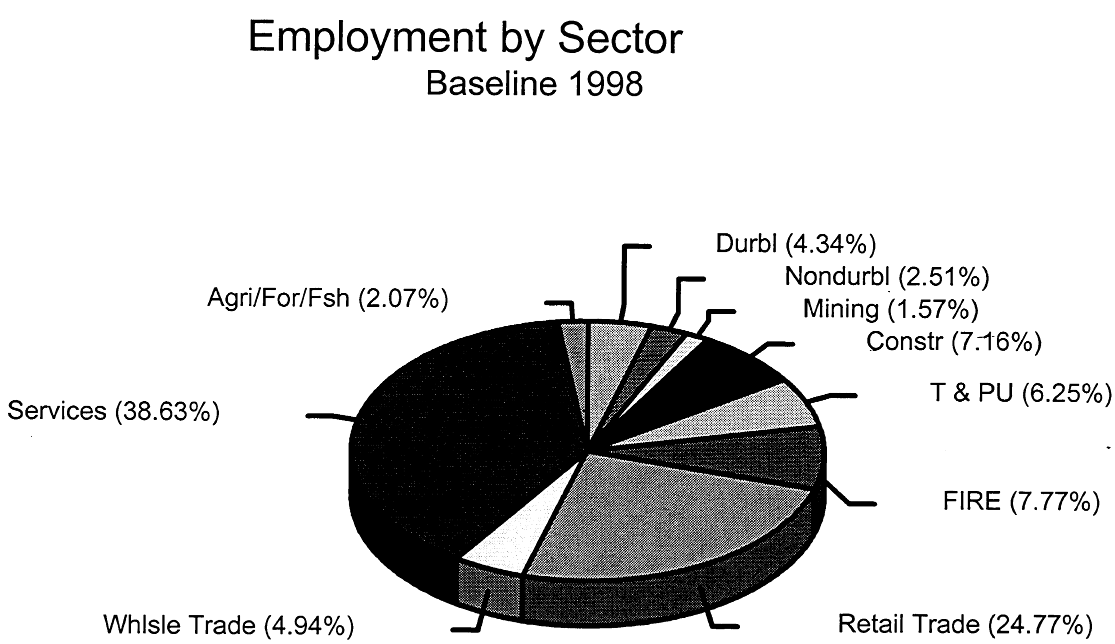

Figure 2.2-2. Employment by Sector, 1998 Baseline
(based on REMI model, see Section 6)

In 1995, the latest year of actual data available by sector, the trucking and warehousing sector of the state's economy produced 2.1 percent of GSP, 1.9 percent of employment (including full-time and part-time), and 1.7 percent of personal income, according to the Census and Economic Information Center of the state Department of Commerce (CEIC, 1998). Care should be taken not to interpret these values as completely indicating the importance of trucking to the state's economy, as these values represent only that trucking activity that is for-hire. These values represent lower-bounds on the importance of trucking: much trucking activity is done within firms whose primary business is not trucking, and for purposes of income and product accounting, this activity is counted as activity occurring in those industries, rather than in trucking. While firm statistics on the level of own-account trucking in the state of Montana are not available, such data have recently been compiled at the national level (Fang et al., 1998). For-hire transportation accounts for 3.1 percent of GDP, while all transportation (own-account and for-hire) accounts for 5.0 percent of GDP.

2.3 MONTANA STATE HIGHWAY SYSTEM

2.3.1 Roadways

In 1995, the federal aid interstate and non-interstate National Highway System, and the state primary, secondary, and urban systems totaled approximately 18,835 kilometers (11,705 miles) of highway in the state of Montana (MDT, 1995). A summary of the routes that comprise these highways is presented in Table 2.3.1-1 and Figure 2.3.1-1. By virtue of being designated to one of these systems, a highway is eligible for one or more types of federal aid funding.

Road surfaces on the Montana state highway system are constructed of asphalt (flexible), concrete (rigid), treated gravel, and gravel. The percent of each system paved with each type of material is reported in Table 2.3.1-1. Asphalt is the most commonly used material on state highways, comprising 80 percent of the roads on the total state highway system. Only on the interstate system is concrete used to any major extent (10 percent), and most of this pavement is on a single interstate route (Interstate 90).

Table 2.3.1-1 State Highway System Length by Federal Aid System (MDT, 1995)

System	Length, km (miles)	Percent of length within each system by surface type		
		% Flexible	% Rigid	% Other[a]
Interstate	1916 (1191)	90	10	0
Primary	8830 (5488)	96	0	4
Secondary	7506 (4665)	57	0	43
Urban	581 (361)	84	1	14
Off system	1833[b] (1139)	-[c]	-[c]	-[c]
Total	**18835 (11705)**	**80**	**1**	**19**

[a] bituminous surface treatment, gravel, or primitive
[b] not included in total
[c] data unavailable

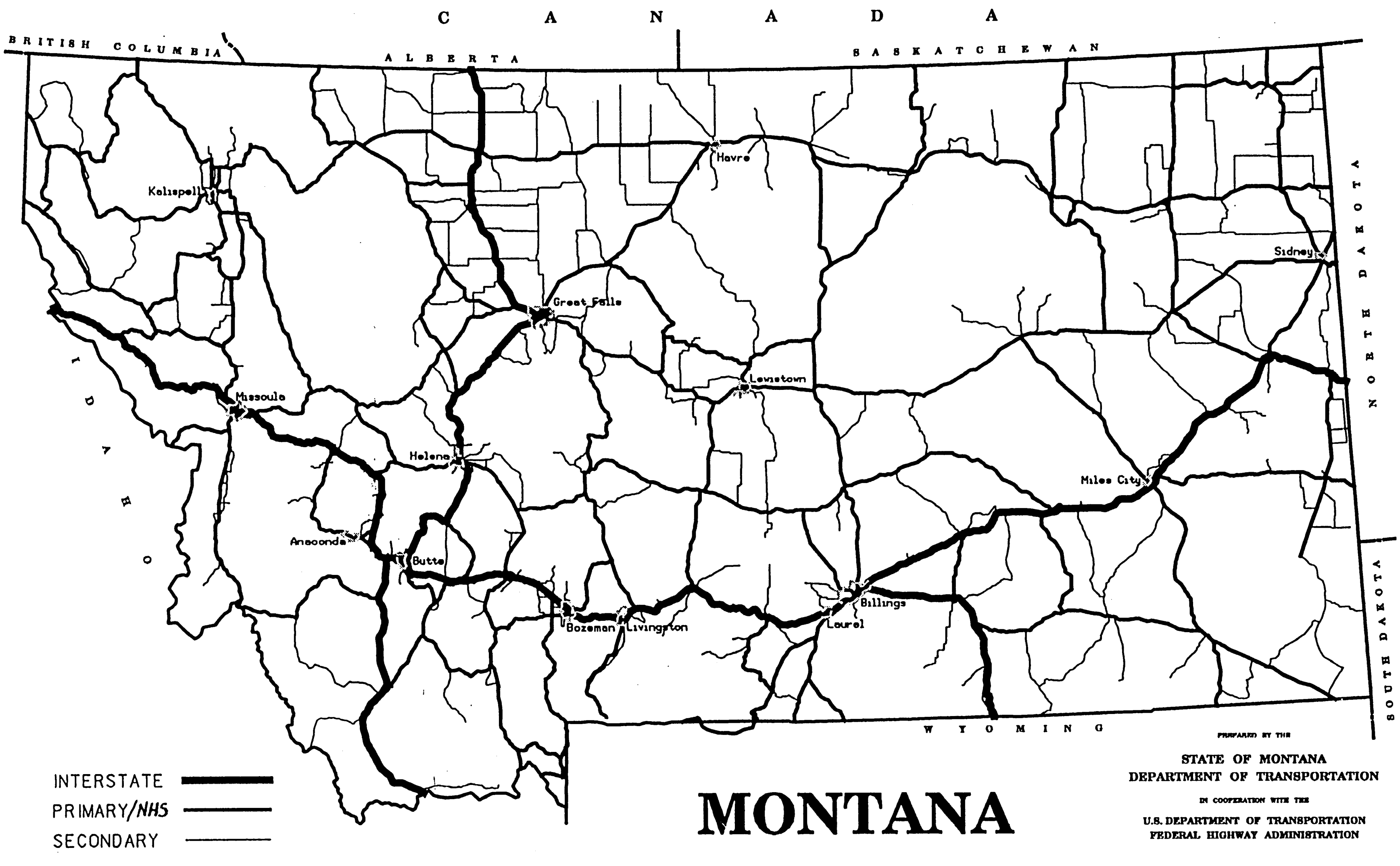

Figure 2.3.1-1 Montana State Highway System

2.3.2 Bridges

A summary of the bridges in the state inventory is presented in Table 2.3.2-1. Bridges on the state highway system are constructed using three types of structural systems, namely, stringer, truss, and flat plate systems. Stringer systems are the most common bridge type in the state, comprising 95 percent of the inventory by length. This type of bridge consists of a series of parallel beams (stringers) oriented in the direction of the span. The beams support the deck and are in turn supported by the abutments and piers. Loads are carried through transverse shear forces and bending moments in the beams. The beams are either simply supported on each end, or they can be continuous across any internal supports. Simply supported stringer bridges compromise 70 percent of all spans (by length) on the state highway system. Continuous stringer bridges compromise only 25 percent of the bridges on the system.

Flat plate bridges and truss bridges comprise only 5 percent of the bridges on the state highway system. To a large extent, flat plate bridges carry loads through the same mechanisms as stringer bridges, but their strength is distributed across the width of the structure rather than being focused at a few locations in a few beams. Truss bridges carry loads through axial forces in their members. Only 3 percent of all bridges in the state inventory are truss structures.

With respect to materials, bridges in Montana are constructed with prestressed concrete, concrete, steel, and wood. The most common bridge on the system is the simply supported, prestressed concrete stringer bridge. These bridges comprise 46 percent of all the bridges on the system (based on length), and they represent even higher proportions of the bridges on the interstate system (65 percent). Prestressed concrete bridges reportedly offer better long-term performance compared to other bridge systems (Dunker and Raubat, undated), and most new and replacement bridges are being constructed using this material (Murphy, 1995). Standard prestressed bridge designs have been developed by MDT based on span length and roadway width. Continuous steel stringer bridges are the second most common bridge on the system, comprising 24 percent of all bridges (by length). Timber bridges comprise a significant part of the inventory (11 percent). Most of the timber bridges are on the primary and secondary systems.

All the bridges on the interstate and primary systems have overall structural ratings of at least good, as this rating is calculated for the National Bridge Inventory System (FHWA, 1988). These good conditions may reflect in part the relative young age of many of the bridges, the relatively light traffic they experience, and the favorable environmental conditions (low relative humidity and only modest use of de-icers) in Montana. Average age and daily traffic on the bridges on each system are summarized in Table 2.3.2-2. The average age of all the bridges in the Inventory was given in 1996 as 37 years (Meyer, 1996).

The Inventory load rating on almost every bridge on the interstate system is at least HS20-44 (two bridges have listed inventory ratings of 75 percent of the HS20-44 load rating (MDT, 1994)). The HS20-44 vehicle is a standard vehicle used by most states for bridge design, and it is the minimum standard used for all new MDT bridge designs (Murphy, 1998). This vehicle is a 3 axle tractor, semi-trailer with a mass of 32,600 kilograms (72,000 pounds) and an over-all wheel base of 8.5 to13.4 meters (28 to 44 ft) (AASHTO, 1992). This vehicle is not intended to represent any specific vehicle that operates on the highway system. The HS20-44 vehicle was developed as a bridge design tool in 1944 to provide a single vehicle to be used in the design process that analytically generates the maximum stresses caused in bridges by a collection of actual truck configurations (Ritter, 1990; Tonias, 1995). The HS20-44 design loading also includes a uniformly distributed lane load developed to model a train of trucks crossing a bridge. The Inventory load rating on approximately 60 percent of the bridges on the primary system is H15 or lower. The H15 design vehicle is a two axle truck with a gross weight

Table 2.3.2-1 Characteristics of Bridges on the State Highway System (MDT, 1994)

Structural System	No. of Spans	Average Length, m (ft)	% (by length) of all spans
Stringer			
Simply supported			
Prestress	3005	18.0 (59)	46
Steel	571	17.1 (56)	8
Wood	2152	6.1 (20)	11
Concrete	437	12.8 (42)	5
Continuous			
Prestress	3	31.4 (103)	0
Steel	886	31.7 (104)	24
Concrete	160	6.7 (22)	1
Total	**7214**	**15.5 (51)**	**95**
Flat Plate			
Simply supported			
Concrete	79	6.1 (20)	0
Continuous			
Concrete	442	6.1 (20)	2
Total	**521**	**6.1 (20)**	**2**
Truss			
Steel	85	39.6 (130)	3
Total	**85**	**39.6 (130)**	**3**
Total	**7820**	**15.2 (50)**	**100**

Table 2.3.2-2 Average Age and Daily Traffic on State Highway Bridges by System (based on information provided by Meyer, 1996)

System	Number of bridges	Average age (yrs)	Average daily traffic
Interstate	843	25	5582
Primary	1193	42	1922
Secondary	556	36	700[a]
Urban	66	35	10429

[a] high uncertainty on exact value, order of magnitude reasonable

of 13,700 kilograms (30,000 lbs) and a wheel base of 4.3 meters (14 ft) (AASHTO, 1992). This design vehicle generally places lower demands on bridges than the HS20-44 vehicle, and it is used on secondary roads when a lesser loading may be appropriate (Ritter, 1990). Eighty percent of the bridges on the primary system with a load rating of H15 or less are short span timber structures. Most of the bridges on the secondary system have Inventory load ratings of H15 or less (66 percent). The majority of these bridges are short span timber structures, as was observed for the primary system.

In almost all cases, the reported Inventory load ratings for bridges across all systems are the vehicles used for the bridge designs (e.g., HS20-44, H15, etc.). Concerns with load ratings generated by a system wide analysis conducted in the 1970s resulted in an administrative decision to replace suspect ratings with the bridge design loads (Murphy, 1996).

2.3.3 Existing Vehicle Configurations

Vehicle configurations in Montana are controlled by legal limits that include requirements on load per unit width of tire, maximum axle group weights, maximum gross vehicle weights, maximum vehicle lengths, and maximum vehicle widths (MCA, 1997). Various configurations of trucks that have evolved under these limits are shown in Figure 2.3.3-1. While vehicle size and weight limits in Montana are generally consistent with regulations around the country, some features of Montana's laws are specific to the western United States and more particularly to the state of Montana. Specific regulations of interest include:

1) maximum gross vehicle weights are determined by the Federal Bridge Formula B,
2) long combination vehicles (LCVs) are allowed to operate, and
3) triple trailers are allowed to operate on the interstate system.

With regard to maximum gross vehicle weights, Montana has elected not to adopt the 36,300 kilogram (80,000 lb) maximum gross vehicle weight endorsed by the federal government, but rather to control demands placed on bridges using Federal Bridge Formula B. This formula gives the allowable weight on any group of two or more axles in terms of the number and spacing of the axles,

$$W = 500\ [LN/(N-1) + 12N + 36]$$

where,

W = allowable weight on the collection of axles under consideration, pounds
L = length between extreme axles in collection of axles under consideration, feet
N = number of axles under consideration

Within the constraints of the Bridge Formula B and maximum axle weights, Montana allows double trailer units up to 30.5 meters (100 ft) long to operate on the state's highways with a special permit. Double trailer units up to 22.9 meters (75 ft) long can operate without a permit. A popular double trailer vehicle configuration, referred to as the Rocky Mountain double, has either 7, 8 or even 9 axles and can operate at gross vehicle weights up to approximately 51,700 ; 53,500; or 55,800 kilograms (114,000; 118,000; or 123,000 lbs), respectively. These vehicles often run with two trailers with lengths of 13.7 and 8.5 meters (45 and 28 ft). Typical legal limits on various vehicle configurations are presented in Table 2.3.3-1. Axle loads in Montana are limited to 9,100; 15,400; and 19,300 kilograms (20,000; 34,000; and 42,500) lbs) on singles, tandems, and tridems, respectively (with tridems controlled by the Bridge Formula). Loads on axles with single tires (except the steering axle) are limited to 91 kilograms per centimeter (500 lbs/in) of width (MCA, 1997).

2.3.4 Present Traffic Distribution by Vehicle Configuration and Weight

The absolute volume of average daily truck traffic on the various elements of the highway system is summarized in Table 2.3.4-1 (1994 data). Large combination trucks (defined as any unit with at least one trailer and an axle configuration potentially capable of operating at a GVW greater than or equal to 36,300 kilograms (80,000 lbs)) comprise only 14, 5, and 3 percent of all traffic (measured in vehicle miles of travel) on the interstate, non-interstate NHS and state

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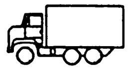
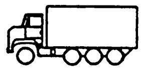
	3SU	3 AXLE SINGLE UNIT
	4SU	4 AXLE SINGLE UNIT
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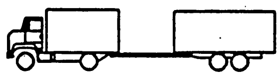
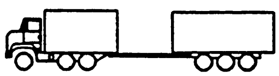
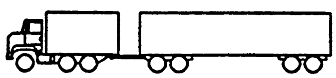
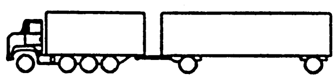
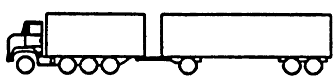
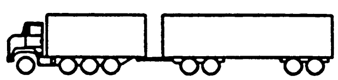
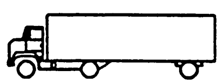
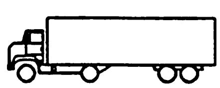
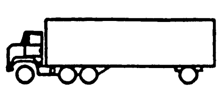
	2-2	TRUCK AND TRAILER
	3-2	TRUCK AND TRAILER
	3-3	TRUCK AND TRAILER
	3-4	TRUCK AND TRAILER
	4-2	TRUCK AND TRAILER
	4-3	TRUCK AND TRAILER
	4-4	TRUCK AND TRAILER
	2S1	3 AXLE TRACTOR SEMI TRAILER
	2S2	4 AXLE TRACTOR SEMI TRAILER
	3S1	4 AXLE TRACTOR SEMI TRAILER

Figure 2.3.3-1 Typical Vehicle Configurations (page 1 of 2)

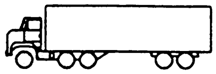
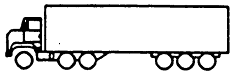
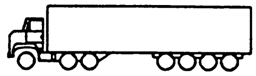
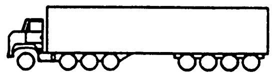
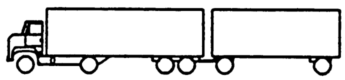
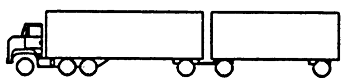
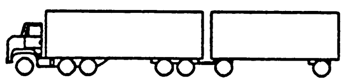
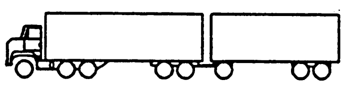
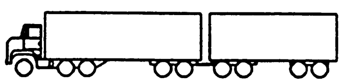
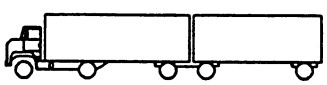
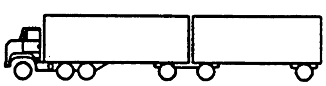
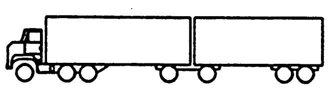
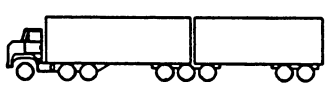
	3S2	5 AXLE TRACTOR SEMI TRAILER
	3S3	6 AXLE TRACTOR SEMI TRAILER
	3S4	7 AXLE TRACTOR SEMI TRAILER
	4S4	8 AXLE TRACTOR SEMI TRAILER
	2S1-2	5 AX A/C TRAIN COMBINATION
	2S2-2	6 AX A/C TRAIN COMBINATION
	3S1-2	6 AX A/C TRAIN COMBINATION
	3S2-2	7 AX A/C TRAIN COMBINATION
	3S2-3	8 AX A/C TRAIN COMBINATION
	3S2-4	9 AX A/C TRAIN COMBINATION
	5 AX BT	B TRAIN COMBINATION
	6 AX BT	B TRAIN COMBINATION
	7 AX BT	B TRAIN COMBINATION
	8 AX BT	B TRAIN COMBINATION

Figure 2.3.3-1 Typical Vehicle Configurations (page 2 of 2)

Table 2.3.3-1 Maximum Gross Vehicle Weights, Widths, and Lengths, Without a Permit, Current Montana Limits, Compiled from Montana Code Annotated (MCA 1997)

Configuration	GVW, kilograms (lbs)	Length[a], meters (ft)	Width meters (ft)
Single Units			
2SU	18,100 (40,000)	16.8 (55)	2.6 (8.5)
3SU	22,700 (50,000)	16.8 (55)	2.6 (8.5)
4SU	26,300 (58,000)	16.8 (55)	2.6 (8.5)
Truck and Full Trailers			
2-1	25,400 (56,000)	22.9 (75)	2.6 (8.5)
2-2	31,800 (70,000)	22.9 (75)	2.6 (8.5)
3-2	38,100 (84,000)	22.9 (75)	2.6 (8.5)
3-3	41,700 (92,000)	22.9 (75)	2.6 (8.5)
3-4	47,100 (103,800)	22.9 (75)	2.6 (8.5)
Tractor, Semi-trailers			
2S1	23,600 (52,000)	22.9 (75)	2.6 (8.5)
2S2	29,900 (66,000)	22.9 (75)	2.6 (8.5)
3S2	36,300 (80,000)	22.9 (75)	2.6 (8.5)
3S3	39,900 (88,000)	22.9 (75)	2.6 (8.5)
3 Unit Combinations			
5 AX A Train, 2S1-2	41,700 (92,000)	22.9 (75)	2.6 (8.5)
6 AX A Train, 2S2-2	48,100 (106,000)	22.9 (75)	2.6 (8.5)
7 AX A Train, 3S2-2	51,000 (112,500)	22.9 (75)	2.6 (8.5)
8 AX A Train, 3S2-3	53,300 (117,400)	22.9 (75)	2.6 (8.5)
9 AX A Train, 3S2-4	55,600 (122,600)	22.9 (75)	2.6 (8.5)

[a] large combination vehicles can operate up to 30.0 meters (95 ft) long with a permit

Table 2.3.4-1 Average Daily Truck Traffic (vehicles capable of operating at GVW's of 36,300 kilograms (80,000 lbs) or greater, 1994 data)

System	Length, kilometers (miles)	AADT
Interstate	1916 (1191)	715
Primary	8830 (5488)	84
Secondary	7506 (4665)	11
Urban	581 (361)	38

primary systems, and the state secondary and urban systems, respectively. These values were calculated using information provided by MDT. Data on the specific vehicle configurations operating around the state are collected by the Data Collection/Analysis Section of MDT. The data consist of visual classification counts, automatic vehicle classification counts, and weight and classification data collected at static weigh stations. These data collection activities are focused on the interstate and primary systems, where much of the vehicle activity in the state is focused. Based on this data, MDT estimated the composition of the traffic stream on every mile of highway in the state for NHS interstate and non-interstate routes and for all state primary, secondary, and urban routes. Information of this type assembled for the year 1994 was used as the basis for this study. Data collected for this year were previously determined to provide a reasonable representation of the vehicles operating on Montana's highways (Stephens et al, 1996), a conclusion which was reaffirmed in this study through comparison of the 1994 data traffic data with information from 1995 and 1996.

Information on vehicle operating weights by configuration was also obtained from MDT. All of the data collected from 32 static weigh station sites around the state in 1994 were used. Once again, data from 1994 had previously been found to reasonably represent the annual weigh station data available for the state. This conclusion was verified by comparing the 1994 data with that from 1995. Note that the operation of overweight vehicles may not be well represented in static weigh station data. The state of Montana has only limited information on the percentage of overweight vehicles that operate on the highways. While overweight vehicle operations can be characterized from weigh-in-motion data, such data is still only available at certain locations around the state, and systems for evaluating and processing this data are still being developed. Therefore, the decision was made to do this analysis without correcting the static weight data for overweight vehicles believed to be in the existing traffic stream. Consistent with this decision, overweight vehicles were not created as part of the new traffic streams generated for each GVW scenario considered in this study.

The composition of the truck fleet (3 axle single units and larger) operating on Montana's highways is summarized in Figure 2.3.4-1. The overwhelming majority of the heavy vehicles using the system are 5 axle tractor, semi-trailers. These vehicles comprise more than 60 percent of the heavy vehicles in the fleet (out of the total of 64 percent of all 5 axle combinations). Vehicles that can potentially operate at weights in excess of 36,300 kilograms (80,000 lbs) (notably, 6 axle tractor, semi-trailers and long combination vehicles) comprise only 16.7 percent of the truck fleet. Of these vehicle configurations, the most frequent vehicle type is 7 axle combinations, which make up 5 percent of all heavy vehicles in the fleet.

This study is most concerned with vehicles operating at gross weights equal to or greater than 36,300 kilograms (80,000 lbs), and the composition of this fraction of the traffic stream, as measured in terms of vehicle miles of travel, is summarized by system in Figure 2.3.4-2. While on all systems the overwhelming majority of the vehicles capable of operating at, or over, GVWs of 36,300 kilograms (80,000 lbs) are 5 axle tractor, semi-trailers, these units are clearly most dominant on the interstate system, comprising approximately 76.6 percent of the large truck traffic. Five axle tractor, semi-trailers only comprise approximately 60 percent of the heavy vehicle traffic on the NHS and state primary systems, and 48 percent on the secondary and urban systems. Traffic on the interstate system is believed to be significantly influenced by interstate haulers, who are constrained to configurations that comply with the lowest maximum GVW allowed by the various states in which they operate (which is likely to be 36,300 kilograms (80,000 lbs) on a 5 axle tractor, semi-trailer).

Vehicles on the NHS, state primary, and state secondary system are believed to be engaged more exclusively in regional, intrastate, or local commerce compared to the trucks on the interstate system. Therefore, from a GVW perspective, a greater percentage of these haulers

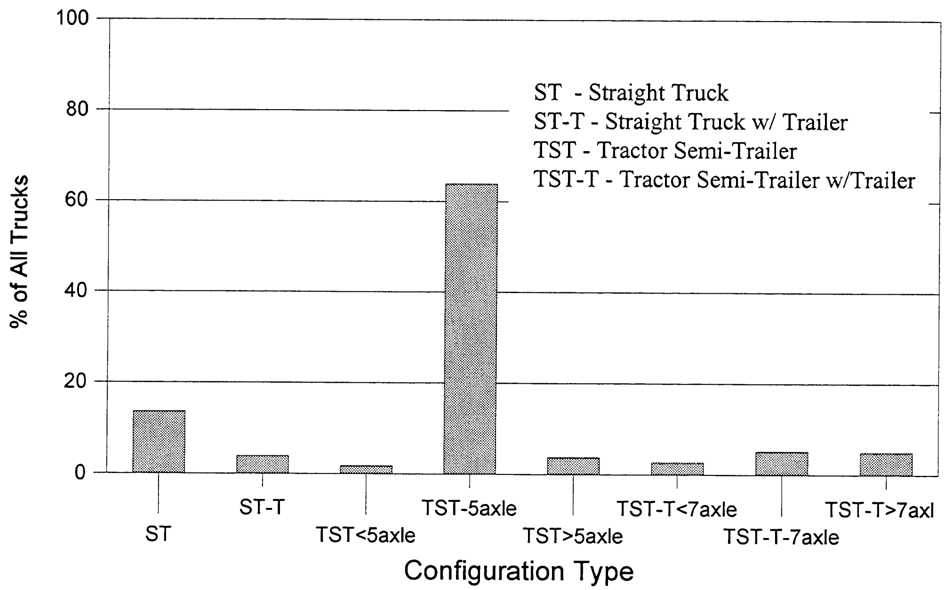


Figure 2.3.4-1 Composition of Truck Fleet (3SU and larger, 1994 data)

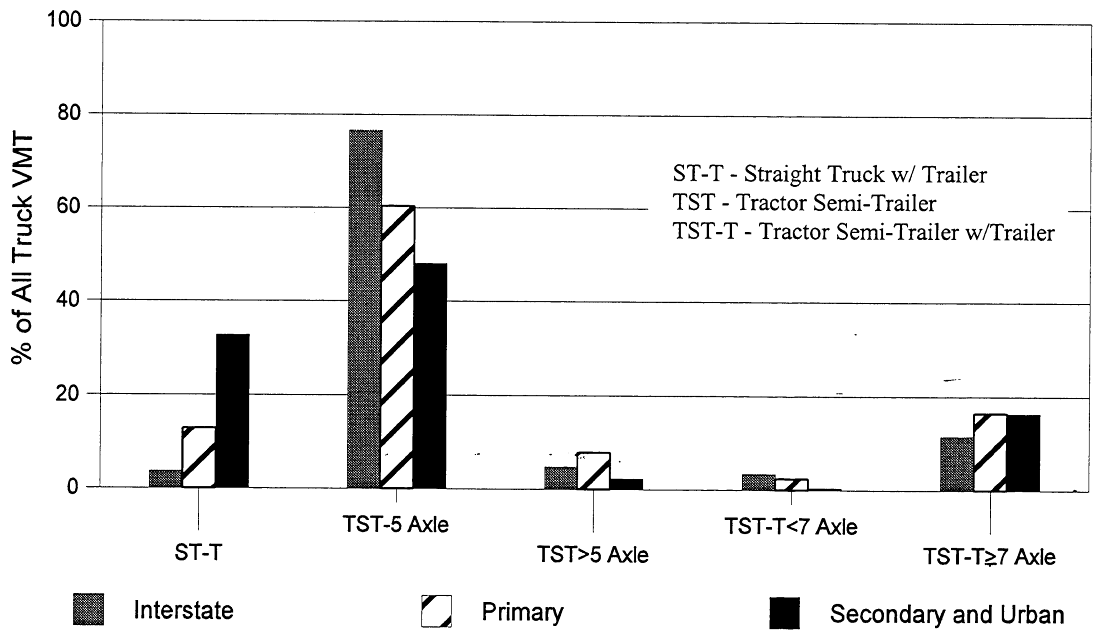


Figure 2.3.4-2 Composition of the Heavy Vehicle Stream (vehicles capable of operating at GVWs of 36,300 kilograms (80,000 lbs) or greater, 1994 data)

are able to operate heavier vehicles than a 5 axle tractor, semi-trailer, vehicles that are configured to comply with regional and state truck regulations. The largest combination vehicles (7 axle combinations and larger) comprise a noticeably greater percentage of the traffic on the NHS and state primary, and secondary routes, than on the interstate system. These large combination vehicles account for only 12 percent of the vehicle kilometers (miles) of travel on the interstate system, compared to 16 percent of the vehicle kilometers (miles) of travel on the other elements of the highway system. Straight truck, full trailer units are also more prevalent on the non-interstate elements of the highway system compared to the interstate routes. The commodities hauled by straight trucks pulling trailers are often short haul/local delivery in nature (e.g., sand and gravel). In Montana, these types of trips tend to entail only limited interstate highway travel.

2.4 GENERAL FREIGHT MOVEMENTS

Only 35 percent of the estimated 73 million metric tons (80 million English tons) of commodities originating in Montana (by weight) are moved by truck (Bureau of Transportation Statistics (BTS), 1996). Montana ranks in the bottom 10 states in the nation with respect to the weight of goods originating in the state that are shipped by truck. Montana produces many bulk commodities (lumber, wood products, coal, farm products, etc.) that have a low value to weight ratio. These commodities and almost all of Montana's exported products need to be shipped hundreds of miles to their markets (approximately 50 percent of the commodities originating in Montana are shipped over 500 miles (BTS, 1996)). In such situations, rail often is used to move commodities, and, indeed, fully 52 percent (by weight) of the commodities that originate in Montana move by rail (BTS, 1996). Eighty-five percent of the wheat grown in the state and 80 percent of the coal mined in the state, for example, are moved by rail (Montana Agricultural Statistics Service, 1997; BTS, 1996). Only in Wyoming is rail responsible for moving a greater percentage of the commodities originating in a state than in Montana. Rail movements are accomplished on 5,310 kilometers (3,300 miles) of track operated by 7 railroad companies (Wilbur Smith and Associates, 1997). Two of these companies operate 90 percent of the track, namely, the Burlington Northern and Santa Fe (65 percent) and Montana Rail Link (25 percent). The available rail service in the state offers access to large markets for Montana's commodities with very little switching of carriers required.

Less than 2 percent of the 48 million metric tons (53 million English tons) of commodities moved annually by rail in the state is believed to represent intrastate commerce (Wilbur Smith and Associates, 1997). As at least 31 million metric tons (34 million English tons) of freight are shipped intrastate annually (BTS, 1996), the majority of intrastate freight movements are accomplished by truck. As the value to weight ratio increases, commodities originating in Montana are also more likely to be shipped by truck rather than rail. While trucks account for 35 percent by weight of the commodities originating in Montana, they account for 62 percent of the value of all commodity shipments originating in Montana.

Information on freight whose destination is Montana is sparse. Based on data from the federal commodity flow study, an estimated 60 percent (by weight) of the freight shipped into the state moves by truck (BTS, 1996).

Quantitative information on the volume of truck freight that simply moves across the state (with both origin and destination in other states) appears to be unavailable. Interstates 90 and 94, which generally traverse the state east-to-west, are one highway link between the Pacific

Northwest and the central and eastern United States. Interstate 15, which traverses the state north-to-south, is a major link between Alberta, Canada, and the United States. Thus, a significant portion of the freight moved on these highways is believed to simply pass through Montana.

Based on the above information, economic activity involving intrastate freight movements was expected to be most affected by changes in vehicle weight regulations, in that:

1) Rail is used for a majority of out-of-state freight movements.
2) Trucks are used for a majority of intrastate freight movements. Furthermore, and as previously mentioned, trucks engaged in only local commerce can be configured to comply with state GVW regulations, which allow GVWs in excess of 36,300 kilograms (80,000 lbs), without concern regarding more restrictive GVW regulations in other states.
3) Trucks involved in freight movements into, out-of, and across Montana are constrained to configurations that comply with the lowest maximum GVW allowed by the various states in which they operate (which is likely to be 36,300 kilograms (80,000 lbs) on a 5 axle tractor, semi-trailer). Therefore, a significant portion of these vehicles already operate at GVWs at or below 36,300 kilograms (80,000 lbs).

3. NEW TRAFFIC STREAMS

3.1 GENERAL REMARKS

Five scenarios with different allowable maximum GVWs were considered in this study, namely, 36,300; 39,900; 47,900; 53,300 (existing limits); and 58,100 kilograms (80,000; 88,000; 105,500; 117,500 (existing limits); and 128,000 lbs). These scenarios and their origins are summarized in Table 3.1-1. The lowest GVW scenario, the 36,300 kilogram (80,000 lb) scenario, represents approximately a 32 percent reduction in allowable GVW compared to existing weight limits, and it is consistent with the present Federal standard enacted across the United States in 1982 on the interstate system. The highest GVW scenario, the 58,100 kilogram (128,000 lb) scenario, corresponds to approximately a 10 percent increase in allowable GVW compared to existing limits, and it follows the regulations proposed in the early 1990's for special 5, 6, 7 and 8 axle long combination vehicles that would be allowed to operate along a north-south corridor between Canada and Mexico (Alberta Transportation and Utilities, 1994). With the exception of the 58,100 kilogram (128,000 lb) scenario, vehicles operating under each scenario were presumed to meet all existing size and weight regulations, with the additional imposition of a maximum GVW cap. Thus, all vehicles still had to meet the existing requirements in Montana on allowable axle loads, axle weights, Federal bridge formula weight restrictions, width requirements, length restrictions, and height limitations. In the 58,100 kilogram (128,000 lb) scenario, the Federal bridge formula requirements and length restrictions were waived for long combination vehicles that adhered to rigid over-all length and interaxle dimension requirements.

It was assumed under all scenarios that the maximum GVW limits would be adopted at least on a regional scale. In making this assumption, however, it was further assumed that in the 36,300; 39,900; and 47,900 kilogram (80,000; 88,000; and 105,500 lb) scenarios, any existing regulations in other states requiring lower GVWs than the maximum value allowed by the scenario took precedence over the scenario value. Thus, these scenarios were intended to represent the imposition of lower allowable GVWs in Montana and the surrounding area, not the liberalization of allowable GVWs in states with GVWs lower than the scenario GVW.

The process of predicting the composition of the new traffic streams that would evolve under the various GVW scenarios consisted of assigning all of the freight presently carried by the system to the most appropriate vehicles allowed under each scenario. "Appropriate" vehicles to receive freight were generally judged to be those vehicles that could most efficiently and legally move the displaced freight, while simultaneously maximizing the re-use of existing equipment. The assumption was made that the volume of freight to be moved on the system would remain constant across all scenarios. In making this assumption, it was inherently assumed that (a) any diversion of freight to other modes of transportation would be negligible and thus could be ignored and (b) any reduction in the total demand for shipping services would be negligible and could be ignored.

Table 3.1-1 Summary of GVW Scenarios

Maximum Allowable Gross Vehicle Weight Scenarios, kilograms (lbs)	Change in Maximum Allowable Gross Vehicle Weight Compared to Currently Allowed[a]	Comments
36,300 (80,000)	32 percent reduction	maximum limit is consistent with maximum Federal limit put in place nationally in 1982, almost all large combination vehicles except the 3S2 and 3-2 disappear from the traffic stream
39,900 (88,000)	25 percent reduction	maximum limit is consistent with current limit on a 3S3 (6 axle tractor, semi-trailer), almost all large combination vehicles except the 3S2 and 3S3 disappear from the traffic stream
47,900 (105,500)	10 percent reduction	maximum limit is consistent with current limit in several neighboring states for 3S2-2 and 3S2-3 (long combination vehicles), minimal changes in the traffic stream
53,300 (117,500)	0[b]	current maximum limits are controlled by the Federal Bridge Formula applied in conjunction with axle weight limits and maximum allowable vehicle lengths, typical configurations at the high end of the weight range operate at around 53,100 to 54,400 kilograms (117,000 to 120,000 lbs)
58,100 (128,000)	10 percent increase	maximum limit is consistent with proposed limit under Canamex, appearance of nominally more 3S2-2 and 3S2-3 vehicles in the traffic stream

[a] Based on approximate existing maximum gross vehicle weight of 53,300 kilograms (117,500 lbs)
[b] Varies based on number of axles and axle spacing

3.2 GENERATION OF NEW TRAFFIC STREAMS

3.2.1 General Remarks

For each GVW scenario, a traffic fleet was created in which all vehicles were in compliance with the maximum allowable GVW of the scenario and which were collectively capable of moving the same quantity of freight as moved with the existing vehicle fleet. The information available to accomplish this task consisted of:

1) the previously mentioned MDT truck weight file, which provided excellent information on the configurations and weights of the vehicles operating on the highway system, but no information on commodities hauled, trip distances, origins, or destinations by configuration,
2) the results of the federal Truck Inventory and Use Survey (TIUS) (U.S. Dept. of Commerce, 1995), which provided good information on the commodities hauled

by configuration and trip distance, but only nominal information on whether these trips were in Montana or elsewhere,

3) the results of the federal Commodity Flow Survey (BTS,1996), which provided broad based information on the types of commodities shipped in Montana and the modes of transportation used,
4) the results of a survey of the members of the Montana Motor Carriers Association with respect to their trucking operations (i.e., commodity, truck type and operating characteristics, trip origin and destination) and opinions on how these operations would change under various GVW scenarios (see Appendix A), and
5) direct and detailed interviews with users and providers of truck transportation services in Montana regarding these same issues.

The information sources relied on most heavily in generating new vehicle fleets and traffic streams for each scenario were the MDT truck weight file, the results of the survey conducted of the Montana Motor Carriers Association, and information obtained during direct interviews with users and providers of truck transportation services in Montana.

The only "new" vehicles introduced in any of the scenarios were the 5, 6, 7, and 8 axle long combination vehicles included in the 58,100 kilogram (128,000 lb) scenario. These vehicles, referred to as Canamex vehicles (Alberta Transportation and Utilities, 1994) are nominally longer than the combination units that are presently allowed to operate in Montana (under permit), and the 7 and 8 axle units are heavier than the 7 and 8 axle combination units than are presently allowed in Montana. Canamex vehicles, which geometrically resemble existing Montana combination vehicles, are required to adhere to current Montana axle weight limits, but they are allowed to operate at Canadian Interprovincial gross vehicle weights. The gross weight limits for 5 and 6 axle combination vehicles under Canamex are identical to the existing weight limits for 5 and 6 axle combinations. Seven and 8 axle C-trains, however, can carry 7 to 9 percent more weight than the corresponding existing A-trains. At such weights, these vehicles violate Bridge Formula B. Weight limits are determined based on axle group type, axle group length, and spacings between axle groups. Minimum and maximum values are specified for (a) the lengths of various components of the vehicle and (b) its overall length. A complete description of the Canamex size and weight limits is presented in Appendix B.

3.2.2 Modal Diversion

Consideration was given to the modes of transportation that might be employed by users of transportation services under each GVW scenario. As the maximum allowable GVW decreases, rail may become a more economical mode of transportation than trucks. Rail would be expected to be particularly attractive in transportation situations involving moderate to long haul distances of bulk commodities (TRB, 1990a; TRB, 1990b). In any specific situation, factors that influence the choice of rail versus highway transport include the physical availability of rail, the cost and availability of transloading facilities, and the timeliness of the service provided. In interviewing several users of transportation services in Montana, it was discovered that rail already is employed for hauling bulk products when they need to be transported more than 320 to 480 kilometers (200 to 300 miles). One problem companies consistently expressed with respect to using rail (presuming it was available) was timeliness in delivery. These companies indicated that timeliness was increasingly critical to satisfying their customers' requirements, even for non-perishable goods. Note that rail already is used to move 52 percent by weight of the commodities that originate in Montana (see Section 2.4), with most of these freight movements being interstate in nature. Rail presently is used for only a very limited amount of intrastate freight movement.

Some insights into the specific amount of mode shifting that might occur under the scenarios considered in this investigation can be obtained from existing studies on the effects of increasing GVW limits on the nation's highways. A 1990 TRB study (TRB, 1990a) looked at the effect nationally of eliminating the 36,300 kilogram (80,000 lb) GVW limit and requiring instead that vehicles simply comply with existing dimensional limits, axle weight limits, and the Federal Bridge Formula B (referred to by TRB as their "Uncapped Formula B Scenario). Montana presently is an "Uncapped Formula B" state, while much of the rest of the United States conforms more closely to an 36,300 kilogram (80,000 lb) limit. Thus, the 36,300 kilogram (80,000 lb) scenario in this investigation is the reverse of the "Uncapped Formula B Scenario" considered by TRB, and their predicted diversion of freight from rail to truck should directly correspond to the truck to rail diversion in this study for the 36,300 kilogram (80,000 lb) scenario. The TRB study predicted a 1.3 percent change in the ton-miles of freight carried by trucks as a result of mode shifting from rail.

A second TRB study (TRB, 1990b) considered the effects nationally of adopting Turner trucks, which are a series of combination vehicles varying in GVW from 41,300 to 57,600 kilograms (91,000 to 127,000 lbs) that were specifically designed to minimize pavement damage while maximizing payload capacity. Once again, this situation is approximately the reverse scenario from the 36,300 kilogram (80,000 lb) scenario considered in this investigation, so their predicted rail to truck diversion should correspond to the truck to rail diversion in this study. This TRB study estimated an average 2 percent shift in freight from rail to truck. The rate of diversion varied with commodity, with the highest diversion rates being determined for lumber and wood products, pulp and paper products, and primary metal products.

In the soon to be released federal truck size and weight study, it apparently was noted that, for the size and weight scenarios they considered, shifts in freight between trucks had significantly greater impacts on changes in the volume of truck traffic than inter-modal freight diversions (FHWA, 1998).

Based on these various considerations, the decision was made to exclude modal diversion in developing the new traffic streams and calculating the infrastructure costs for each scenario. This approach should result in infrastructure demands (and costs) being nominally overstated for the scenarios that represent a reduction in maximum allowable GVW (as some freight would be shifted from truck to rail in these cases) and nominally understated for the scenario in which the maximum allowable GVW is increased (as some freight would be expected to shift from rail to truck in this case). This approach is expected to closely match what will occur in the short to medium term (5 years), as companies attempt to maximize the use of their existing equipment while they develop long term transportation strategies and build new facilities, as necessary, to support these strategies (such as rail terminals and lines).

3.2.3 Development of New Vehicle Fleets

For each scenario, a vehicle fleet was created that was capable of carrying the same amount of freight on the system as the current vehicle fleet while complying with the maximum allowable GVW imposed by the scenario. These fleets were created by diverting freight between the vehicles in the existing fleet, as that fleet was characterized by the static scale data. As might be expected, it was discovered that for the 36,300; 39,900; and 47,900 kilogram (80,000; 88,000; and 105,500 lb) scenarios, more lighter vehicles were required in the fleet than presently operate on the system to move the same freight. Conversely, for the 58,100 kilogram (128,000 lb) scenario, fewer heavier vehicles were required than presently operate on the system to move the same freight.

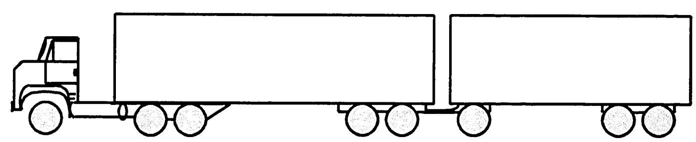
Specific choices of vehicles to receive diverted freight in each scenario were made based on maximizing the efficiency of the transportation operation while reusing as much existing equipment as possible. The diversions performed in each scenario are presented in Table 3.2.3-1. These diversion choices were generally confirmed by direct interviews with users and providers of freight services in Montana, and they were found to be consistent with the results of the survey conducted by mail and fax of the Montana Motor Carriers Association. Every vehicle in the truck weight data sample was evaluated individually for possible freight diversion. Algorithms were developed for this purpose that automatically a) checked the GVW of the vehicle to determine if it exceeded the maximum allowable GVW of the scenario, and b) if the maximum allowable GVW was exceeded, it reassigned the freight carried by the vehicle to some other vehicle based upon preestablished guidelines related to its weight and configuration.

Table 3.2.3-1 Summary of Freight Diversions by Vehicle Configuration and Scenario

Truck Configuration	Maximum Gross Vehicle Weight Scenario			
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	58,100 kg (128,000 lb)
Single Unit				
2 SU, 3 SU, 4 SU	U	U	U	U
Straight Truck w/ Trailer				
2-1, 2-2	U	U	U	U
3-2	L	U	U	U
3-3	D	D	U	U
3-4, 4-4	D	D	L	U
Tractor-Semi-Trailer				
2S1, 2S2	U	U	U	U
3S2	R	R	U	D
3S3	D	R	U	U
3S4	D	D	U	U
4S4	D	D	L	U
3 Unit Combinations				
2S1-2	L	U	U	U
2S2-2	L	L	U	U
3S1-2	D	L	U	U
3S2-2	D	D	L	H
3S2-3	D	D	L	H,R
3S2-4	D	D	L	H

U = Unchanged; L = Lower GVW, same configuration; D = Diverted to different configuration; R = Received freight from diversion; H = Higher GVW, same configuration

Consider, for example the case of an 8 axle long combination vehicle operating at 52,200 kilograms (115,000 lbs) (see Figure 3.2.3-1). This vehicle consists of a 5 axle tractor,semi-trailer, pulling a full trailer (often referred to as a pup). For the 36,300 kilogram (80,000 lb) scenario, the algorithm would effectively decide that the operator would unhook the pup and run the forward part of the configuration as a 5 axle tractor, semi-trailer, which would be in compliance with the 36,300 kilogram (80,000 lb) maximum GVW. The freight on the pup would be shifted with other partial loads until a new trip was generated for the same 5 axle tractor, semi-trailer. Under the 39,900 kilogram (88,000 lb) scenario, the algorithm would perform a similar diversion. The operator's only easy choice of configurations that comply with the 39,900 kilogram (88,000 lb) scenario within the bounds of his existing equipment is still the 5 axle tractor semi-trailer that makes up the forward portion of his long combination vehicle. Therefore, much of his freight would still be moved with 5 axle tractors, semi-trailers. A limited amount of freight shipped on some long combination vehicles was moved onto 6 axle tractor, semi-trailers. Some operators indicated that they had the volumetric capacity to run the front end of their long combination vehicles as tractor, semi-trailers operating at 39,900 kilograms (88,000 lbs), and that they would immediately add axles to their two axle semi-trailers and run them with their existing tractors as 6 axle tractor, semi-trailers.



Existing 3S2-2 at GVW = 53,300 kgs (117,500 lbs)

Becomes

1.67 ~ 3S2 at GVW = 36,300 kgs (80,000 lbs)

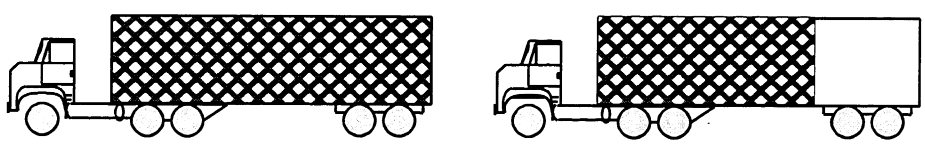


Figure 3.2.3-1 Example of Conversion, Rocky Mountain Double to 5 axle tractor, semi-trailers (36,300 kilogram (80,000 lb) scenario)

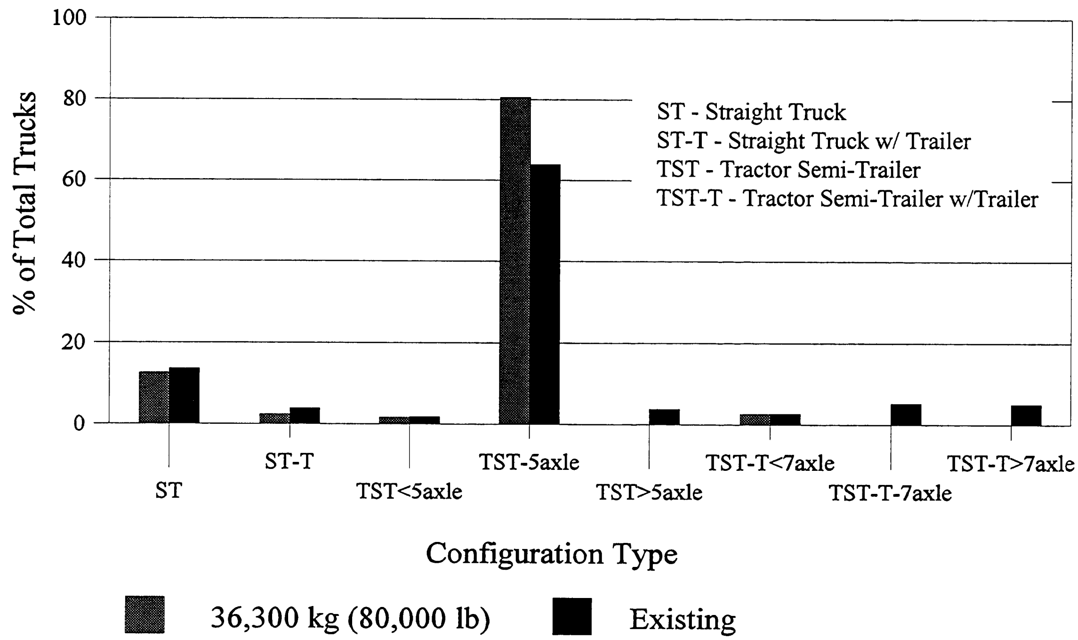
At a maximum gross vehicle weight of 47,900 kilograms (105,500 lbs), the algorithm would simply haul the freight on the same 8 axle long combination vehicle configuration but carrying 4,310 kilograms (9,500 lbs) less payload in each trip. Finally, at the 58,100 kilogram (128,000 lb) scenario, the algorithm would still run the existing equipment at 52,000 kilograms (115,000 lbs) for 50 percent of the trucks of this configuration and weight in the fleet; while in the other 50 percent of the cases, it would increase the GVW of the truck to 56,200 to 58,100 kilograms (124,000 to 128,000 lbs) and haul the same amount of freight in fewer loads. This approach was used to account for volume limited rather than weight limited vehicles operating at heavy weights. Note that 10 percent of the freight hauled on 5 axle tractor, semi-trailers was also shifted to 8 axle combination configurations. Geometrically, the vehicle lengths permitted under this scenario provide operators of 5 axle tractor, semi-trailers, with the simple option of adding a short trailer with a stabilized dolly to their existing vehicle and thus create an 8 axle combination with an allowable GVW of 58,100 kilograms (128,000 lbs). The resulting payload was judged sufficient to attract some operators of 5 axle tractor, semi-trailers to long combination vehicles.

The vehicle fleets developed using the process outlined above are described in Figure 3.2.3-2. Several of the vehicle operators commented that they had optimized their present equipment to function under existing GVW regulations. Some of these operators went on to comment that this equipment poorly supported some of the scenarios under consideration. Notably, few operators appeared to be equipped to easily run 6 axle tractor, semi-trailers. Operators also indicated that the 5 axle tractor, semi-trailer portion of their Rocky Mountain Doubles may not be optimally configured to run as a stand alone 5 axle tractor, semi-trailer under a 36,300 kilogram (80,000 lb) scenario. Finally, some of the existing Rocky Mountain Doubles may not conform to the dimensions required in order to operate at the highest GVWs in the 58,100 kilogram (128,000 lb) scenario. These situations were taken into account in determining the vehicles that would be used in each industry under the various GVW scenarios.

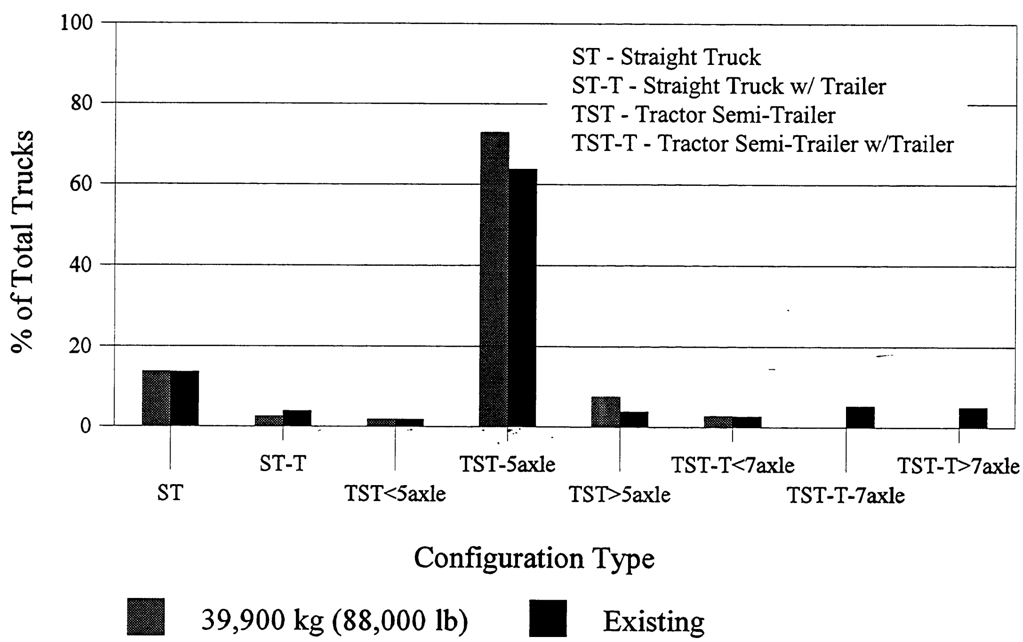
Referring to Figure 3.2.3-2a, the fraction of the vehicle fleet comprised of 5 axle tractor, semi-trailers was expected to increase from 64 to 81 percent for the 36,300 kilogram (80,000 lb) scenario. All of the large combination vehicles were effectively eliminated from the fleet under this scenario, and the freight hauled by these vehicles was shifted to 5 axle tractor semi-trailers. The vehicle fleet expected to evolve under the 39,900 kilogram (88,000 lb) scenario, described in Figure 3.2.3-2b, was similar to that predicted for the 36,300 kilogram (80,000 lb) scenario. Almost all of the large combination vehicles were again eliminated from the fleet, to be replaced with 5 and 6 axle tractor, semi-trailers. While the 6 axle tractor, semi-trailer appeared attractive under this scenario, much of the freight from large vehicles was still diverted to 5 axle tractor semi-trailers due to a) the increased availability of 5 compared to 6 axle tractor, semi-trailers and b) the apparently modest increase in payload for the 6 axle tractor, semi-trailer operating at 39,900 kilograms (88,000 lbs) compared to the 5 axle tractor, semi-trailer. The 5 and 6 axle tractor, semi-trailers increased as a fraction of the vehicle fleet by 11 and 4 percent, respectively.

The vehicle fleet expected to evolve under the 47,900 kilogram (105,500 lb) scenario, described in Figure 3.2.3-2c, was relatively unchanged from the existing vehicle fleet. As might be expected, the 5 and 6 axle tractor, semi-trailer traffic was unaffected in this scenario. Large combination vehicles increased from being 13 to being 13.5 percent of the traffic stream, as the freight these vehicles presently carry was hauled using the same configurations operating at lower GVWs. Finally, under the 58,100 kilogram (128,000 lb) scenario, large combination vehicles were expected to nominally increase as a fraction of the vehicle fleet from 13 to 17 percent (Figure 3.2.3-2d). This net change reflects a decrease in large combination vehicles as a result of increased payloads for these vehicles under the 58,100 kilogram (128,000 lb) scenario, countered by an increase in large combination vehicles as 5 axle tractor, semi-trailers switch to these configurations under the liberalized weight allowance of 58,100 kilograms (128,000 lbs).

The vehicle fleets described above were subsequently sorted by configuration , and the average operating characteristics of each configuration for each scenario were determined. This information and the basic diversion algorithms were then used to transform the existing traffic streams on highway routes throughout the state (available from MDT) into the new traffic streams expected to evolve on these routes under each GVW scenario. An example of the traffic streams generated along an Interstate route under each scenario is presented in Table 3.2.3-2.

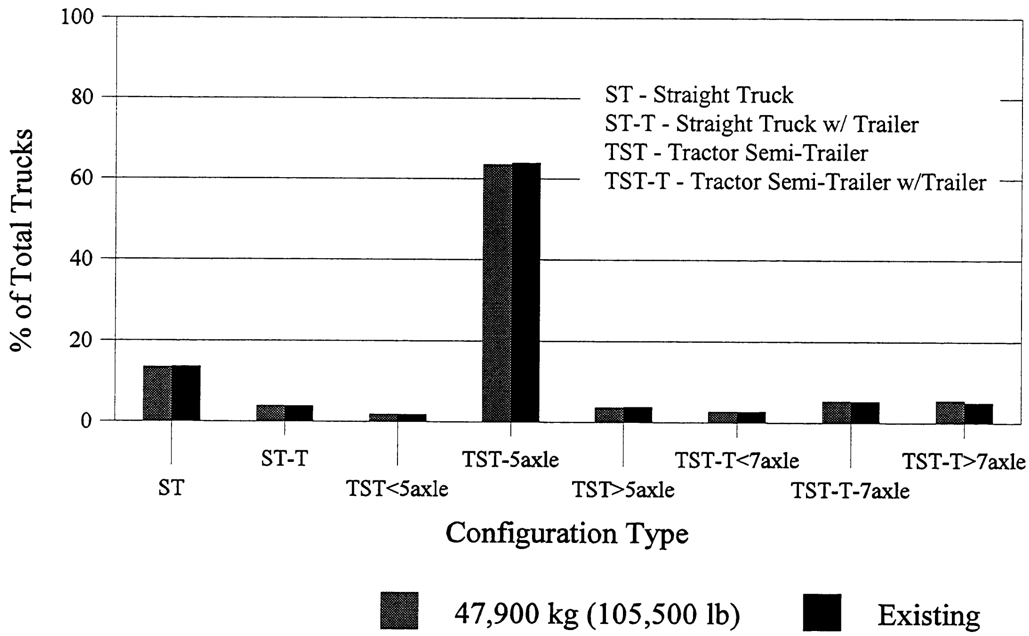


a) 36,300 Kilogram (80,000 lb) Scenario

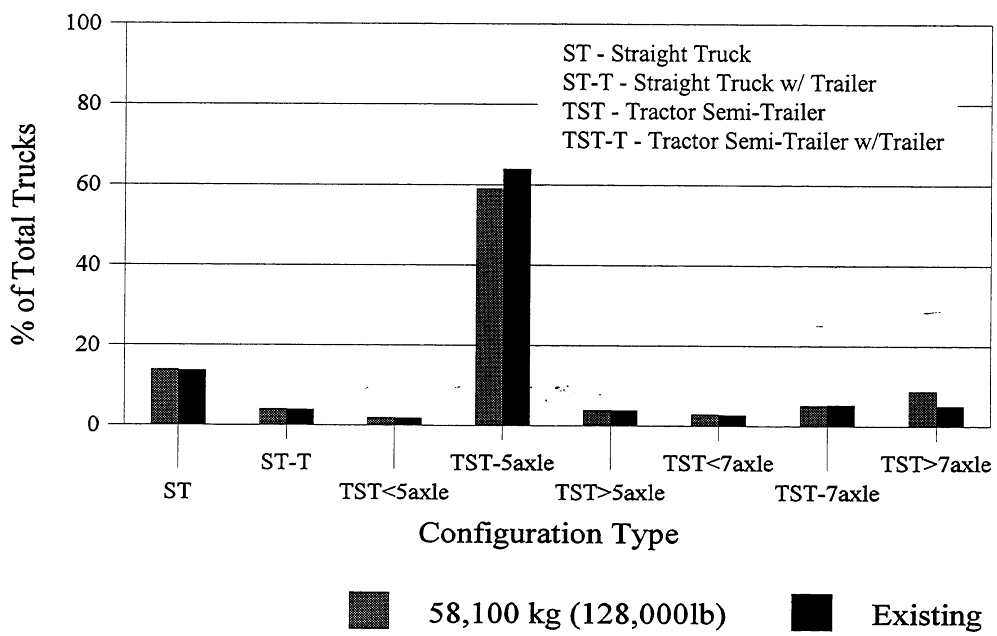


b) 39,900 kg (88,000 lb) Scenario

Figure 3.2.3-2 Predicted Compositions of the Heavy Vehicle Fleet (page 1 of 2)



c) 47,900 kg (105,500 lb) Scenario



d) 58,100 kg (128,000 lb) Scenario

Figure 3.2.3-2 Predicted Compositions of the Heavy Vehicle Fleet (page 2 of 2)

Table 3.2.3-2 Typical Configuration of the Traffic Stream on an Interstate in Montana

Route # I-90	**Segment** MP 110 Bonner to Drummond			**Length** 69 km (43.1 miles)	**AADT** 8076
Vehicle Configuration	Annual Average Daily Traffic				
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	58,100 kg (128,000 lb)
Motorcycle	16	16	16	16	16
Pass. Car	4232	4232	4232	4232	4232
Pickup	2189	2189	2189	2189	2189
2A-4T RV	0	0	0	0	0
2A-4T SU	0	0	0	0	0
School Buses	32	32	32	32	32
2A-Com. Buses	0	0	0	0	0
3A-Com. Buses	0	0	0	0	0
2A-6T RV	0	0	0	0	0
2A-6T SU	194	194	194	194	194
3A-RV	0	0	0	0	0
3A-SU	40	40	40	40	40
4A-RV	0	0	0	0	0
4A-SU	24	24	24	24	24
2-1 3A-TR	1	1	1	1	1
2-2 4A-TR	27	27	27	27	27
2S1 3A-ST	6	6	6	6	6
2S2 4A-ST	6	6	6	6	6
3S2 5A-ST	1328	1204	1026	1026	924
3-2 5A-TR	32	32	32	32	32
3S3 6A-ST	0	115	69	69	69
3S4 7A-ST	0	0	0	0	0
4S4 8A-ST	0	0	0	0	0
3-3 6A-TR	0	0	37	36	36
3-4 7A-TR	0	0	0	0	0
3-5 8A-TR	0	0	0	0	0
3-6 9A-TR	0	0	0	0	0
4-6 10A-TR	0	0	0	0	0
2S1-2 5A-TU	16	16	16	16	16
3S1-2 6A-TU	16	16	16	16	16
2S2-2 6A-TU	0	0	0	0	0
3S2-2 7A-TU	0	0	67	66	63
3S2-3 8A-TU	0	0	50	47	97
3S2-4 9A-TU	0	0	0	0	0
3S1-2-1 7A-MT	0	0	0	0	0
2S2-2-2 7A-MT	0	0	0	0	0
3S1-2-2 8A-MT	0	0	0	0	0
Total AADT	**8159**	**8150**	**8080**	**8075**	**8020**

The changes estimated in the number of trucks (5 axle tractor, semi-trailer and larger vehicles) operating on the highway system under each scenario are reported in Figure 3.2.3-3 by element of the highway system. As would be expected, the amount of large truck traffic increased on all systems under the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. For the 36,300 kilogram (80,000 lb) scenario, truck traffic increased by 8, 12, and 16 percent on the interstate, NHS and state primary, and state secondary and urban systems, respectively. The changes in truck traffic were similar and slightly lower in magnitude for the 39,900 kilogram (88,000 lb) scenario compared to the 36,300 kilogram (80,000 lb) scenario. Truck traffic under the 47,900 kilogram (105,500 lb) scenario was expected to increase by less than 2 percent across all systems. For the 58,100 kilogram (128,000 lb) scenario, a net reduction in heavy truck traffic of 3 to 5 percent was predicted. The relative changes in truck traffic by system within each scenario directly reflect the variations in the composition of the existing traffic stream on the different elements of the highway system. As previously mentioned, large combination vehicles make up a greater fraction of the truck traffic on the NHS, and state primary, secondary, and urban systems than on the interstate system. Therefore, changes in traffic are more pronounced on the NHS and state primary, secondary, and urban systems compared to the interstate system.

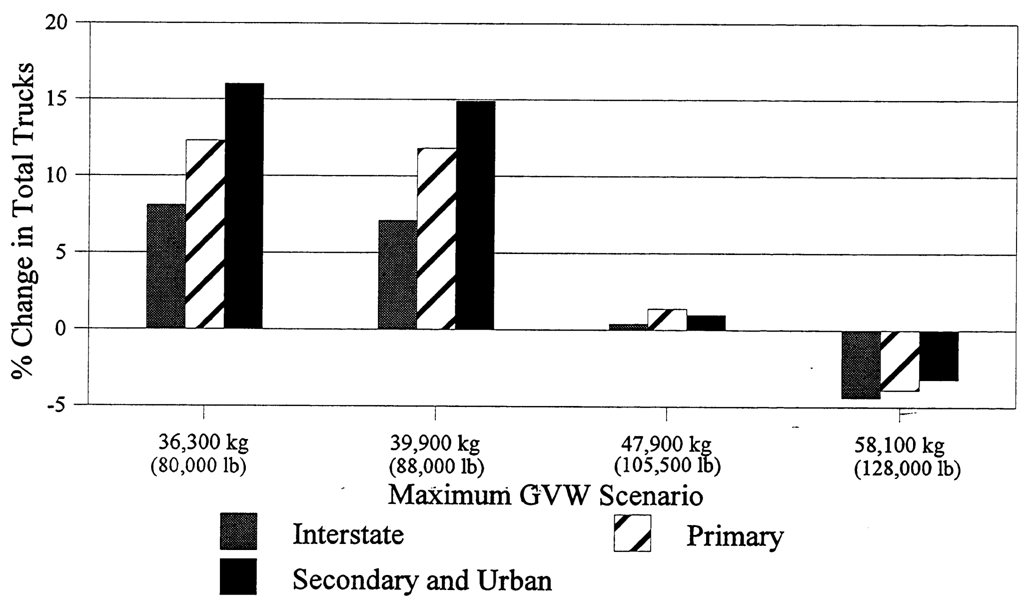


Figure 3.2.3-3 Change in Number of Trucks in the Traffic Stream (vehicles capable of operating at GVW's of 36,300 kilograms (80,000 lbs) or greater)

Only nominal changes occurred in the total volume of traffic operating on the highway system under all scenarios. Total vehicle miles of travel (for all vehicles) was calculated to increase by only 0.9, 0.8, and 0.1 percent in the 36,300; 39,900; and 47,900 kilogram (80,000; 88,000; and 105,500 lb) scenarios, respectively, relative to the existing vehicle miles traveled. A nominal decrease in vehicle miles of travel (0.3 percent) was predicted in the 58,100 kilogram (128,000 lb) scenario.

4. PHYSICAL IMPACTS

4.1 GENERAL REMARKS

Changes in the maximum allowable GVW of the vehicles that operate on the highway system could affect the performance and design requirements of the highway infrastructure. The primary elements of the system that are sensitive to load related issues are the pavements and the bridge system. Pavements are most directly affected by the magnitude, type, and number of axle loads they experience. While the maximum allowable axle loads are the same under all of the scenarios considered herein (and in compliance with existing axle load regulations), pavement demands could still change under each scenario as commodities are shifted to vehicles with different axle configurations and axle weights, and as different numbers of trips are required to ship the same total amount of goods on the highway system. Therefore, analyses were done to determine how the remaining life of existing pavements and future pavement designs would change under each scenario.

Bridges are sensitive to the magnitude and spacing of the axle loads they are exposed to as they are traversed by various vehicles. Allowable combinations of axle load and spacing that a bridge can carry are further affected by the span length(s) of the bridge and its structural classification (simple or continuous). With the exception of the 58,100 kilogram (128,000 lb) scenario, the vehicles in the scenarios considered in this study meet the existing regulations in Montana that were enacted to limit the demands vehicles place on bridges. These regulations control the axle spacings, axle weights, and maximum gross vehicle weights of vehicles that operate on the system by way of the Federal Bridge Formula. Questions have been raised, however, regarding the ability of existing laws to insure that bridges are only subjected to loads that they can safely carry. Therefore, the demands placed on the bridge system by typical vehicles from all scenarios were reviewed with respect to bridge capacity. These analyses were performed using a reliability based approach to assessing structural capacity, rather than the working stress based approach used in many previous infrastructure studies (e.g., TRB,1990a; FHWA , 1997). Reliability based methods of analysis provide greater assurance than working stress methods that all structures provide a uniform and acceptable level of safety; such methods have generally been adopted across all areas of structural engineering over the past 25 years.

While the focus of this study was on the impact of changes in maximum allowable GVW on pavements and bridges, other features of the highway infrastructure that could be impacted by such changes include its basic geometry, that is, items such as lane width, intersection width, sight distances, minimum curve radii, etc. These characteristics of the system would primarily be impacted only to the extent that GVW influences vehicle dimensions and handling characteristics. Note that the existing system is already being used by all the vehicles under the scenarios considered herein, except for the heaviest vehicles operating under the 58,100 kilogram (128,000 lb) scenario. Furthermore, the lowest GVW scenario, the 36,300 kilogram (80,000 lb) scenario, still allows long semi-trailer units (22.9 meters (75 ft)) to operate on the system.

Changes in the maximum GVW of vehicles allowed on the highway system can affect the flow of traffic on the system, if the number and type of vehicles using the system changes between scenarios. System safety is the most important consideration in this regard (and a consideration which is also related, among other things, to the handling characteristics of the vehicles that use the system). Simple calculations were performed to obtain an indication of the changes in the number of accidents that may occur under each scenario. A second consideration with respect to traffic flows under each scenario was possible problems with system capacity resulting from any increases in traffic volume. These issues were investigated and found to be, at present, of only limited concern under Montana's generally sparse traffic.

Finally, while not the focus of this study, items such as fuel consumption, air pollution, and noise pollution may be influenced by changes in maximum allowable GVW, and these issues were examined.

4.2 PAVEMENT IMPACTS

4.2.1 General Remarks

The impacts of the adoption of different maximum allowable GVWs on the pavement were determined by a) estimating the demand expected to be placed on the pavement under the existing and alternate scenarios proposed herein, b) determining the remaining life of existing pavements under these demands, and c) calculating the required overlay thickness to meet these demands in the future to extend the life of the pavement an additional 20 years. These calculations were performed for a sampling of pavement segments from the entire interstate system and from typical non-interstate NHS, primary, and secondary routes around the state. These results were then extrapolated to cover each route in its entirety, and then further extended to represent the situation across the entire system (including the 581 kilometers (361 miles) of the urban system, which was not specifically sampled).

All impact calculations were performed for flexible pavements. Less than 5 percent of the pavement on the state highway system is rigid, and the decision was made that a reasonable representation of total system performance would be realized by considering just flexible pavement.

4.2.2 Relationship Between Traffic and Pavement Demand

The damage sustained by a given pavement by the passage of a vehicle is affected by several factors related to both the vehicle and the pavement. Important characteristics of the vehicle include individual axle loads, axle configuration, tire configuration, tire size and pressure. Pavement related parameters of interest include pavement type, thickness, subgrade conditions, temperature, and present condition. Gillespie and his colleagues (1993) compiled an excellent summary of the relationship between these various parameters and pavement damage. Pavement demands and damage are generally viewed with respect to two mechanisms, (a) immediate structural failure of the pavement under a few applications (or even under the single application) of a severe demand, and (b) progressive fatigue and/or rutting failure of the pavement under high cycles of moderate demand. Maximum local wheel load demands under all the scenarios considered in this study are identical, as the maximum allowable axle loads are the same in all scenarios (and consistent with existing Montana axle load limits). Thus, the potential for immediate structural failure will be the same for all scenarios. The cyclic demands on pavements are expected to change for each scenario, however, in response to changes in the number and type of the trips taken in each regulatory situation.

The effects of changes in cyclic pavement demand can be investigated using pavement performance models. Considerable research has been done on developing mechanistic models to relate the various vehicle and pavement characteristics listed above to pavement behavior and performance, and some of these mechanistic relationships are beginning to be used in practice. The recently completed federal cost allocation study, for example, used the nationwide pavement cost model (NAPCOM), which relates axle loads to engineering response and finally to pavement distress, to assess pavement demands under different axle loads (FHWA, 1997). NAPCOM has only recently been developed, and it was not available for use in this study. Therefore, more traditional models relating axle demands to pavement deterioration were used in this study.

Empirical relationships have traditionally been used to predict pavement performance as a function of a variety of parameters known to influence pavement damage. This situation has emerged in light of the apparent complexity of the problem from a mechanistic perspective. A well-known empirical approach used to quantify and design for fatigue type damage in pavements is the AASHTO ESAL approach (AASHTO, 1993). While this design process and the entire ESAL concept are not universally accepted, this is the design process currently used by MDT. Therefore, this approach was used in this investigation. Comparisons between AASHTO ESAL and NAPCOM results indicate that pavement damage does not increase as rapidly with axle load in the NAPCOM model as it does under the AASHTO approach (Mingo, 1997). Using the NAPCOM model, however, load related damage was found to be a greater fraction of total damage than might be traditionally expected.

Following the AASHTO approach to pavement design, vehicle demands on pavements are quantified in terms of equivalent single axle loads or ESALs (AASHTO, 1993). An ESAL represents the relative amount of damage inflicted by a particular type of axle (e.g., single axle, tandem, or tridem) under a specific load in terms of the number of passages of a single axle loaded at 8,200 kilograms (18,000 lbs) required to inflict an equivalent level of damage. Relationships between ESALs and axle loads were determined from the results of the AASHO road test (Highway Research Board, 1962). In part of this test, sections of road were loaded with repeated cycles of the same axle load until a predetermined level of deterioration was reached. Deterioration was measured in terms of the present serviceability index (PSI), a parameter specifically developed to provide a general indication of a pavement's ability to serve traffic. The index ranges from 1 to 5, with a value of 5 corresponding to pavement in excellent condition. Pavements on major roads with a PSI of 2.5 are considered in need of repair. The relationships between ESAL and axle load for single and tandem axles on the same pavement are shown in Figure 4.2.2-1. Pavement damage decreases when the applied load is carried on closely spaced axles compared to widely spaced axles. This effect has been attributed to favorable interference in the stress patterns generated by the individual axles in the group. ESAL to axle load relationships for tridems and quadrums were analytically developed from the single and tandem axle expressions, as these axle configurations were not part of the AASHO road test matrix. Thus, the validity of the tridem and quadrum relationships is less certain than the single and tandem relationships.

The amount of damage sustained by a pavement under the passage of a particular axle load is directly dependent on the type of pavement, its thickness, and the subgrade conditions. In the case of flexible pavements, various combinations of materials, thicknesses, and subgrade conditions can be collectively evaluated using the structural number (SN) (AASHTO, 1993). Values for SN range between 1 and 6, with a value of 6 corresponding to the strongest/best flexible pavement. The influence of SN on the ESAL-to-axle load relationship is shown in Figure 4.2.2-1. As might be expected, strong pavements are less affected by the passage of a given axle load than weak pavements, as evidenced by the lower ESAL values for pavements with higher SN values. ESAL values at the load ranges of interest, however, are relatively insensitive to SN value.

The ESAL approach provides a tool for calculating the demand placed on a pavement by a traffic stream of mixed vehicles operating at various weights. ESALs can be calculated for each axle of a vehicle based on the individual characteristics of the axles and then summed to obtain the ESALs for the vehicle. These values can be further summed across all vehicles to obtain the ESALs for the entire traffic stream. Expected total ESALs of demand at a given location can be used in the pavement design process following an approach published by AASHTO that relates pavement thickness to, among other things, strength of the base, the selected terminal condition at failure, and total ESALs of demand across its expected lifetime.

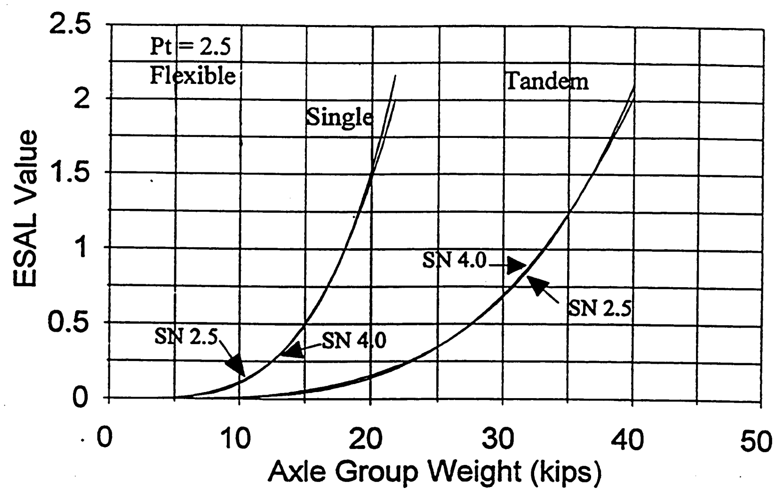


Figure 4.2.2-1 Typical Axle Load to ESAL Relationships, SN=2.5 and SN=4.0 (based on AASHTO (1993))

4.2.3 ESAL Calculations

Calculations of ESAL demands were done for the existing and projected traffic streams along the interstate and selected non-interstate NHS, state primary, and state secondary routes around the state. The routes considered in this analysis are shown in Figure 4.2.3-1. Pavement segments on both systems were sampled at 16 kilometer (10 mile) intervals along the length of the routes analyzed.

The total ESAL demands at each location under each scenario were calculated from the composition of the traffic stream at that location using average operating ESAL values for each vehicle type. Average ESAL values for each configuration were calculated from the weight/frequency distributions previously generated for each scenario according to the procedures described in Section 3. A structural number (SN) of 3.5 was used for all pavements in performing these calculations. While this SN value was judged to be appropriate for the pavements in the state, it was also observed that ESAL magnitudes were relatively insensitive to

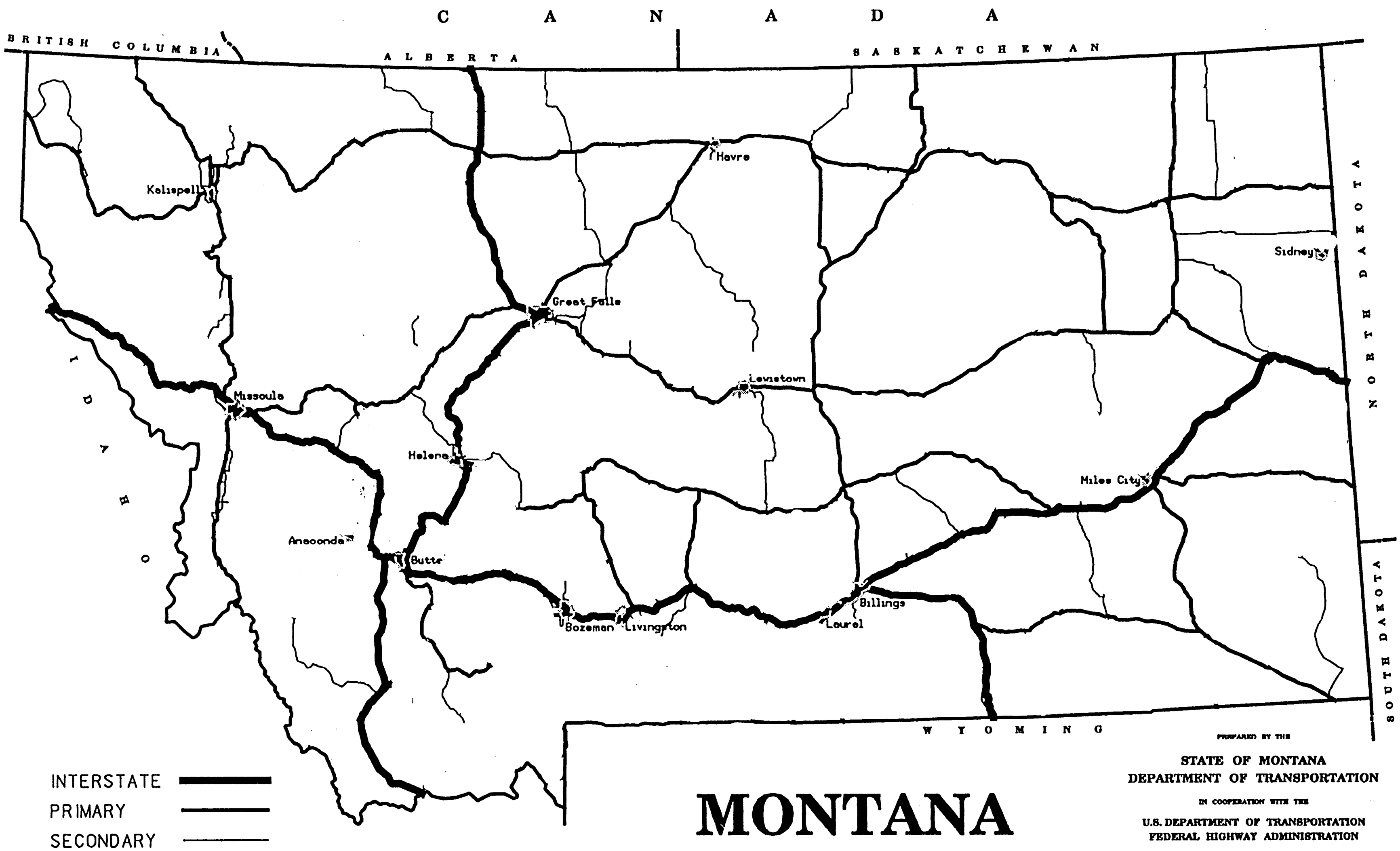


Figure 4.2.3-1 Routes used in Pavement Analysis

this parameter across the range of realizations believed to be appropriate for this problem. A terminal PSI value of 2.5 was used in all calculations, which is consistent with MDT practice.

The change in ESALs of demand predicted along the interstate, primary, and secondary routes under each scenario is summarized in Table 4.2.3-1. Pavement demands nominally increased on all systems under the 36,300 kilogram (80,000 lb) scenario compared to those under the existing traffic stream. The smallest increase in demand, 2.6 percent, was observed on the interstate system. The increases on the NHS and state primary and on the state secondary systems were similar in magnitude and averaged around 6 to 7 percent. The relative magnitude of these increases reflected the relative use of the various systems by the vehicles most affected by the 36,300 kilogram (80,000 lb) scenario. Under the existing weight regulations, axle weights on heavy vehicles are often limited by the Federal Bridge Formula, rather than by the maximum legal axle weights. Under the 36,300 kilogram (80,000 lb) scenario, freight was shifted off these vehicles onto vehicles with lower GVWs but which operate at higher individual axle (or axle group) weights. Additionally, more trips were required to carry the same freight using 36,300 kilogram (80,000 lb) vehicles compared to existing vehicles. In this situation, pavement damage actually increased in moving the same total weight of freight as is presently carried on the system.

Table 4.2.3-1 Predicted Changes in ESAL Demands, Projected Traffic Streams Versus the Existing Traffic Stream

Route	Percent Change in ESAL Demands by Scenario							
	36,300 kg (80,000 lb)		39,900 kg (88,000 lb)		47,900 kg (105,500 lb)		58,100 kg (128,000 lb)	
	All Vehicles, %	Large Trucks, %	All Vehicles, %	Large Trucks, %	All Vehicles, %	Large Trucks, %	All Vehicles, %	Large Trucks, %
Interstate	2.6	2.9	0.3	0.3	-1.2	-1.3	1.1	1.2
Primaries	6.0	8.6	3.2	4.3	-1.5	-2.1	3.0	4.0
Secondaries & Urban	7.4	12.3	5.8	8.8	-1.7	-2.9	4.7	7.7
Total	**3.2**	**3.8**	**0.8**	**0.9**	**-1.2**	**-1.4**	**1.4**	**1.7**

Pavement demands increased for the 39,900 kilogram (88,000 lb) scenario, in a pattern similar to that for the 36,300 kilogram (80,000 lb) scenario. The increase in pavement demands, however, was nominally less for the 39,900 kilogram (88,000 lb) scenario compared to the 36,300 kilogram (80,000 lb) scenario. The 39,900 kilogram (88,000 lb) scenario involved the use of more 6 axle tractor, semi-trailers than the 36,300 kilogram (80,000 lb) scenario. Pavement damage from the tridem axles on these trailers operating at their maximum allowable weight was significantly less than that from the tandem axles on the trailers of the 5 axle units operating at their full weight. Note that due to the perceived limited availability of 6 axle tractor, semi-trailers in the existing vehicle fleet, much of the freight in this scenario was still shifted to 5 axle tractor, semi-trailers. The increase in pavement demand for the 39,900 kilogram (88,000 lb) scenario would be less pronounced, if the use of 6 axle tractor, semi-trailers were to be more prevalent than predicted herein.

A nominal reduction in pavement demands was observed for the 47,900 kilogram (105,500 lb) scenario compared to the demands placed on the pavement by the existing vehicle fleet. Pavement demand dropped by 1.2 percent in this scenario. Many heavy vehicles already operate at GVWs that range from 47,900 to around 52,200 kilograms (105,500 to around 115,000 lbs). In most cases, the assumption was made that operators of these vehicles would simply limit their gross weights to 47,900 kilograms (105,500 lbs) which would result in lower axle loads and less pavement damage per trip. The reduction in pavement damage per trip was sufficiently large to overcome the negative effects of the nominal increase in the number of trips required to haul the same amount of freight as presently moves on the system.

Pavement demands nominally increased (1.5 percent) in the 58,100 kilogram (128,000 lb) scenario relative to the pavement demands under the existing traffic stream. In direct contrast to the 47,900 kilogram (105,500 lb) scenario, existing configurations under the 58,100 kilogram (128,000 lb) scenario were allowed to operate at higher GVWs than are presently legal. Increasing the gross weight on these vehicles while keeping the same axle configuration resulted in higher axle loads than are currently used. These higher axle loads generated increased pavement demands under this scenario, despite the nominal decrease in the total number of trips required to move the same quantity of freight.

4.2.4 Remaining Life/Future Overlay Predictions

The remaining service life of existing pavements and the characteristics of the subsequent overlays required to provide repeated cycles of 20 years of service were estimated under each scenario using a damage model based on the AASHTO ESAL concept (AASHTO, 1993). These calculations were driven by the ESAL demands calculated above. Traditionally, pavements have been designed to resist some total number of repetitions of load expressed in ESALs and some level of absolute maximum wheel load. The maximum wheel loads allowed under the size and weight scenarios considered herein remained unchanged, thus failure of the pavement in a single load event was no more or less likely than under current conditions. The ESALs of demand changed for each scenario, however, as freight was loaded and moved on different vehicles.

To predict remaining pavement life, the basic AASHTO design equations were used in a fashion similar to that used by Deacon (1988) in a TRB study of truck size and weight (TRB, 1990a). The basic design approach was modified following the work of Deacon (1988) to address environmental effects (Stephens, et al, 1996). The thickness of the overlay required at the end of the remaining life of each pavement section required to provide 20 more years of service was calculated using this same performance model. In this case, the ESALs and environmental demands over the 20 year design life were known, the structural number required was calculated, and a pavement thickness to produce this structural number was determined.

In general, these various calculations found that the remaining service life of existing pavements would change by less than 1 year across all the scenarios. The average change in overlay thickness was less than 1.0 percent (note that a minimum overlay thickness of 0.82 meter (0.25 ft) was enforced).

4.2.5 Pavement Costs

The impact on pavement costs of adopting the maximum allowable GVWs considered in this study were calculated using the remaining life and overlay thickness information generated above. These impacts were expressed for each scenario in terms of an equivalent uniform annual cost (EUAC). These costs were calculated for the entire interstate system and typical routes on the primary and secondary systems, with the results extrapolated as necessary across the entire system. In each case, costs of the required overlays were calculated in terms of 1998 dollars and then adjusted to the actual cash flow based on when the first overlays were required.

Overlay costs in 1998 dollars were calculated using generic cost information provided by MDT (see Table 4.2.5-1) multiplied by a factor of 1.5 to cover internal MDT costs incurred on each project. Overlay cost was expressed as an EUAC using the equation,

$$EUAC = P_{OL} \frac{i\,(1+i)^{-n_{RL}}}{(1+i)^{n_{OL}} - 1} \; \frac{(1+i)^{n}}{(1+i)^{n} - 1}$$

where,

P_{OL} = present cost of overlay
n_{RL} = remaining life of present pavement
n_{OL} = design life of overlay (assumed = 20 years)
n = total number of periods being considered (assumed = 75 years)
i = discount rate (assumed = 7 percent)

Table 4.2.5-1 Basic Cost Data for Overlays (adapted from information from Wissinger, 1995)

Item	Unit Cost, dollars/metric ton ($/ton)
Bituminous Asphalt	265 (240)
Aggregate	11 (10)
Placement Cost	11 (10)
Sealer	237 (215)
Cover Aggregate	22 (20)
Mobilization	6 % of total cost
Traffic control	4 % of total cost
Miscellaneous	14 % of total cost

The EUAC values calculated for all scenarios were similar in magnitude and were around $125 million. The change in overlay costs for each GVW scenario, calculated with respect to pavement costs under existing GVW regulations, are presented in Table 4.2.5-2.

Table 4.2.5-2 Relative Overlay Costs for Each Scenario, Expressed as an EUAC

System	Change in Overlay Costs by Scenario, Millions of Dollars							
	36,300 kg (80,000 lb)		39,900 kg (88,000)		47,900 kg (105,500 lb)		58,100 kg (128,000 lb)	
	$	%	$	%	$	%	$	%
Interstate	0.25	0.58	0.02	0.05	-0.17	-0.38	0.06	0.14
Primary	1.12	1.89	0.63	1.13	-0.39	-0.65	0.53	0.90
Secondary	0.18	0.76	0.20	0.84	-0.02	-0.08	0.14	0.62
Total	**1.55**	**1.17**	**0.85**	**0.67**	**-0.58**	**-0.45**	**0.73**	**0.55**

The change in EUACs ranged from an increase of $1.5 million under the 36,300 kilogram (80,000 lb) scenario to a decrease of $0.6 million under the 47,900 kilogram (105,500 lb) scenario. These values represent an increase of 1.2 percent and a decrease of 0.5 percent, respectively, relative to comparable costs under the existing traffic stream. The percentage change in cost was consistently less than the percentage change in ESALs of demand, as has been observed by other investigators (Stephens, et al,1996; Khalil, 1996; Deacon, 1988). The marginal change in costs relative to increase in ESALs of demand is greater for the primary system than for the interstate system. Thus, the increase in ESALS of demand is more readily accommodated on the stronger interstate pavements compared to the primary pavements.

Note that pavement maintenance costs were assumed to remain constant under each scenario. With respect to existing pavements, the assumption was made that the level of maintenance work would remain constant under each scenario, and that the remaining life of the pavement would change in response to the different pavement demands under each scenario. With respect to new pavements, the assumption was made that all new designs would be done to accommodate the expected increase or decrease in demands under each scenario, and that these pavements would then receive similar maintenance treatment throughout their service lives.

4.3 BRIDGE IMPACTS

4.3.1 General Remarks

The important aspects of bridge performance that could possibly be affected under each GVW scenario were safety, serviceability, and durability. While compromises can be made with respect to serviceability and durability in the interest of transportation efficiency, the fundamental safety of the existing bridge system must always be maintained. The strength and safety of the bridge system was addressed by doing a reliability based safety analysis of the system under the demands generated by selected vehicles from each scenario. Note that as previously mentioned, only the 58,100 kilogram (128,000 lb) scenario includes vehicles that place demands on the bridge system in excess of those which it already routinely experiences. Detailed analyses of bridge serviceability and durability were not conducted as part of this study. A review of existing information on these issues indicated that the system will offer similar serviceability and acceptable longevity under all of the scenarios considered in this study.

4.3.2 Strength/Safety

Bridge safety was assessed under each scenario using a reliability based safety analysis. The philosophy behind this approach to bridge analysis is to insure that bridges provide the motoring public with a uniform and acceptable level of safety across a variety of situations. This approach to assessing bridge capacity contrasts with traditional approaches, which utilize a uniform level of maximum stress (rather than a uniform level of safety) in determining the load carrying capacity of a bridge. The safety based approach to assessing capacity acknowledges the differences in uncertainties associated with the different types of loads a bridge must carry, as well as differences in absolute level of demand based on traffic levels and other factors. This type of approach to capacity assessment is referred to as reliability based because its objective is to ensure a consistent level of reliability in structural performance, where reliability is defined as the probability that a structure will perform its intended function for a specified period of time under a given demand situation.

One implementation of reliability based structural analysis evaluates the adequacy of a structure under a given demand in terms of the reliability index β. The magnitude of the reliability (or safety) index β calculated in this type of analysis is a direct reflection of the underlying level of safety offered by the structure under the given demand. The larger is β, the lower is the probability of failure, and the greater is the margin of safety of the structure. An approximate correlation between the value of the reliability index and probability of failure is presented in Table 4.3.2-1. The adequacy of a given structure to carry some load of interest is evaluated by comparing the calculated β value for the structure with a minimum acceptable β value for the situation. The calculated β value reflects the configuration and properties of the structure, the level and type of the given demand, and the uncertainties associated with each of these quantities. The minimum acceptable magnitude of β is determined by the probability of failure that the user or designer of the structure is willing to accept. For some types of structures, this value can be estimated based on the historical performance of existing structures. A β value of 2.7 was assumed as the threshold for acceptable safety in this study, as is discussed further below.

Table 4.3.2-1 Approximate Correlation Between Reliability Index and Probability of Failure (from Moses and Verma, 1987)

Reliability Index, β	Probability of Failure, p_f
1.5	0.07
2	0.023
2.5	0.006
3	0.001
3.5	0.0002
4	0.00003
5	10^{-7}
6	10^{-9}

The safety index, β, for each bridge on the state highway system was calculated using the following expression:

$$\beta = \frac{\ln(R/S)}{\sqrt{V_R^2 + V_S^2}}$$

where
- R = resistance of the bridge
- S = demand on the bridge
- V_R = coefficient of variation of the resistance
- V_S = coefficient of variation of the demand

A brief summary of the manner in which this equation was evaluated in this study is given below; a more detailed description of the evaluation procedure is presented in Appendix C. The evaluation procedure was closely patterned after an approach developed by Moses and Verma (1987) for this purpose. A procedure of this type was also recently used to evaluate the adequacy of the Ontario bridge system under various vehicles (Ministry of Transportation of Ontario, 1997).

In evaluating this expression for each bridge, capacity and demand were measured in terms of bending moment in the primary structural system in the span-wise direction of the bridge (typically in Montana, some sort of stringer system). Previous work by Stephens and his colleagues (Stephens, et al 1996) indicated that this type of demand (bending moment) generated in this element of a bridge structure (e.g, longitudinal stringers) typically controlled the capacity of the structure. This observation was confirmed through discussions with MDT (Murphy, 1998). Note that other major structural elements of a bridge typically consist of the deck, which is supported by the stringer system, and the bents or abutments, which support the stringer system. Decks on existing structures typically were over-designed with respect to strength. Their subsequent in-service performance appears to be only nominally affected by load related factors (Stephens, et al 1996). The bents and abutments that support the stringers are generally designed consistent with the loads delivered to them by the stringers, and thus have a consistent capacity with the stringers.

The capacity of the primary structural system in the span-wise direction of each bridge was estimated using information contained in the state bridge inventory (MDT, 1994). The bridge inventory contains over 90 items of information on each bridge, from which it was possible to estimate a load rating for each bridge. The inventory information was insufficient, however, to perform detailed structural analyses on individual bridges. In this case, bridge capacity was estimated based on information in the inventory on structure type, age, span length, and load rating. This information was used to infer the maximum bending moment used in the design process to create a bridge of the listed span length(s) with the indicated load rating under the standard design vehicle.

The demand(s) experienced by each bridge under the various GVW scenarios was calculated based on information in the inventory on span type (simple or continuous) and geometry (total length of bridge, length of main span, and number of approach spans). Demand was calculated as the maximum bending moment generated in the primary structural system in the spanwise direction of each bridge as it was traversed by vehicles loaded at the maximum

GVW allowed under each scenario. Note that the demands for each scenario were calculated using three to ten typical vehicles loaded at the maximum GVW allowed under the scenario (see Appendix C). While these calculations were expected to reveal general trends in bridge adequacy by GVW scenario, a more exhaustive evaluation of demand would need to be made in future work, in which more of the combinations of axle spacings and weights admissible under each scenario are considered. These bending moments were used in conjunction with factors related to load distribution and the probability of multiple vehicle presence on a bridge as a function of traffic volume in arriving at a final measure of bridge demand.

The coefficients of variation on capacity and demand were obtained from information presented in the literature (Moses and Verma, 1987; Ghosn and Moses,1986). The coefficient of variation for the capacity varied from 9 to 20, based on bridge type. The coefficient of variation for the demand was set at 10 percent for dead load and 20 percent for live load.

The average values of the reliability index calculated by bridge type for all scenarios across all systems are presented in Table 4.3.2-2. Referring to Table 4.3.2-2, as the allowable GVW increased in each scenario, the average β values consistently and gradually decreased (see Figure 4.3.2-1). The fact that this trend was observed for the 36,300 kilogram (80,000 lb), 39,900 kilogram (88,000 lb), 47,900 kilogram (105,500 lb), and the existing scenario implies that demands do nominally increase with increasing GVW, despite what the intentions of the current regulations (notably the Federal bridge formula) may be. Problems with the bridge formula fulfilling its intended function of limiting overstress independent of GVW has been noted by others (Noel, et al, 1985).

Table 4.3.2-2 Average Value of the Reliability Index by Bridge Type

Bridge Type	Average Value of the Reliability Index, β, for each Scenario					
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	58,100 kg (128,000 lb)	HS 20
Reinforced Concrete	2.58	2.58	2.55	2.55	2.49	2.16
Prestressed Concrete	6.43	6.43	6.43	6.43	6.43	5.48
Continuous Reinforced Concrete	3.63	3.63	3.63	3.63	3.38	3.14
Simply Supported Steel	4.18	4.15	3.69	3.69	3.32	3.37
Continuous Steel	4.76	4.70	4.24	4.24	3.75	4.21
Timber	3.10	3.10	3.10	3.10	3.10	2.78
All Bridges	**4.56**	**4.55**	**4.49**	**4.49**	**4.42**	**3.94**

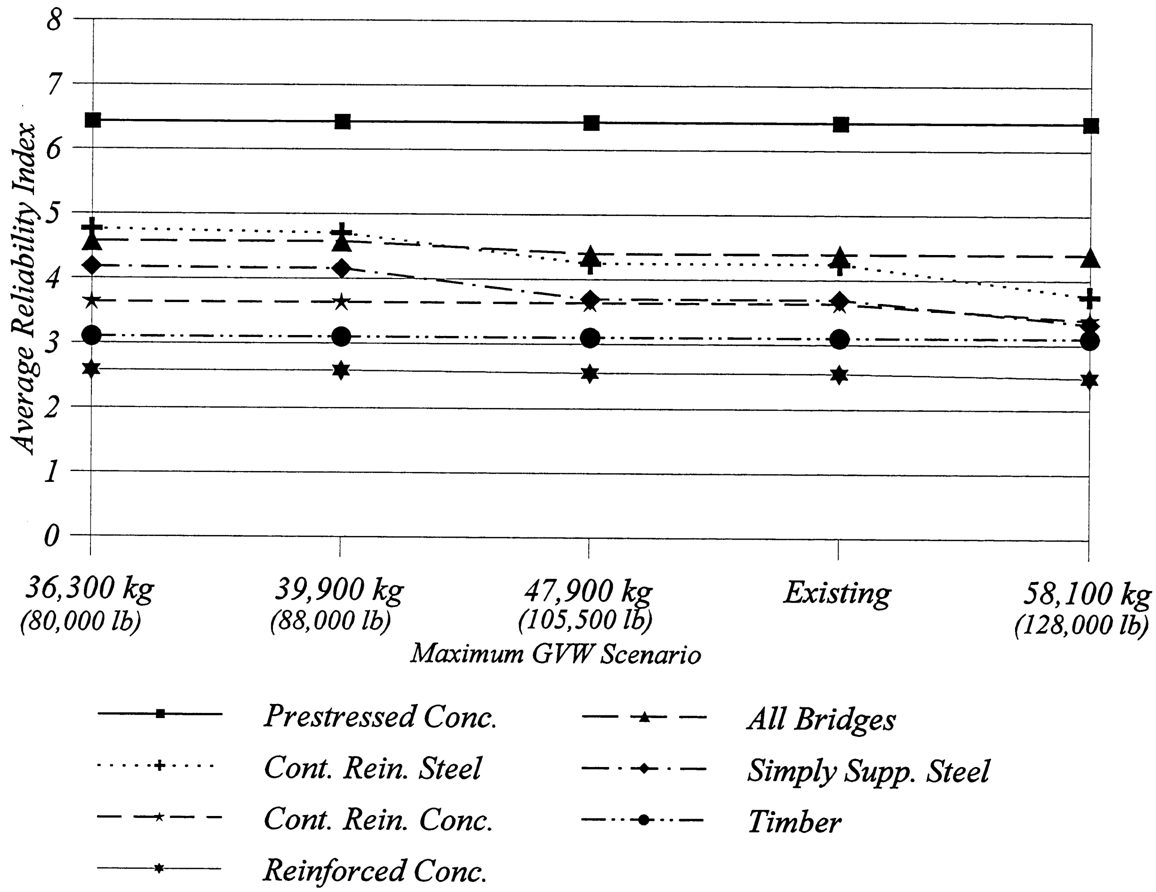


Figure 4.3.2-1 Reliability Index for Each Bridge Type Over Each Scenario

With respect to bridge type, the highest values of the reliability index were consistently calculated for prestressed concrete stringer bridges (average across all scenarios and systems of 6.43); the lowest values, for reinforced concrete bridges (average across all scenarios and systems of 2.55). Many of the prestressed concrete bridges are on the interstate system and were constructed within the last 30 years. Thus, they were constructed to a higher design standard than many of the bridges on the primary, secondary and urban systems. The reinforced concrete spans on the system appear to be of such a span length as to be particularly sensitive to the specific axle weights and spacings found on many vehicles. The average value of the reliability index for timber bridges was also low in magnitude (3.10); many of these bridges were designed for the H15 rather than the HS20-44 vehicle.

Average values of the reliability index calculated for the bridge system under the HS20 design vehicle are also presented in Table 4.3.2-2. Note that the HS20 design demand has become the basic design standard for the entire state bridge system. The average values of β for the HS20 design vehicle were generally lower than the average β values determined under the vehicles operating in the various GVW scenarios. The notable exception to this observation were the β values for simply supported and continuous steel bridges for the 58,100 kilogram (128,000 lb) scenario, which were nominally lower than the β values for the HS20 case.

Presented in Table 4.3.2-3 are the average values of the reliability index calculated by element of the highway system. The highest average reliability index was calculated for the bridges on interstate system, in part due to the dominant type of bridge on this system (prestressed concrete) and the relative newness of these bridges (25 years). The lowest average reliability index was calculated for the secondary system. Once again, this value reflects the dominant types of bridges on this system (relatively high percentage of timber bridges compared to the other systems).

The adequacy of each bridge under each scenario was determined by comparing the calculated reliability index with a minimum acceptable reliability index of 2.7. This minimum acceptable β value was determined by calculating β values for bridges with known load ratings under the demands imposed by the rating vehicle. Approximately 800 bridges on the system with HS20 load ratings were used in these calculations. Note that a minimum acceptable value of β of 2.5 was selected by Moses and Verma (1987) in their study on bridge design codes.

Table 4.3.2-3 Average Value of the Reliability Index by System

System	Average Value of the Reliability Index, β					
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	51,800 kg (128,000 lb)	HS 20
Interstate	5.82	5.82	5.82	5.82	5.82	5.01
Primary	3.97	3.97	3.94	3.94	3.92	3.42
Secondary	3.93	3.93	3.92	3.92	3.88	3.40
Urban	4.51	4.51	4.51	4.51	4.35	3.80

A β value of 2.8 was used to assess bridge deficiencies in a recent highway infrastructure study completed by the Ministry of Transportation of Ontario (1997). A β value of approximately 3.0 has been used for flexural members in building construction (American Institute of Steel Construction, 1994).

The numbers of bridges found to be inadequate under each scenario (β less than 2.7) by bridge type are given in Table 4.3.2-4. As would be expected, trends in deficiencies with respect to bridge type and scenario generally mimic trends already observed in the corresponding average values of β. That is, bridges and scenarios with low β values were found to have relatively high numbers of deficiencies. With respect to bridge type, the lowest percentage of deficiencies was consistently reported across all scenarios for prestress concrete stringer bridges; the highest percentage, for reinforced concrete bridges. The only pronounced increases in deficiencies with increasing maximum allowable GVW were observed for steel bridges (both simply supported and continuous) in going from the 88,000 pound scenario to the 105,500 pound scenario. Approximately a 50 percent increase in deficiencies was observed across these GVW scenarios.

Information on bridge deficiencies by highway system is presented in Table 4.3.2-5. All the bridges on the interstate system were found to be adequate under all scenarios. An increasing percentage of bridges were observed to become deficient for each system under all scenarios in moving from the primary system, to the state secondary system, and finally to the urban system.

Table 4.3.2-4 Number and Percent of Deficient Bridges by Bridge Type (β<2.7)

Bridge Type	36,300 kg (80,000 lb)		39,900 kg (88,000 lb)		47,900 kg (105,500 lb)		Existing		58,100 kg (128,000 lb)		HS 20	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Reinforced Concrete	66	39.5	66	39.5	67	40.1	67	40.1	71	42.5	79	47.3
Prestressed Concrete	0	0	0	0	0	0	0	0	0	0	2	.21
Continuous Reinforced Concrete	6	3.2	6	3.2	6	3.2	6	3.2	18	9.5	18	9.5
Simply Supported Steel	27	21.2	27	21.2	36	28.1	36	28.1	46	35.9	40	31.3
Continuous Steel	20	8.2	20	8.2	32	13.2	32	13.2	44	18.1	35	14.4
Timber	162	18.9	162	18.9	162	18.9	162	18.9	162	18.9	275	32.1
All Bridges	**281**	**11.2**	**281**	**11.2**	**303**	**12.0**	**303**	**12.0**	**341**	**13.5**	**449**	**17.8**

Table 4.3.2-5 Number and Percent of Deficient Bridges by System (β<2.7)

System	36,300 kg (80,000 lb)		39,900 kg (88,000 lb)		47,900 kg (105,500 lb)		Existing		58,100 kg (128,000 lb)		HS 20	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Interstate	0	0.0	0	0.0	0	0.0	0	0.0	2	0.25	2	0.25
Primary	177	15.7	177	15.7	190	16.9	190	16.9	217	19.3	310	27.6
Secondary	91	17.7	91	17.7	100	19.5	100	19.5	109	21.2	121	23.6
Urban	13	19.7	13	19.7	13	19.7	13	19.7	13	19.7	14	21.2
Totals	**281**	**11.2**	**281**	**11.2**	**303**	**12.0**	**303**	**12.0**	**341**	**13.5**	**447**	**17.8**

Referring to Table 4.3.2-5, the number of bridge deficiencies gradually increased as the maximum allowable GVW increased, with 11.2 percent of the system deficient at 36,300 and 39,900 kilograms (80,000 and 88,000 lbs); 12 percent of the system deficient at 47,900 kilograms (105,500 lbs) and under the existing traffic stream; and 13.5 percent deficient under the 58,100 kilogram (128,000 lb) scenario. In all scenarios except the 58,100 kilogram (128,000 lb) scenario, however, the bridges identified as deficient were also found to be deficient under the HS20 design vehicle. Thus, if the HS20 vehicle represents the state design standard, these bridges would require upgrading independent of the scenario under consideration (except for the 58,100 kilogram (128,000 lb) scenario). Many of the deficient bridges are older structures built to a lower design standard than HS20. The issue was raised with MDT regarding continued use of the HS20 standard if the maximum allowable GVW were to change. MDT indicated that at the lowest allowable maximum GVW considered in this study, namely 36,300 kilograms (80,000 lbs), the HS20 standard would probably remain in place (Murphy, 1998). Demands from specialty vehicles and overweight movements would be generally unchanged in all cases.

The deficiencies reported above for the 58,100 kilogram (128,000 lb) scenario (13.5 percent of the bridges on the entire system) is close to the 17 percent deficiencies calculated for the system under this scenario by Stephens and his colleagues (1996) using the allowable stress based operating rating of the bridges. The similarity in deficiencies obtained by the two approaches is also consistent with the observation that under conditions in Montana (low traffic, good enforcement, good structural conditions), reliability based rating procedures have generically been shown to produce load ratings equal to or greater than allowable stress based operating ratings for many structures.

4.3.3 Fatigue, Durability, and Serviceability

4.3.3.1 Fatigue - Fatigue demands on the bridge system will be different under the various maximum allowable GVW scenarios considered in this study. Fatigue damage is related to the magnitude and number of stress cycles experienced by a structure. For bridge structures, the magnitude and number of stress cycles are directly related to the number of axle passages the bridge experiences and the magnitude of the associated axle loads. In general, increases in the magnitude and/or number of live load stress cycles will accelerate the accumulation of fatigue damage. Both the magnitude and number of these live load related stress excursions will change as the type and number of vehicles in the traffic stream changes in each scenario.

Materials demonstrate different levels of sensitivity to fatigue type damage. Steel bridges are subject to fatigue damage, and, presuming they are stressed at a level higher than the fatigue limit, damage can be assumed to accumulate as a function of the third power of the tensile stress range (Schillings and Klippstein, 1978; Saklas, et al, 1988). Thus, the fatigue demand on a bridge is proportional to (a) the number of vehicle passages over the bridge (related to the number of fatigue cycles) and (b) the stress produced in the bridge by each passage (magnitude of the cycle) raised to the third power.

One approach to quantifying the relative fatigue demand of a mixed traffic stream is the equivalent fatigue truck. Moses and Verma (1987) suggested a basic truck configuration to be used in evaluating fatigue considerations. This suggestion has been included in an AASHTO guide on the fatigue evaluation of bridges (AASHTO, 1990a). The weight of this truck, determined in its simplest form from the characteristics of the traffic stream, is indicative of the relative fatigue demand of the vehicles in a specific traffic stream upon bridges. This equivalent fatigue truck concept was simply implemented in this study to obtain an approximation of the relative fatigue damageability of the various scenarios under consideration. An equivalent fatigue truck weight was calculated for each traffic stream as,

$$W_q = \left[\frac{\sum (f_i W_i^3)}{\sum (f_i)} \right]^{1/3}$$

where,

W_q = weight of the equivalent fatigue vehicle

W_i = average operating weight of vehicles in weight class i

f_i = number of vehicles in weight class i

Changes in the weight of the equivalent fatigue vehicle for each scenario with respect to the existing situation are presented in Table 4.3.3-1. The change in the weight of the equivalent fatigue vehicle ranged from a reduction of 10 percent for the 36,300 kilogram (80,000 lb) scenario, to increase of 3 percent for the 58,100 kilogram (128,000 lb) scenario. Note that these findings only have meaning if fatigue was the controlling behavior in the original design. Historically, due to the relatively light traffic on Montana's highways, providing adequate strength for single extreme load events controlled the majority of bridge designs, rather than fatigue considerations. In the recent federal cost allocation study (FHWA, 1997), the statement is made that "fatigue rarely governs the final design", and fatigue was not considered as a factor in allocating bridge demands by vehicle type or operating weight.

Table 4.3.3-1 Percent Change in Fatigue Damage by Scenario

Route	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	58,100 kg (128,000 lb)
Interstate	-11.34	-9.41	-0.36	3.58
Primary	-7.45	-6.31	-0.50	2.98
Secondary	-15.03	-13.44	-0.58	2.63
Total	**–9.74**	**-8.34**	**-0.49**	**3.05**

4.3.3.2 Serviceability - The bridge system was expected to offer similar and adequate serviceability under all the GVW scenarios. Serviceability is defined as the ability of a structure to serve its intended function, independent of strength/safety considerations. Serviceability criteria are often deflection related, and deflection limits are imposed in bridge design (a) to control objectionable vibrations and deflection effects experienced and observed by bridge users and (b) to reduce impact effects on the structure, itself. In rural environments larger deflections are tolerated than in urban environments.

The present bridge system carries existing vehicle configurations without problems or complaints regarding serviceability issues (Murphy, 1998), and future bridge designs under the 36,300; 39,900; and 47,900 kilogram (80,000; 88,000; and 105,000 lb) scenarios are not expected to be altered based on serviceability issues. The 58,100 kilogram (128,000 lb) scenario represents an increase in GVW relative to the existing situation, and larger deflections will be experienced on long span bridges (greater than 21.3 meter (70 ft)) in this scenario than under the current situation. Calculations done by Stephens et al (1996), for example, found that live load deflections will increase by 30 percent on a 33.5 meter (110 ft) simply supported span. Once again, this result only has meaning if deflection was a controlling behavior of the structure. For composite construction, typical of many stringer bridges on the interstate system, deflection rarely controls stringer design (Xanthakos, 1994). Even on the primary system, with a broad mix of structure types, only the timber structures are expected to be sufficiently flexible for deflection to be a problem. With respect to new bridge construction, MDT no longer uses timber on any of the elements of the state highway system. Thus, the decision was made not to further pursue deflections as a major concern in this investigation.

4.3.3.3 Durability - With respect to magnitude of applied loads and the durability of bridges, concerns are generally voiced regarding concrete bridge decks and prestressed concrete beams. These elements of the system were expected to offer similar and adequate performance across all of the scenarios considered in this study. One of the primary functions of bridge decks is to transfer wheel loads from their point of application to the adjacent stringers. Axle and wheel loads are identical in all of the scenarios considered in this study, and thus the magnitudes of the demands placed on decks in performing this function will be the same in all scenarios. The specific number and nature of the load cycles experienced by the decks, however, will change under each scenario. An extensive review of the general performance of concrete bridge decks and of the specific performance of decks on the interstate system in Montana by Stephens and his colleagues (1996) found that magnitude and number of load cycles is only one of several factors that influence the rate of deck deterioration. In reviewing the performance of Montana bridge decks, for example, it was concluded that deterioration of the decks must be primarily dependent on other factors than their age and the volume/type of traffic that they carried.

The longevity of prestress concrete beams is related, in part, to keeping the beams in flexural compression across their entire depth. If the concrete is in compression, cracks will not develop that allow moisture and other agents of deterioration access to the inside of the beams and to the prestressing strands. Compression is maintained across the depth of the section by tension forces in the prestressing strands. This compression is offset by tension demands placed on the beam in carrying dead and live load bending moments. Bending moments generated by the heaviest vehicles in the 58,100 kilogram (128,000 lb) scenario exceed the moment demands placed on some bridges under the existing vehicle fleet. None the less, based on work by Stephens and his colleagues (1996), cracks were not expected to open up in any of these beams under these increased demands.

4.3.4 Bridge Costs

Based on the above considerations, the bridge system appeared to offer an acceptable level of safety, serviceability, and durability under the vehicles that currently operate on it, and with the exception of the 58,100 kilogram (128,000 lb) scenario, future work done on the system and its associated cost will be similar under the various scenarios. Demands placed on the system by vehicles in the 58,100 kilogram (128,000 lb) scenario, however, would require that some bridges be replaced that would not have to be replaced in bringing the system up to an HS20 standard.

A summary of the cost to immediately replace those bridges found to be deficient under the 58,100 kilogram (128,000 lb) scenario above and beyond the bridges already deficient under the HS20 design vehicle is presented in Table 4.3.4-1. This cost was expressed as an EUAC using a service life of 75 years and a discount rate of 7 percent. The EUAC was $0.9 million. In calculating the costs presented in Table 4.3.4-1, it was assumed that strengthening existing bridges was not an option, as such options can be both awkward and expensive to implement, depending on the structural system and material (Murphy, 1996). Therefore, the conservative assumption of complete replacement was selected over strengthening. The further assumption was made that all spans of a structure would be replaced at a width of 12.8 meters (42 ft).

Table 4.3.4-1 Bridge Costs in Millions of Dollars

System	HS 20	58,100 kg (128,000 lb)			
	Immediate Replacement Cost, $	Immediate Replacement Cost, $	Change in Replacement Cost, %	Incremental Cost Compared to HS 20, $	
				Immediate	EUAC
Interstate	0.7	0.7	0	0.0	0.0
Primary	70.3	80.9	15	10.6	0.7
Secondary	39.2	42.1	7	2.9	0.2
Urban	9.8	9.7	-2	-0.1	-0.0
Total	**120.0**	**133.4**	**11**	**13.4**	**0.9**

Bridge replacement costs were simply calculated using a unit cost of \$980 per square meter (91 $\$/ft^2$). The average unit cost used by MDT to estimate bridge replacement costs is \$947 per square meter (88 $\$/ft^2$). This cost includes both external contract and internal MDT costs. This cost was increased by 3.5 percent to accommodate an increase in design standard for new bridges to carry the heavy vehicles in the 58,100 kilogram (128,000 lb) scenario from HS20-44 to HS25-44. The relative magnitude of this cost increase was estimated from work done by Moses (1992). Suggesting an increase in design demands for new bridges while judging the majority of existing bridges (which were designed under lower demands) as adequate, may seem inconsistent. Most existing bridges in Montana, however, were designed using relatively simple procedures that applied global factors of safety to account for a variety of behaviors and load situations not explicitly considered in the analysis. Those design procedures have been refined and new design procedures have been introduced that explicitly consider many of these behaviors and load situations in the design process. Therefore, the "reserve" capacity that some structures designed using older procedures may possess in any given situation is explicitly taken into account following new design procedures, and such procedures should be applied using the actual expected demands.

4.4 GEOMETRIC AND CAPACITY CONSIDERATIONS

4.4.1 General Remarks

While the focus of this part of this study was on direct weight related impacts experienced by the highway infrastructure under different maximum allowable GVWs, consideration was given to the general manner in which some of the geometric features of the highway system may be affected in these scenarios. These features include lane widths, curve geometries, intersection geometries, maximum grades, lengths of merging lanes and passing zones, etc. Many of these characteristics of the highway system are primarily driven by the basic dimensions and internal articulations of the vehicles that are allowed to operate on the system, rather than the weights of these vehicles. Allowable vehicle dimensions and configurations were the same in all the scenarios considered in this study, except for the 58,100 kilogram (128,000 lb) scenario. None the less, in developing the new vehicle fleets for each scenario, changes were observed in the configurations that are actually expected to be used in each scenario. Notably, for example, in the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios, several heavy, long combination vehicles were expected to disappear from the vehicle fleet. Thus, the defacto geometric demands placed on the system could be different under the different scenarios. In general, due to the specific trucks allowed to operate in Montana, only nominal quantifiable differences were found between the geometric requirements of the roadways for each scenario. The investigation performed herein was, however, abbreviated in nature, and additional investigation of geometric considerations may be warranted.

4.4.2 Lane Width and Intersection Geometry

The basic width of vehicles allowed under all the scenarios considered herein is 2.6 meters (8.5 ft). Thus, the same basic lane and roadway width would be expected to be used for all scenarios. Required roadway widths at intersections and curves, however, are influenced by the handling characteristics of a vehicle in addition to its basic width. The ability of a vehicle to negotiate intersections and curves without encroaching on adjacent lanes is related to its offtracking characteristics. Offtracking is defined as the lateral deviation of the path of the steering axle compared to the path of the rearmost axle as a vehicle negotiates a turn (TRB, 1989). In low speed turns (speeds of approximately 64 kilometers per hour (40 mph) and lower), the rearmost axle tends to travel along a path inside the path of the steering axle. Low speed offtracking thus is a problem in intersections and on slow speed roads with curves. The widths of intersections and curves has to be increased to accomodate vehicles that exhibit large low speed offtracking. In high speed turns, the rearmost axle tends to travel along a path outside the path of the steering axle. Therefore, high speed offtracking is a problem on high speed roads with curves. Once again, roadway widths have to be larger for vehicles that exhibit large high speed offtracking. Low speed offtracking is insensitive to vehicle weight; high speed offtracking increases with gross vehicle weight.

The low speed offtracking characteristics of a vehicle are influenced, among other things, by its overall length, the length of each trailer, and the distance between points of articulation (TRB, 1990b; Fancher and Gillespie, 1997). While a detailed analysis of the low speed offtracking characteristics of all the vehicles in each scenario was not performed, this parameter was approximately evaluated for selected vehicles in each configuration using a procedure outlined by Heald (1986) and used in a study by Gericke and Walton (1981). A turning radius of 18.3 meters (60 ft) (consistent with a principal city street) was used in these analyses. The vehicles selected for these calculations were those with the largest over-all lengths, and/or the greatest distances between points of articulation. A 5 axle tractor, semi-trailer with a 5.6 meter (53 ft) trailer was found to have one of the highest offtracking values. This vehicle was common to all the scenarios, and it was expected to be one of the longest vehicles operated under both the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. Note that with a permit, semi-trailers up to 17.4 meters (57 ft) long can be operated in Montana (and could operate under all scenarios). The offtracking for this vehicle exceeded that of the corresponding vehicle with a 5.6 meter (53 ft) trailer by 20 percent.

The highest low speed offtracking values for typical large vehicles operating under the 47,900 kilogram (105,500 lb) scenario were found to be only nominally higher than the offtracking value for the 5 axle tractor, semi-trailer (5.6 meter (53 ft) trailer length). Rocky Mountain Doubles operating with trailer lengths of approximately 14.6 and 8.5 meters (48 and 28 ft) and an over-all length of 29.0 meters (95 ft), for example, exhibited offtracking 8 percent higher than that of a 5 axle tractor, semi-trailer. Note that double trailer units of this kind can only operate in Montana under permit, and that the maximum length of one trailer is 48 feet. Vehicles under the 58,100 kilogram (128,000 lb) scenario can operate at lengths up to 29.9 meters (98 ft). Based on the various dimensions allowed for the components of these vehicles (Appendix B), it is conceivable that a vehicle could operate under this scenario with an offtracking that exceeded that of the 5 axle tractor, semi-trailer (5.6 meter (53 ft) trailer length) by up to 30 percent.

High speed offtracking for a vehicle increases with the number of articulation points and decreases with increasing wheelbase and lighter axle load (TRB, 1990b). Based on values of highspeed offtracking published in a TRB study on infrastructure impacts of a new system of vehicle size and weight limits designed to optimize transportation efficiency (TRB, 1990b), five axle double trailers, a common configuration in all the scenarios considered in this study, were expected to exhibit relatively high offtracking compared to all other vehicles. The relatively poor offtracking characteristics of this vehicle were attributed to the short wheelbase of the 28 foot trailers, and the relatively high loads on the axles.

Based on these considerations, the decision was made to neglect differences in geometric requirements between the scenarios with respect to basic roadway and intersection width. This action was easily justifiable for the 36,300; 39,900; and 47,900 kilogram (80,000; 88,000; and 105,500 lb) scenarios, in that the estimated differences in the offtracking characteristics of the extreme vehicles in each scenario were small in magnitude. Vehicles operating under the 58,100 kilogram (128,000 lb) scenario were found to possibly exhibit low speed offtracking significantly in excess of that observed in vehicles operating in the other scenarios. Thus, geometric issues related to low speed offtracking should be investigated in future work for the 58,100 kilogram (128,000 lb) scenario, and infrastructure impacts for this scenario may be understated in these analyses.

4.4.3 Roadway Features Related to Vehicle Power

In general, as GVW increases, vehicle speeds on grades and general acceleration rates are expected to decrease (TRB, 1990a). This effect could change the relative adequacy under each scenario of existing merging lanes used by vehicles attempting to enter high speed facilities. Differences in acceleration could also result in changing requirements under each scenario for sight distances at intersections, curves, and changes in grade, as vehicles approaching these features encounter slow moving vehicles. The relative acceleration rates of vehicles with different GVWs and engines can be approximately quantified using the ratio of gross weight of the vehicle to net horse power (NHP) of the engine. The value of this ratio historically used in design is 300:1 (AASHTO, 1990b). Studies apparently have shown that as the number of axles increases, the weight to horsepower ratio increases (AASHTO, 1990b). Values as high as 420:1 have been reported for Rocky Mountain Doubles (Safwat and Walton, 1986). Montana, however, similar to most states, does not currently regulate acceleration rate (or weight to power ratio). Therefore, acceleration rates on vehicles in the existing fleet are unknown, and existing weight to power ratios could exceed 300:1 for vehicles of various sizes. Therefore, pending further investigation of these issues, no impact to the roadway was assessed based on vehicle power.

4.4.4 Capacity Considerations

4.4.4.1 General Remarks - One definition of the capacity of a highway is the maximum number of vehicles that can reasonably use a highway in a given period of time under prevailing roadway and traffic conditions (Institute of Transportation Engineers (ITE), 1992). To some extent, the acceptability of the capacity of a system is judged by its users, as they perceive the acceptability of their travel times, number of delays, ability to maneuver, etc. This aspect of the performance of a system is referred to as the level of service. Typically, as the volume of traffic on a roadway increases, thresholds are passed at which the level of service provided noticeably declines. This decline in level of service can occur not only on heavily traveled urban routes, but also on lightly traveled rural roads. Problems on rural roads often arise from the disparity in speeds between the various vehicles using the system. Problems often develop with respect to fast moving vehicles being able to pass slower moving and larger vehicles (such as trucks, recreational vehicles, and buses) with minimum delay as the volume of traffic increases. These problems become increasingly acute as traffic volume increases, as platoons of slow moving vehicles form that are more difficult to pass than single vehicles.

Due to their size and their obvious potential to be among the slower moving vehicles in the traffic stream, the percentage of heavy vehicles that operate on a highway influence its capacity. Capacity typically declines as the percentage of trucks, buses, and recreational vehicles in the traffic stream increases. The size and volume of heavy trucks operating on the highway system is expected to vary between the GVW scenarios considered herein, and hence the relative adequacy of the existing system from a capacity perspective could change between scenarios.

4.4.4.2 Relationship Between Capacity and Heavy Vehicle Presence - Engineering equations used in calculating capacity include a reduction factor that specifically addresses the presence of heavy vehicles in the traffic stream (AASHTO, 1990b; Garber and Hoel, 1997):

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1) + P_B(E_B - 1)}$$

where,

f_{HV} = adjustment factor for the presence of heavy vehicles
P_T, P_R, P_B = relative fraction of trucks, RVs, and buses in the traffic stream
E_T, E_R, E_B = PCE of trucks, RVs, and buses

Primary variables that will change in this equation across the GVW scenarios considered herein are the proportion of trucks in the traffic stream, PT, and the passenger car equivalent, PCE, of these trucks. The percentage of trucks (6 tire, 2 axle SU and large in the traffic stream) averaged across the entire system under each scenario is summarized in Table 4.4.4-1. As previously noted in Section 3.2.3, changes in trucks as a fraction of the total traffic stream were nominal in magnitude across all scenarios. PCE is a measure of the relative influence of a vehicle on traffic operations compared to that of a passenger car. PCE magnitudes reflect, among other things, the ability of a vehicle to accelerate, as represented by its weight to power ratio. The PCE for a type of vehicle increases as its weight to power ratio increases. A vehicle's ability to accelerate has increased significance when substantial grades must be traversed, and thus truck PCE increases with roadway grade.

For the purposes of this study, an average weight to power ratio of 200 was assumed for trucks with GVWs less than or equal to 39,900 kilograms (88,000 lbs). This value is generally supported by a 1985 study of the relationship between weight to power ratio and GVW reported by AASHTO (1990b). A weight to power ratio of 300 was assumed for vehicles with GVWs in excess of 36,300 kilograms (80,000 lbs). Assuming a grade of 5 percent, a grade length greater than 1.2 kilometers (0.75 miles), and a volume of truck traffic equal to 10 percent of the traffic stream, the PCE for vehicles with a GVW less than 39,900 kilograms (88,000 lbs) was found from AASHTO (1990b) design tables to be 8; the PCE for vehicles with a GVW in excess of 39,900 kilograms (88,000 lbs) was found to be 13. These values were used to calculate a weighted average PCE for truck traffic expected to operate under each scenario (based on relative proportion of vehicle miles traveled). These weighted average PCEs are reported in Table 4.4.4-1. Finally, the heavy vehicle adjustment factors presented in Table 4.4.4-1 were calculated using the above equation and inputs. The effects of RVs and buses were neglected in these calculations, which in this case was expected to result in a nominal exaggeration of differences between scenarios.

Referring to Table 4.4.4-1, less than a 2 percent difference was calculated in the heavy vehicle adjustment factors for each scenario relative to that calculated for the existing traffic stream. Based on this situation, and the nominal differences between scenarios in the total volume of traffic carried on the highway system (less than 1 percent), it was concluded that the highway system would offer similar levels of service/capacity under all scenarios. Refined and more detailed analyses of these issues, however, may be merited in future work.

Table 4.4.4-1 Capacity Adjustment Factors for the Presence of Heavy Vehicles in the Traffic Stream for Each GVW Scenario

Traffic Parameter	Scenario				
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	58,100 kg (128,000 lb)
Percent change in large truck traffic[a]	11.5	11.0	1.1	0.0	-4.0
Percent of trucks in the traffic stream[b]	13.4	13.3	12.7	12.6	12.3
Weighted PCE for trucks, E_T	8	8	8.5	8.5	8.5
Capacity Adjustment Factor for Heavy Vehicles, f_{HV}	0.52	0.50	0.51	0.51	0.51

[a] - trucks capable of operating at or above 36,300 kilograms (80,000 lbs) GVW

[b] - 6 tire, 2 axle single units and larger

4.5 SAFETY

4.5.1 General Remarks

Highway safety, as measured by the number and severity of accidents that occur, will be affected by changes in the maximum allowable GVW of the vehicles that operate on the highway system. These changes will occur in response to changes in the number and type of vehicles that are required under each GVW scenario to move the same amount of freight as is presently shipped on the system. Precise prediction of the changes in the number and severity of accidents that will occur under each scenario is a complex task, in that accident rates are influenced by many parameters related to the roadway, environmental conditions, traffic conditions, and the operating characteristics of the vehicles on the highway. The effects of these parameters can be confounded, so that it can be difficult to isolate the influence of individual factors on accident rate and severity. The parameters that varied between scenarios in this study consisted of type of truck, weight of truck, and the distance traveled by various types of trucks. Of these variables, type of truck and distances traveled were used in estimating changes in the number and severity of accidents expected under each GVW scenario. Basic accident rates by truck type and distance traveled were treated as constants across all scenarios. Changes in accident rates related to changes in truck type and amount of travel were believed to be secondary in magnitude over the situations considered and thus were ignored.

A recent traffic safety report issued by MDT indicated that, over the past 5 years, trucks have been responsible for approximately 6 percent of all crashes and 10 percent of all crashes with fatalities on Montana's highways (MDT, 1998a). These figures are presented, however, without reference to the relative proportion of vehicle miles driven attributable to trucks, or a detailed explanation of what constitutes a truck.

4.5.2 Accident Rates

The basic accident rates used in this study were drawn from a recent investigation performed for FHWA on the safety of long combination vehicles (LCVs) (Ticatch, et al, 1996). The specific objective of this study, conducted by Scientex Corporation, was to determine if the accident rates of LCVs were different from those of other combination vehicles (non-LCVs). LCVs were considered to be double and triple trailer units operating at over 36,300 kilograms (80,000 lbs), while non-LCVs were combinations operating at less than 36,300 kilograms (80,000 lbs) and tractor, single semi-trailers. The accident rates determined for LCV doubles and non-LCV vehicles, calculated from data collected from 17 states that allow LCV operation, are presented in Table 4.5.2-1. Accident severity by vehicle type is presented in Table 4.5.2-2. The overall accident rate for LCV doubles is 50 percent lower than the accident rate for non-LCVs. Accidents are more severe, however, when LCV doubles are involved. The fatality rate, given that an accident has occurred, is 150 percent higher for LCV doubles compared to non-LCVs. Note, however, that when presented in terms of volume of travel (measured by distance), the fatal accident rates for LCV doubles are only 30 percent greater than for non-LCVs. The injury rate, given that an accident has occurred, is 30 percent higher for LCV doubles compared to non-LCVs. When normalized by distance travelled, the fatal and injury accident rate for LCV

Table 4.5.2-1 Accident Rates For Non-LCVs and LCVs (Ticatch, et al, 1996)

Configuration	Accident Rates, per million kilometer miles of travel (per million vehicle miles traveled (VMT))		
	FHWA Study, National Average		
	Collisions	Non-Collisions	All Accidents
Non-LCVs	0.73 (1.17)	0.38 (0.61)	1.12 (1.79)
LCV doubles	0.36 (0.57)	0.22 (0.35)	0.58 (0.92)
All Non-LCVs and LCVs	0.65 (1.04)	0.34 (0.55)	0.99 (1.59)

Table 4.5.2-2 Accident Severity for Non-LCVs and LCVs (Ticatch, et al, 1996)

Configuration	Severity Rates, per 100 Accidents			
	FHWA Study, National Average		Adjusted Rate for Montana	
	Fatal	Injury	Fatal	Injury
Non-LCVs	1.51	16.71	2.00	12.23
LCV doubles	3.74	21.77	4.95	15.93
All Non-LCVs and LCVs	1.78	16.55	2.36	12.11

doubles is 33 percent less than that for non-LCVs. In accepting and using these various accident rates from the Scientex study, it is important to recognize that:

a) a general analysis of all carrier safety records performed as part of the study revealed that carriers that presently operate LCVs have significantly better safety records than the general carrier population.
b) statistically significant conclusions could not be drawn in some cases between accident rates for different types of LCVs,
c) the presented results are consistent with results of some earlier studies and inconsistent with the results of other studies, and
d) definitive cause and effect relationships for could not be established for the trends observed in the study results.

Note that the absence of defined cause and effect relationships that explain the observed trends in the study results makes the extrapolation of these results to new situations and specific locations somewhat uncertain. In this case, traffic conditions in Montana were expected to be consistent with those in which the LCV accident data was collected, in that the majority of the existing LCV states (which include Montana) are located in the Intermountain west.

In an effort to use accident rates that might more specifically reflect conditions in Montana, the decision was made to multiply the rates reported above by the ratio of some measure of Montana's highway safety versus that of the entire nation. Information published by FHWA (1996) on state and national fatalities and injuries as a function of vehicle distance traveled (published as VMT) were used for this purpose. In general, Montana's fatality rate measured as a function of vehicle distance traveled exceeded the national average (by approximately 35 percent), while the injury rate as a function of vehicle distance traveled was lower than the national average (by approximately 25 percent). The reasonableness of the resulting rates was verified by comparing the accidents predicted using these rates (presented in Table 4.5.2-1) with the actual number of accidents which occurred in 1996 (Montana Highway Patrol, 1996). These two values agreed within 5 percent. Consideration was also given to more closely fitting the information available in the LCV report to conditions in Montana by using the rates presented in the report for Rocky Mountain Doubles rather than the average rates for LCV doubles. Rocky Mountain Doubles are believed to be the primary type of LCV operated in Montana (Galt, 1997). This approach yielded approximately 20 percent lower accident rates than the approach described above. Rocky Mountain Doubles had a lower accident rate based on vehicle miles of travel compared to some of the other types of LCVs, but they had a higher fatality and injury rate per accident than some of the other vehicles.

4.5.3 Accident Occurrence

The number of fatalities and injuries from accidents involving large trucks expected under each scenario are summarized in Table 4.5.3-1. These values were calculated by multiplying the accident rates in Table 4.5.2-1 by the corresponding vehicle miles of travel expected for LCVs and non-LCVs under each scenario, and then multiplying this product by the adjusted severity rates given in Table 4.5.2-2. The zeros in the LCV columns for the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios simply indicate that LCVs are expected to disappear from the traffic stream at these GVW limits.

Referring to Table 4.5.3-1, less than a 10 percent difference (2 accidents) was found in the predicted fatalities in all scenarios relative to the existing situation. Similarly, for injuries, only nominal changes (less than 15 percent) were observed between the existing situation and the various scenarios. In all cases, total fatalities and injuries steadily increased for the lower GVW scenarios, and they nominally decreased for the higher GVW scenario. A similar trend was observed in a 1990 TRB study of truck size and weight issues (TRB, 1990a).

Based on the relatively simple nature of the analysis procedure used herein, and the nominal magnitude of the differences in safety predicted between scenarios, the decision was made that the highway system would offer a similar level of safety to its users across all scenarios.

Table 4.5.3-1 Predicted Number of Fatalities and Injuries Occurring in Montana for Each Scenario

a) Fatalities

Item	Number of Fatalities by Scenario				
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	58,100 kg (128,000 lb)
Non-LCVs	24.9	23.9	19.8	19.8	18.4
LCVs	0	0	3.6	3.2	3.9
Total Fatalities	**24.9**	**23.9**	**23.4**	**23.0**	**22.3**

b) Injuries

	Number of Injuries by Scenario				
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	58,100 kg (128,000 lb)
Non-LCVs	216.6	208.2	172.1	172.0	160.6
LCVs	0	0	19.9	18.3	22.2
Total Injuries	**216.6**	**208.2**	**192.0**	**190.3**	**182.8**

4.6 OTHER IMPACTS

Changes that occur in heavy vehicle operations under each scenario could physically impact additional things outside of the highway infrastructure. Other potential impacts of interest, for example, are impacts on:

a) health, possibly related to changes in noise and air pollution,
b) vegetation, possibly related to the volume of exhaust gases generated and any secondary greenhouse effects, and
c) fuel consumption, although any increases or decreases in fuel consumption related to changes in vehicle miles driven may be tempered by gains and losses in the fuel economy of the vehicles involved.

In the recent federal cost allocation study (FHWA, 1997), these costs were termed "Non-Agency" costs, in that they are associated with highway transportation, but they are not paid for by a government agency from user collected revenues. Determining the magnitude and significance of many of these types of impacts is a difficult task, in that the quantitative relationships between the highway parameters of interest and the impact in question can be uncertain and/or the monetary value of the impact is unknown. The manner in which vehicle emissions, for example, contribute to greenhouse gases and global warming is subject to debate. Even if this relationship was known, the impact of global warming on the environment, and the cost of this impact, remains uncertain. In the federal cost allocation study, for example, the calculated cost of noise pollution and air pollution related to highway transportation varied by a factor of 10, depending on the assumptions made in the calculation procedure.

Based on the above considerations, the conclusion was reached that changes in "Non-Agency" costs of highway transportation cannot presently be calculated with sufficient confidence to include them in this study. In reaching this conclusion, it is important to recognize that these costs may be significant, and if members of society are interested in addressing them, this issue should be revisited.

4.7 SUMMARY OF DIRECT HIGHWAY IMPACTS

Under the various maximum allowable GVW scenarios considered in this study, only nominal changes were expected to occur in the highway infrastructure relative to its current configuration and condition. Increased demands on the infrastructure (and increased costs) were expected for all scenarios, except for the 47,900 kilogram (105,500 lb) scenario, in which a nominal decrease in demands and costs was determined. Total changes expected in pavement and bridge costs are summarized in Table 4.7-1. A maximum change in the EUAC for pavement and bridges (relative to projected expenditures under current weight limits) was $1.61 million for the 58,100 kilogram (128,000 lb) scenario. Pavement costs nominally decreased (by $0.51 million per year) in moving from the existing regulatory situation to a maximum allowable GVW of 47,900 kilograms (105,500 lbs) and then increased (by $1.51 million per year) in moving further to a 36,300 kilogram (80,000 lb) maximum GVW. Pavement costs also nominally increased in moving to a higher maximum allowable GVW of 58,100 kilograms (128,000 lbs). Significant bridge impacts and associated changes in bridge costs were only found to occur under vehicles in the 58,100 kilogram (128,000 lb) scenario. The bridge system was found to provide a similar level of safety under the vehicles operating in the other scenarios.

While pavement and bridge impacts were the focus of this study, consideration was also given to the affects of changes in maximum allowable GVW on other aspects of the system and its operation. In all cases, the decision was made to neglect changes expected to occur in these attributes of the system due to changes in the maximum allowable GVW. With respect to highway geometrics, capacity, and safety, this decision was made based on the small differences calculated to occur between scenarios in system requirements and performance. With respect to issues outside of the physical infrastructure and its operation, such as changes in air pollution, noise pollution, etc. this decision was made based on the high level of uncertainty associated with the available methods to address these issues.

Table 4.7-1 Relative Infrastructure Costs by Scenario

Item	Relative Infrastructure Costs by Scenario, $/yr (millions)				
	36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	Existing	58,100 kg (128,000 lb)
Pavement	1.51	0.83	-0.51	0	0.71
Bridges	0	0	0	0	0.90
Total	**1.51**	**0.83**	**-0.51**	**0**	**1.61**

5. CASE STUDIES

5.1 GENERAL REMARKS

To provide a variety of perspectives on the impacts on Montana's economy of changes in truck weight regulations, case studies were conducted on specific industries within the state. The objective of these studies was to determine the net change in truck transportation related cost for these industries under each scenario, and then to further determine possible consequences of this change in cost (e.g., increased profit for a manufacturer, higher prices for a commodity, decreased demand for a commodity, etc.). Studies were done on industries in the areas of agriculture, extractive resources, forestry and wood products, construction, and retail sales. A summary of these case studies is presented in Table 5.1-1. Only two of the major sectors of the state's economy were not covered by these case studies, namely, government and tourism, both of which were thought to be only indirectly involved in trucking operations. These sectors were incorporated in the statewide economic model, however, via the indirect and induced effects of changes in those industries which were directly affected by changes in trucking operations.

Table 5.1-1 Case Studies by Sector of the Economy, Industry, and Transportation Operation

Sector	Industry	Transportation Operation
Agriculture	Dairy	Raw milk from dairy to processor
	Wheat	Wheat from farm to elevator
	Beef Cattle	Beef cattle from field/livestock yard to slaughter
	Sugar Beets	Sugar beets from farm to processor
Extractive Industries	Crude Oil	Crude oil from well to pipeline
	Talc	Ore from mine to mill
Forestry and Wood Products	Logging	Logs from forest to mill
	Wood Chips/Liner Bd	Wood chips from mill to liner board plant
Construction	Sand and Gravel	Sand and gravel from pit to construction site
	Cement	Cement from plant/rail terminal to user
Retail	Food (Groceries)	Groceries from distribution center to retail store
	Motor Fuel	Motor fuel from terminal to retail station

5.2 METHODOLOGY

A common methodology was used in developing the case studies for each industry. Work began with the identification of a primary transportation operation within the industry of interest. The purpose of this operation, the type and characteristics of the vehicles involved, and the volume of goods to be moved were determined. A prediction was made for each scenario of how the transportation operation would be affected if maximum allowable gross vehicle weights were changed. Predictions were then made of the vehicle configurations that would be used and their operating characteristics. These predictions were made based on input from vehicle operators, which generally followed the philosophy described in Section 3.2, which was to select efficient alternatives under each scenario that reused as much existing equipment as possible. As previously mentioned, some operators commented that they had optimized their present equipment to function under existing GVW regulations, and that this equipment poorly supported some of the scenarios under consideration. These situations were taken into account in determining the vehicles that would be used in each industry under the various GVW scenarios.

The possibility that a different mode of transportation (generally rail instead of truck) would be selected to move the commodity in question if the maximum allowable GVW was changed was also considered. Rail diversion analyses, when believed to be appropriate, were only done for the 36,300 kilogram (80,000 lb) scenario. If a mode switch was judged to be likely, simple analyses were performed to obtain a general indication of how such action would affect the economics of producing the commodity.

Once the nature of the new transportation activity under each GVW scenario was established, the change in the physical demands that these activities placed on the highway system was determined. Pavement demands under each scenario were calculated using the AASHTO ESAL model (previously introduced in Section 4.2.1 of this report). Damage factors expressed in ESALs were calculated for the vehicles expected to be used in each scenario. The pavement damage associated with each scenario was then calculated by multiplying the damage factors for the vehicles by the loaded distance they traveled. The assumption was made in all cases that the total amount of goods to be moved remained the same across all scenarios, independent of the manner and cost of their transportation. The reasonableness of this assumption was subsequently validated by the results of the economic analyses. These analyses revealed that while significant economic impacts result from changes in allowable GVWs, these impacts are not so large as to produce rapid and dramatic changes in economic activity.

Costs were assigned to pavement damage using a unit damage cost expressed in terms of dollars per ESAL kilometer (ESAL mile) of travel. A unit damage cost was established from the results of the cost analyses performed in Section 4.4.2 by dividing the cost of typical overlays by their length and the ESALs of service they were designed to provide. This approach to determining an ESAL based unit damage cost was admittedly simplistic, in that it only nominally addressed the fact that the marginal cost of additional ESALs programmed in at the time of design decreases as the number of design ESALs increases (following the AASHTO design approach). This approach was expected, however, to give useable results as long as the predicted changes in ESAL kilometers (ESAL miles) of travel were relatively small, as was the case in this situation (ESAL kilometers (ESAL miles) of travel and vehicle kilometer (miles) of travel change by less than 3 percent across all scenarios).

The unit damage cost was further adjusted to account for environmental related deterioration as opposed to load related deterioration. While in actuality these two mechanisms of deterioration are interrelated, a simple and commonly used approach to addressing them separately is to assign a fixed fraction of deterioration to each mechanism. As has been previously done for the Montana highway system (Stephens and Hafferman, 1992), load effects were assumed to be responsible for 80 percent of pavement deterioration on the interstate system and 60 percent on the NHS and non-NHS primary systems. The resulting unit damage cost used for the entire system, representing an average of the interstate and NHS and non-NHS primary systems weighted by their respective lengths, was $0.10 per ESAL per kilometer ($0.16 per ESAL per mile).

With the exception of the 58,100 kilogram (128,000 lb) scenario, the assumption was made that the bridge system was adequate to carry the vehicles allowed under each scenario, as discussed in Section 4.2.2. Demands from the heaviest vehicles operating under the 58,100 kilogram (128,000 lb) scenario were sufficiently high that some bridges which meet HS-20 design vehicle requirements were unsafe under these new vehicles, and these bridges would require replacement. Bridge costs in this situation were calculated on a per vehicle mile traveled basis using a damage cost calculated as the previously determined EUAC for bridge replacement divided by the annual total vehicle miles of travel of the trucks that were expected to take advantage of the increased weight under the 58,100 kilogram (128,000 lb) scenario. This cost was found to be $0.025 per kilometer ($0.04/mile) traveled by the affected vehicles.

Above and beyond simple changes in infrastructure costs, the market related economic impacts associated with each scenario were calculated by:

1) estimating the change in transportation costs associated with the change in transportation operations for each scenario,
2) determining the current economic environment of the affected firms, and
3) indicating possible outcomes resulting from these changes in costs.

The information required to perform the analyses described above was collected from a variety of sources. These sources are summarized following the narrative for each case study. In general, the previously mentioned survey on motor vehicle freight transportation in Montana that was sent out to members of the Montana Motor Carriers Association provided useful data on the manner in which commodities are moved by truck around the state of Montana. Extensive telephone and site interviews were also conducted with both users and providers of truck transportation services for each industry. To respect the confidentiality of some of the information provided through these means, employee and company names are not included in the references. These sources of information are identified in the reference by type (i.e., producer, shipper, purchaser), with an estimate of the fraction of the industry by market share from which information was received. Economic information was also obtained from various governmental agencies involved in tracking commerce and economic activity (e.g., Census and Economic Information Center, Montana Agricultural Statistics Service, etc.). Despite this extensive data collection effort, many inferences had to be drawn and assumptions had to be made in completing each case study. None the less, the case studies are believed to reasonably reflect the trends and general magnitudes of the economic impacts that would be experienced under the GVW scenarios.

In estimating the change in transportation costs associated with a change in transportation operations, the assumption was typically made that any such change in cost was proportional to the change in the number of trips required to move the same amount of the commodity under study, adjusted as appropriate for differences in operating costs between vehicle configurations. Operating costs for long combination vehicles reportedly range from 15 to 24 percent more than the operating costs for 5 axle combination vehicles (TRB, 1990b), on a per unit distance of travel basis. The change in cost within this range experienced in specific situations is related to the type of truck and cargo under consideration. This estimate of relative operating costs did not account for any differences in operating costs associated with differences in the level of supervisory and clerical support required to operate vehicle fleets of different sizes. Interviews with carriers conducted as part of this study indicated that if these types of costs are included in such comparisons, the difference in operating costs between 5 axle tractor, semi-trailers and long combination vehicles is less than reported above. Middendorf and Bronzini (1994) reported an increase in operating costs of 15 percent specifically for the use of Rocky Mountain Doubles instead of single trailer combination vehicles. This value is consistent with the opinion of several carriers interviewed in this study who indicated that over-all operating costs for long combination vehicles are only nominally higher than those for 5 axle tractor semi-trailers. The highest cost given in these carrier interviews for the operation of Rocky Mountain Doubles relative to 5 axle tractor, semi-trailers was 33 percent (per vehicle trip).

Based on the above mentioned information, the decision was made to assume that

1) carrier provided estimates on the expected relative cost of operation of 5 axle tractor, semi-trailers compared to large combination vehicles would be used in these analyses, when such estimates were available from the carrier interviews,
2) in the absence of carrier provided information, the cost of operation of large combination vehicles was assumed to be 15 percent higher than the cost of operation of 5 axle tractor, semi-trailers,
3) operating costs for the heaviest vehicles under the 58,100 kilogram (128,000 lb) scenario were assumed to be 3 percent higher than those for large combination vehicles.

In all cases, large combination vehicles were assumed to be all vehicles with a GVW in excess of 45,400 kilograms (100,000 lbs) pulling at least one trailer.

Changes in total transportation costs were simply calculated as the relative number of vehicle trips required to haul the same amount of commodity under the scenario in question multiplied by the relative cost of operating the vehicle configurations used in the scenario compared to the vehicle configurations presently being used. This basic approach was used across all scenarios.

The changes in truck transportation costs calculated for each scenario were assumed to inherently account for any changes in infrastructure costs for the scenario. Infrastructure costs are part of the basic operating costs for trucks, as paid for through user taxes and fees. Assuming current user fees are sufficient to cover infrastructure costs, as the number of trips changes, the total amount paid by trucks toward highway infrastructure costs will change commensurate with cost of providing highway service. Results from the recent federal cost allocation study, however, indicate that combination trucks do not pay sufficient taxes and fees to cover the cost of providing them with highways service (the amount they underpay appears to be at least 10 percent). Thus, assuming infrastructure costs are accounted for through changes in existing transportation costs results in the effects of any increases in infrastructure costs being understated. Furthermore, the majority of user fees do not directly account for vehicle configuration used, and they may therefore do a poor job in recovering the cost of providing specific vehicles with highway service. For these reasons, explicit changes in infrastructure costs were calculated for each scenario. These costs can be used in conjunction with the calculated change in transportation costs as the reader believes to be appropriate.

Only a first round analysis of economic impacts was performed in each case study. That is, the analyses did not take into account any changes in production costs that may occur as other sectors of the Montana economy are affected by changes in the maximum allowable GVW. These analyses also do not address changing costs associated with retiring existing equipment in favor of new equipment configured to optimally function under the new GVW regulations. Finally, these analyses do not consider any changes in product demand in response to changes in costs. In many cases, the calculated changes in costs were significant, but not necessarily so radical as to expect immediate and dramatic market effects. Effects of this kind were reflected in the results produced from the statewide economic model (see Chapter 6).

5.3 AGRICULTURE

5.3.1 Dairy (Raw Milk)

5.3.1.1 Change in Transportation Operations - Raw milk presently is collected from dairies around the state of Montana primarily using 8 and 9-axle double trailer combination vehicles. The estimated operating characteristics of these vehicles are reported in Table 5.3.1-1.

Table 5.3.1-1 Vehicles Currently Used in Transporting Raw Milk from the Farm to the Processing Plant.

Configuration	Percent of All Trips	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
8 axle Rocky Mtn Double	33	48,100 (106,000)	32,200 (71,000)
9 axle Double Trailer Combination	67	49,900 (110,000)	33,100 (73,000)

The configurations of the vehicles used to collect raw milk were expected to change under the GVW scenarios being investigated in this study. The specific vehicles expected to be used to haul raw milk under each scenario are listed in Table 5.3.1-2. If the maximum allowable gross vehicle weight on Montana's highways was restricted to 36,300 kilograms (80,000 lbs), for example, 5-axle tractor, semi-trailers would be used instead Rocky Mountain Doubles for this purpose. Based on the relative amount of freight carried on these configurations, 54 percent more trips would be required to haul the same amount of milk at the 36,300 kilogram (80,000 lb) weight limit relative to existing weight limits. The predicted changes in the number of trips required to haul raw milk under the other GVW scenarios are reported in Table 5.3.1-2. The maximum increase in the number of trips was for the 36,300 kilogram (80,000 lb) scenario (54 percent, as previously stated); the maximum and only decrease in trips was for the 58,100

Table 5.3.1-2 Summary of Case Study Results: Dairy - Raw Milk

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3S2	54	0.04	0	0.04	54	1.01	2.26
39,900 kg (88,000 lb)	3S2 3S3	51	0.04	0	0.04	51	0.96	2.16
47,900 kg (105,500 lb)	3S2-3 3S2-4	25	-0.01	0	-0.01	25	0.46	1.03
Existing	3S2-3 3S2-4	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3S2-3 3S2-4	-6	0.02	0.02	0.04	-6	-0.11	-0.24

kilogram (128,000 lb) scenario (6 percent). Due to the perishable nature of the product and the geographic dispersion of the dairies that provide raw milk, it was assumed that raw milk would continue to move exclusively by truck under all scenarios.

5.3.1.2 Infrastructure Impacts - The damage experienced by the roadway as raw milk is hauled from the farm to the processing plant was expected to change under each of the GVW scenarios. The change in damage between scenarios was quantified using the relative ESAL miles of travel in each scenario. In this particular situation, for example, pavement damage was predicted to increase by 71 percent if raw milk was hauled using vehicles in compliance with the maximum allowable GVW of 36,300 kilograms (80,000 lbs) maximum as opposed to vehicles operating under current GVW limits. Assigning a precise cost to the change in pavement damage predicted for each scenario was difficult, in that this cost was related to the specific weight carried by each particular vehicle on each leg of its milk collection route. To establish the order of magnitude of this cost, the present annual demand placed by double trailer combinations hauling raw milk on the highway system was assumed to be equivalent to a fully loaded 9 axle double traveling 400,000 kilometers per year (250,000 miles/yr). The total cost of the increased pavement damage generated at this level of operation using 5 axle tractor, semi-trailers under the 36,300 kilogram (80,000 lb) scenario instead of 8 and 9 axle double trailer combinations, for example, was estimated to be $40,000 per year (total cost for all trucks and all trips). Changes in pavement costs for the other scenarios, which were all less than that expected for the 36,300 kilogram (80,000 lb) scenario, are presented in Table 5.3.1-2. The increase in bridge costs for vehicles operating under the 58,100 kilogram (128,000 lb) scenario was estimated to be $20,000, resulting in a change in total infrastructure costs of $40,000 per year for this scenario.

5.3.1.3 Economic Impact - Economic activity in the dairy sector of the state's economy would be affected by the change in vehicle configurations predicted above in response to the imposition of maximum gross vehicle weights of 36,300; 39,900; 47,900 and 58,100 kilograms (80,000; 88,000; 105,500; and 128,000 lbs). As raw milk would still be transported only by truck under all scenarios, transportation costs would be expected to change commensurately with the predicted change in the number of trips required to move the same total weight of milk using the specified vehicles in each scenario. Based on discussions with a major milk transport company, any increase in the number of trips would result in a proportionally equal or larger increase in transportation costs. In these analyses, the decision was made to assume transportation costs would increase in direct proportion to the change in trips associated with each scenario (Table 5.3.1-2). Transportation costs would increase 54 percent, for example, for the 36,300 kilogram (80,000 lb) scenario.

The statewide average cost of hauling raw milk to the processing plant is $0.0142 per kilogram ($0.643 per hundred weight). The actual cost ranges from $0.0091 to $0.0161 per kilogram ($0.415 to $0.73 per hundred weight), varying inversely with the proximity of the dairy to the processor. The cost of hauling raw milk is paid by the dairy, so that transportation costs reduce the income the dairy farmer receives from the processor. The change expected in dairy cash receipts and dairy income under each scenario is presented in Table 5.3.1-2. These values were calculated using the current statewide average transportation cost and the projected increase in transportation costs determined above. Under the 36,300 kilogram (80,000 lb) scenario, for example, dairy cash receipts and dairy income would decline 2.2 percent. Based upon 1996 dairy income in Montana of $44.7 million–the latest full year of data available, but also the highest cash receipts year for dairy in a decade in Montana–the decrease in dairy income would be approximately $1 million. Conversely, for the 58,100 kilogram (128,000 lb) scenario, a nominal increase of $0.11 million per year would be expected in dairy income.

The impact just noted glosses over the differences amongst dairies. Dairies that are closer to the processor would be less affected in absolute dollar terms than those that are farther away and are faced with the highest transportation costs. What could not be determined from these data was how vulnerable particular dairies would become to financial disaster in the event of a decline in income.

5.3.1.4 References -

General

Montana Agricultural Statistics Service (1997)
Milk Control Bureau (1997)
Montana dairy cooperative newsletter

Direct Interview and/or Survey Response

1 freight company that specializes in raw milk
1 purchaser of raw milk
1 purchaser and hauler of raw milk

Estimated fraction of transportation activity surveyed: Greater than 66 percent

5.3.2 Wheat

5.3.2.1 Change in Transportation Operations - Approximately 176 million bushels of wheat were produced in Montana in 1996. This wheat was moved by truck from the farm to the grain elevator, where it was subsequently shipped by truck or rail to a purchaser. Grain elevators are located throughout the wheat producing regions of the state, and they are typically adjacent to both a rail line and a highway. In a survey of over 400 farms in Montana, it was found that the distance measured as "the crow flies" from any given farm to the nearest elevator averaged 25.6 kilometers (16 miles), with the shortest reported distance being less than 0.8 kilometers (½ mile); the longest reported distance, 134 kilometers (84 miles). During interviews with grain growers, shippers, and elevator operators, however, it was discovered that grain is not always hauled from the farm to the nearest elevator. For a variety of reasons (notably type of product, price, and elevator capacity), grain may be hauled to distant elevators. Based on the above information, the average length of the truck trip from the farm to the elevator was assumed to be 64 kilometers (40 miles), one-way.

Common vehicle configurations used in hauling wheat from the farm to the elevator include 3 axle straight trucks pulling 2 axle trailers, 5 and 6 axle tractor, semi-trailers, and 7, 8, and 9 axle Rocky Mountain Doubles. The estimated operating characteristics of these vehicles are reported in Table 5.3.2-1. The estimated percent of all farm to elevator trips made by each configuration is also listed in Table 5.3.2-1. These values were determined from information obtained from interviews of growers, shippers, and elevator operators.

Table 5.3.2-1 Vehicles Currently Used in Transporting Wheat from the Farm to the Elevator

Configuration	Percent of All Trips	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
3 axle truck, 2 axle full trailer	5	38,100 (84,000)	23,600 (52,000)
5 axle tractor, semi-trailer	40	35,800 (79,000)	23,600 (52,000)
6 axle tractor, semi-trailer	5	39,000 (86,000)	25,400 (56,000)
7 axle Rocky Mtn Double	35	52,200 (115,000)	35,800 (79,000)
8 axle Rocky Mtn Double	10	53,500 (118,000)	36,300 (80,000)
9 axle Rocky Mtn Double	5	56,200 (124,000)	37,600 (83,000)

The vehicles that were expected to be used in hauling grain under each GVW scenario, and the change in the number of trips required to move the same quantity of grain as is presently hauled, are listed in Table 5.3.2-2. Under the 36,300 kilogram (80,000 lb) scenario, for example, operators were expected to use 5 axle tractor, semi-trailers and/or 3 axle straight trucks pulling 2 axle trailers. Twenty-seven percent more trips would be required using these vehicles to move the same amount of wheat as is presently moved from farm to elevator. Under the 58,100 kilogram (128,000 lb) scenario, the number of truck trips required for this purpose would decrease by 3 percent. Changes in trips for the other scenarios are bracketed by these values. Due to the generally dispersed geographic nature of farm to elevator wheat movements, rail was not considered a viable alternative for this transportation operation.

Once delivered to the elevator, wheat is reloaded onto rail cars or trucks for the next leg of its journey. For the last few years, over 90 percent of the wheat produced in Montana was shipped out-of-state, with the majority of the out-of-state shipments being to the Pacific Northwest. Almost all of this wheat was shipped by rail. Movements by truck account for only 6 percent of the wheat shipped from elevators. The percentage of wheat shipped from elevators by truck has actually declined in Montana over the past several years, while the fraction shipped by rail has increased. Truck movements are believed to consist of elevator to elevator transfers, deliveries for domestic consumption (particularly for seed), and movements to transloading facilities in neighboring states. Some of these movements also are back hauls for 5 axle tractor, semi-trailers that have delivered goods to Montana from the Pacific Northwest. The remainder of this case study specifically considers the movement of wheat by truck between the farm and the elevator. For the majority of the wheat produced in Montana, this movement represents that portion of its transportation cost that will be most affected by changes in the maximum allowable GVW of trucks.

Table 5.3.2-2 Summary of Case Study Results: Wheat

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/ yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3-2 3S2	27	-0.20	0	-0.20	16	5.50	0.78
39,900 kg (88,000 lb)	3-2 3S2 3S3	25	-0.19	0	-0.19	16	5.63	0.80
47,900 kg (105,500 lb)	3-2 3S2, 3S3 3S2-2 3S2-3 3S2-4	8	-0.58	0	-0.58	7	2.28	0.32
Existing	3-2 3S2, 3S3 3S2-2 3S2-3 3S2-4	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3-2 3S2, 3S3 3S2-2 3S2-3 3S2-4	-3	0.11	0.18	0.29	-1	-0.44	-0.06

5.3.2.2 Infrastructure Impacts - The change in pavement damage between scenarios was calculated using relative ESAL kilometers (ESAL miles) of travel. In this particular situation, for example, pavement damage was predicted to decrease by 6 percent if wheat has to be hauled using vehicles in compliance with the maximum allowable GVW of 36,300 kilograms (80,000 lbs) opposed to vehicles operating under current GVW limits. This reduction primarily resulted from shifting wheat off of 7 axle Rocky Mountain Doubles onto other vehicles. The 7 axle Rocky Mountain Double is one of the few large combination vehicles that inflicts more pavement damage per unit weight of freight hauled than a 5 axle tractor, semi-trailer. Pavement damage was expected to increase by 4 percent under the 58,100 kilogram (128,000 lb) scenario, as axle weights increase in response to higher allowable GVWs on existing vehicle types.

Estimated costs associated with the different pavement demands calculated above are presented in Table 5.3.2-2. These cost changes directly reflect the relative changes in ESAL kilometers (miles) of demand, as would be expected. The changes ranged from a reduction in expenses of approximately $200,000 per year for the 36,300 kilogram (80,000 lb) scenario to an increase of $115,000 per year for the 58,100 kilogram (128,000 lb) scenario. The total infrastructure cost for the 58,100 kilogram (128,000 lb) scenario, considering pavement and bridge costs, was $300,000, annually.

5.3.2.3 Economic Impact- Economic activity in the wheat sector of the state's economy would be affected by the change in vehicle configurations predicted above in response to the imposition of maximum gross vehicle weights of 36,300; 39,900; 47,900; and 58,100 kilograms (80,000; 88,000; 105,500; and 128,000 lbs). As wheat would still be transported only by truck under all scenarios, transportation costs were expected to change commensurately with the predicted change in the number of trips required to move the same total weight of wheat using the specified vehicles in each scenario. In these analyses, the decision was made to assume transportation costs increased in direct proportion to the change in trips associated with each scenario (Table 5.3.2-2), adjusted as appropriate for changes in the relative operating costs of the vehicles used in each scenario. The predicted change in transportation costs are presented in Table 5.3.2-2. Under the 36,300 kilogram (80,000 lb) scenario, for example, transportation costs were expected to increase by 16 percent. Conversely, a nominal decrease in transportation costs of 1 percent was observed for the 58,100 kilogram (128,000 lb) scenario.

The statewide average cost of hauling wheat from the farm to the elevator was estimated to be $5.68 per cubic meter ($0.20 per bushel) (64 kilometer (40 mile) trip, one way). Specific costs were expected to vary indirectly with the proximity of the farm to the elevator. The cost of hauling wheat to the elevator is paid by the producer, so that transportation costs reduce the income the wheat farmer receives at the elevator. The change expected in wheat cash receipts and wheat income under each scenario is presented in Table 5.3.2-2. These values were calculated using the current statewide average transportation cost and the projected increase in transportation costs determined above. Under the 36,300 kilogram (80,000 lb) scenario, for example, wheat transportation costs would increase by $0.91 per cubic meter ($0.032 per bushel). The cost to move the 6.23 million cubic meters (177 million bushels) of wheat produced in Montana in 1996 would increase by $5.5 million. This increase represents 0.78 percent of the reported $713 million value of this crop. Cost increases of 0.80 and 0.32 percent of the value of the crop were predicted for the 39,900 and 47,900 kilogram (88,000 and 105,500 lb) scenarios, respectively. For the 58,100 kilogram (128,000 lb) scenario, a nominal decrease in

Note that the value of wheat can change dramatically over time. The impacts stated above in terms of the fraction of the value of wheat are based on a value of around $113 per cubic meter ($4 per bushel). Wheat prices have approached as low as $57 per cubic meter ($2 per bushel), which would effectively double these impacts (as a percent of value).

The impacts just noted gloss over the differences amongst farms. Farms that are closer to elevators would be less affected in absolute dollar terms than those that are farther away and are faced with the highest transportation costs. As in the previous case study, what could not be determined from these data was how vulnerable particular farms become to financial difficulties in the event of a decline in income. Depending on this vulnerability, some farmers might consider switching from wheat to other types of farm products.

5.3.2.4 Other Considerations - Wheat presently hauled in elevators is often loaded onto "unit trains" for transportation out-of-state. "Unit trains" consist of a predetermined number of grain cars which are delivered to an elevator site and are picked up as a "unit" when filled. This approach to transporting grain by rail offers improved efficiencies (and lower costs) relative to single car operations. Some aspects of unit train operations may be changed in the future, which could have some effect on trucking operations. Specifically, some railroads have recently begun publishing tariffs for 104-car unit trains, in addition to the currently used 52-car (and some 76-car) unit train tariffs. The larger unit trains require large investments in capital facilities capable of loading the larger trains. These facilities, however, are built and owned by shippers rather than the railroads. In light of recent unfavorable market conditions (e.g., low wheat prices and Asian economic turmoil), many shippers have been reluctant to undertake such large investment projects. Thus, although the railroads favor the move to larger unit trains, the switch is not likely to occur for several years. The results of the wheat transportation case study assume the status quo as the baseline, and hence would require modification should unit train changes occur in the short term.

In reviewing the information presented in Table 5.3.2-2, it is interesting to note that the predicted change in transportation costs for the 39,900 kilogram (88,000 lb) scenario nominally exceeded that of the 36,300 kilogram (80,000 lb) scenario. The nominal reduction in number of trips in the 39,900 kilogram (88,000 lb) scenario compared to the 36,300 kilogram (80,000 lb) scenario was more than offset by the assumed increased in operating costs for the 39,900 kilogram (88,000 lb) vehicle, resulting in a net increase in cost to operate more 39,900 kilogram (88,000 lb) trucks.

5.3.2.5 References -

General

Montana Agricultural Statistics Service (1997)
Montana Grain Growers Association (1998)
Montana Wheat and Barley Committee (1998)
Trade Research Center (1998)

Direct Interview and/or Survey Response

4 elevator operators
4 grain haulers

Estimated fraction of transportation operation surveyed: Uncertain

5.3.3 Livestock (Beef Cattle)

5.3.3.1 Change in Transportation Operations - In 1996, Montana sent 0.54 million kilograms (1.2 million lbs) of beef cattle to market. Almost all these cattle were shipped live by truck to feed lots or slaughter houses in other states. Common destinations for this beef included the western, central, and north central United States. Popular vehicle configurations for hauling cattle to these locations include 5, 6, and 7 axle tractor, semi-trailers. The estimated percentage of trips, typical GVW, and payload for these trips is presented in Table 5.3.3-1. While a correlation may exist between trip length and choice of vehicle configuration (notably, a tendency to use 5 axle tractor semi-trailers for long trips due to the need to comply with the most restrictive weight regulations of the many states to be traveled through), a common one-way trip length of 960 kilometers (600 miles) was assumed for all configurations. Comments were made during some of the interviews with people involved in the cattle industry that double trailer configurations are unpopular in the industry due to problems with loading and maneuvering these vehicles. Heavy double trailer configurations are also not allowed in some states through which cattle are commonly hauled.

Table 5.3.3-1 Vehicles Currently Used in Transporting Beef Cattle to Feed Lots/Slaughter

Configuration	Percent of All Trips	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
5 axle tractor, semi-trailer	60	35,800 (79,000)	23,600 (52,000)
6 axle tractor, semi-trailer	30	39,500 (87,000)	25,900 (57,000)
7 axle tractor, semi-trailer	10	42,600 (94,000)	27,700 (61,000)

The vehicles expected to transport cattle to market under the various GVW scenarios considered in this study are presented in Table 5.3.3-2. If the maximum allowable GVW was restricted to 36,300 kilograms (80,000 lbs), for example, truck transport of cattle was expected be accomplished using 5 axle tractor, semi-trailers. These trucks were expected to operate at an average loaded weight of 35,800 kilograms (79,000 lbs) (payload of 23,600 kilograms (52,000 lbs)). Use of rail appeared to be unlikely in this situation, in that cattle shipped long distances already move exclusively by truck.

Based on the information and assumptions presented above, the change in the number of trips required to haul cattle to feed lots or slaughter was calculated for each scenario. These changes are listed in Table 5.3.3-2. No changes were expected under the 47,900 and 58,100 kilogram (105,500 and 128,000 lb) scenarios, in that almost all cattle trucks currently operate at GVWs below these values. Changes expected for the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios were nominal in magnitude, due to the volume of cattle already shipped on vehicles with GVWs at or below 36,300 kilograms (80,000 lbs). Under the 36,300 kilogram

Table 5.3.3-2 Summary of Case Study Results: Cattle

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/ yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3S2	5	0.18	0	0.18	3	1.14	0.20
39,900 kg (88,000 lb)	3S2 3S3	1	0.01	0	0.01	1	0.28	0.05
47,900 kg (105,500 lb)	3S2 3S3 4S3	0	0	0	0	0	0	0
Existing	3S2 3S3 4S3	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3S2 3S3 4S3	0	0	0	0	0	0	0

(80,000 lb) weight limit, for example, the number of trips was calculated to increase by 5 percent. The increase in trips was even lower in magnitude under the 39,900 kilogram (88,000 lb) scenario.

5.3.3.2 Infrastructure Impacts - Differences in the damage sustained by the pavement in shipping cattle to feed lots or slaughter under the various GVW scenarios were calculated using relative ESAL kilometers (ESAL miles) of travel. These calculations were done for that portion of all loaded trips estimated to be on Montana's highways. The total cost of the increased pavement damage generated using exclusively 5 axle tractor, semi-trailers under the 36,300 kilometer (80,000 lb) scenario, for example, was estimated to be $180,000 per year (total cost for all trucks and all trips). A much smaller increase in cost ($10,000 per year) was found for the 39,900 kilogram (88,000 lb) scenario. Infrastructure cost changes for the 47,900 and 58,100 kilogram (105,500 and 128,000 lb) scenarios were set equal to zero, as cattle haulers were not expected to operate vehicles of this size, even if the opportunity to do so existed.

5.3.3.3 Economic Impact - Based on information provided by stock growers and shippers, the average cost of moving cattle across all configurations and trips is $1.25 per trip kilometer ($2.00 per trip mile). Using this figure, and the estimated number of trips required to move the same amount of beef the same distance, the changes in truck transportation costs given in Table 5.3.3-2 were determined. Impacts of $1.14 and $0.28 million per year were determined for the 36,300 and 39,900 kilometer (80,000 and 88,000 lb) scenarios, respectively. These impacts correspond to 0.2 and 0.05 percent of the annual market value of Montana beef cattle, which was reported to be approximately $582 million in 1996. These relative modest changes in costs/producer income were not expected to significantly impact beef cattle operations in Montana. The relative low values for the expected changes in cost are consistent with the level of present use of 36,300 kilogram (80,000 lb) vehicles in the cattle industry, and the relatively high value of beef on a per weight basis.

5.3.3.4 References -

General

Montana Agricultural Statistics Service (1997)
Montana Department of Livestock (1997)

Direct Interview and/or Survey Response

2 stockyard/livestock brokers
2 freight companies that specializes in cattle hauling
1 producer

Estimated fraction of transportation operation surveyed: 25 percent or less

5.3.4 Sugar Beets

5.3.4.1 Change in Transportation Operations - Sugar beets are grown in the northeastern and south central parts of Montana. The sugar beets are transported by truck from the field to processing plants located in Sydney and Billings. At the processing plants, the sugar beets are used in the production of sugar and other sweeteners. Over 202 square kilometers (50,000 acres) of sugar beets are harvested each year in Montana, yielding over a 907,000 metric tons (1 million English tons) of sugar beets.

Sugar beets are generally hauled from the field to the processing plants using 9 axle Rocky Mountain Doubles. These vehicles typically operate at a loaded weight closely approaching their maximum allowable gross vehicle weight of 55,800 kilograms (123,000 lbs). Thus, assuming an empty weight of 18,100 kilograms (40,000 lbs), they haul 37,600 kilograms (83,000 lbs) of sugar beets on each trip. The vehicles expected to be used to haul sugar beets under each scenario and the expected change in total trips under each scenario are summarized in Table 5.3.4-1. If the maximum allowable gross vehicle weight on Montana's highways were to be restricted to 36,300 kilograms (80,000 lbs), for example, sugar beets would be transported on 5 axle tractor, semi-trailers. The estimated payload per trip for these vehicles was 24,500 kilograms (54,000 lbs), assuming an empty weight of 11,800 kilograms (26,000 lbs). Based on the relative payload capacity of the 9 axle Rocky Mountain Double versus the 5 axle tractor, semi-trailer, a 54 percent increase in trips would be necessary to carry the same volume of sugar beets using 5 axle tractor, semi-trailers. A 6 percent reduction in trips was calculated for the 58,100 kilogram (128,000 lb) scenario, with the trip changes for the remaining scenarios being bracketed by this value and that for the 36,300 kilogram (80,000 lb) scenario. Rail was not considered as an alternate means to move this product from field to processing plant.

5.3.4.2 Infrastructure Impacts - Estimates of the change in cost of the pavement damage inflicted in moving sugar beets from the field to the processing plant under each scenario are presented in Table 5.3.4-1. Determining precise costs for the changes in pavement damage predicted under each scenario was difficult, in that this cost is related to the specific weight carried by each particular vehicle on each trip. To establish the order of magnitude of these costs, it was estimated that 1,180,000 metric tons (1,300,000 English tons) of sugar beets move from field to processing plant each year in Montana. It was further assumed that all sugar beets move on 9 axle Rocky Mountain Doubles. The average loaded trip length was assumed to be 64 kilometers (40 miles) (one way). Under these assumptions, a maximum change in pavement costs of $223,000 per year (increase) was calculated for the 36,300 kilogram (80,000 lb) scenario. Pavement costs steadily decreased across the 39,900 and 47,900 kilogram (88,000 and 105,500 lb) scenarios, with a cost savings of $200,000 per year calculated for the 47,900 kilogram (105,500 lb) scenario. Total bridge and pavement costs for the 58,100 kilogram (128,000 lb) scenario were $111,000 per year.

5.3.4.3 Economic Impact - As sugar beet movements from fields and storage facilities will still be accomplished by truck under each scenario, transportation costs for sugar beets were expected to change commensurate with predicted changes in the number of trips required to move the same total amount of sugar beets under each scenario and the types of vehicles being used to move the beets. Based on detailed estimates prepared by one major sugar beet hauler, transportation costs were expected to increase around 21 percent under a 36,300 kilogram

Table 5.3.4-1 Summary of Case Study Results: Sugar Beets

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3S2	54	0.22	0	0.22	21	1.39	2.68
39,900 kg (88,000 lb)	3S2 3S3	50	0.16	0	0.16	20	1.32	2.54
47,900 kg (105,500 lb)	3S2-4	28	-0.20	0	-0.20	24	1.55	2.98
Existing	3S2-4	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3S2-4	-6	0.04	0.07	0.11	-4	-0.25	-0.47

(80,000 lb) maximum GVW. Transportation costs from field to processing plant were estimated to be 10 to 15 percent of the value of the transported beets. Thus, assuming transportation costs were 12.5 percent of total sugar beet costs, production costs would increase (or farm income would decrease) by approximately 2.68 percent in the 36,300 kilogram (80,000 lb) scenario. Changes in transportation costs as a fraction of sugar beet value in the remaining scenarios, presented in Table 5.3.4-1, ranged from an increase of 2.98 percent in the 47,900 kilogram (105,500 lb) scenario to a decrease of 0.47 percent in the 58,100 kilogram (128,000 lb) scenario.

Several things could happen in response to a 2.68 percent cost increase for sugar beet production observed in the 36,300 kilogram (80,000 lb) scenario:

1) this cost could simply be passed on to the sugar beet processors,
2) producers could absorb the cost internally by reducing their profit,
3) producers could grow a different (and less profitable) crop, which would result in the processing plants going out of business, or
4) the processor could elect to shutdown if the price of sugar beets increased, which would result in the producers being forced to grow a different crop.

Note that it has been estimated that over $40 million are spent annually by over 500 Montana farmers in sugar beet production. The processing plants have payrolls of almost $10 million.

In evaluating the likelihood of occurrence of the above outcomes, note that Montana only accounts for 5 percent of the national sugar beet crop, and that production costs in the northwestern United States already appear to be approximately 10 percent higher than the national average. Further note that the companies that process Montana's sugar beets operate in several other states and also handle other sweetener related crops (sugarcane). Finally note that the cost of the beets was estimated to be over 50 percent of the cost of producing sugar from sugar beets, and thus a 2.7 percent increase in sugar beet costs would represent a 1.3 percent increase in sugar production costs.

In any event, assuming an annual crop value of $52 million, the change in operating costs associated with moving sugar beets from the field to the processing plant under each scenario are presented in Table 5.3.4-1. Under the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios, transportation costs were expected to increase approximately $1.39 and $1.32 million per year, respectively. A nominally larger increase in transportation costs of $1.55 million per year was predicted for the 47,900 kilogram (105,500 lb) scenario. In the 47,900 kilogram (105,500 lb) scenario, the sugar beet hauler was assumed to use the same vehicle configuration as currently is being used to haul sugar beets, operated at the lower GVW limit of 47,900 kilograms (105,500 lbs). When operated at this GVW limit, this vehicle apparently is less cost effective for hauling sugar beets than 5 and 6 axle tractor, semi-trailers operating at 36,300 and 39,900 kilograms (80,000 and 88,000 lbs), respectively. A nominal reduction in transportation costs ($0.25 million per year) was calculated for the 58,100 kilogram (128,000 lb) scenario

5.3.4.4 Other Considerations - From a conservation perspective, fuel use would increase if sugar beets were moved, for example, by 5 axle tractor, semi-trailers instead of 9 axle Rocky Mountain Doubles. One major shipper of sugar beets has developed a sophisticated software program for use in estimating transportation resource requirements and costs. This program indicated that fuel consumption would increase by 15 percent in moving beets by 5 axle tractor, semi-trailer under the 36,300 kilogram (80,000 lb) scenario compared to using existing vehicles.

5.3.4.5 References -

General

Montana Agricultural Statistics Service (1997)
American Sugar Alliance (1998)
Economic Research Service (1997a)

Direct Interview and/or Survey Response

1 Hauler
Estimated fraction of transportation operation surveyed: at least 50 percent

5.4 EXTRACTIVE INDUSTRIES

5.4.1 Crude Oil

5.4.1.1 Change in Transportation Operations - Oil wells operating in north central and northeastern Montana presently produce approximately 2,540,000 cubic meters (16,000,000 barrels) of crude oil per year. While a majority of this crude oil moves by feeder pipeline from the well site to the main pipeline, increasingly these feeder pipelines, typically underground, are being abandoned in favor of moving the crude oil by truck. Reasons for this trend include the costs of maintaining the feeder pipelines and concerns about environmental contamination from faulty pipelines.

Common vehicles used for hauling crude oil from the well to the pipeline are 3 and 4 axle straight trucks pulling 4 axle full trailers and 7 axle Rocky Mountain doubles. Estimates of the relative amount that these vehicles are used in hauling crude oil and of their basic operating characteristics are given in Table 5.4.1-1. Interviews with operators revealed that conventional long combination vehicles can be difficult to maneuver in the oil fields, and thus while their capacities are attractive, they are not commonly used.

Table 5.4.1-1 Vehicles Currently Used in Transporting Crude Oil from the Well to the Pipeline

Configuration	Percent of All Trips	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
3 axle truck, 4 axle full trailer	32	46,300 (102,000)	31,800 (70,000)
4 axle truck, 4 axle full trailer	60	48,100 (106,000)	32.200 (71,000)
7 axle Rocky Mountain Double	8	51,700 (114,000)	34,500 (76,000)

The vehicles that were expected to be used in hauling crude oil under each GVW scenario, and the change in the number of trips required to move the same quantity of crude oil as is presently hauled, are listed in Table 5.4.1-2. Calculated changes in trips with respect to the current situation ranged from an increase of 37 percent under the 36,300 kilogram (80,000 lb) scenario to a decrease of 1 percent under the 58,100 kilogram (128,000 lb) scenario. Under the 36,300

Table 5.4.1-2. Summary of Case Study Results: Crude Oil

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/ yr (millions)	Change in Infrastructure Cost, $/yr (millions)	Change in Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3-2 3S2	37	0.12	0	0.12	19	1.80	0.71
39,900 kg (88,000 lb)	3-4 3S2 3S3	29	-0.01	0	-0.01	16	1.49	0.59
47,900 kg (105,500 lb)	3-4 4-4 3S2-2	1	-0.01	0	-0.01	1	0.08	0.03
Existing	3-4 4-4 3S2-2	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3-4 4-4 3S2-2	-1	0.01	0	0.01	-1	-0.06	-0.03

kilogram (80,000 lb) scenario, for example, operators were expected to use 5 axle tractor, semi-trailers and/or 3 axle straight trucks pulling 2 axle trailers. The estimated payload per trip for these vehicles was 23,600 kilograms (52,000 lbs) (27.2 cubic meters (171 barrels)). Based on the relative capacity of these 5 axle combinations compared to the vehicles currently being used to haul crude, an estimated 37 percent more trips would have to be made by the 5 axle combinations to carry the same total amount of crude oil. Rail was not considered as an alternate means to move this product from the well site to the collector pipe line. Feeder pipelines were also not considered to be a sufficiently attractive alternative from a cost perspective to be used instead of trucks to move crude oil, in part due to the limited remaining life of these oil fields over which the cost of feeder pipelines could be depreciated, and environmental concerns regarding underground pipelines (as mentioned above).

5.4.1.2 Infrastructure Impacts - Changes in the damage inflicted on the pavement in moving crude oil from the field to the processing plant under each scenario were calculated in terms of relative ESAL kilometers (ESAL miles) of travel. Pavement damage was expected to increase by 43 percent, for example, if 5 axle combination units operating at a maximum GVW of 36,300 kilograms (80,000 lbs) had to be used for this activity instead of the current vehicles. This increase was the largest in magnitude of all the scenarios. Nominal reductions in pavement damage (3 to 5 percent) were expected under the 39,900 and 47,900 kilogram (88,000 and 105,500 lb) scenarios, with a nominal increase in damage (3 percent) predicted for the 58,100 kilogram (128,000 lb) scenario. Assigning precise costs to the changes in pavement damage predicted above for each scenario was difficult, in that this cost was related to the specific weight carried by each particular vehicle on each trip. To establish the order of magnitude of these costs, it was estimated that 954,000 cubic meters (6,000,000 barrels) of crude oil in Montana move by truck from the oil field to the pipeline. It was further assumed that the average length of a loaded trip was 48 kilometers (30 miles) one way. Under these assumptions, the changes in pavement damage given in Table 5.4.1-2 were calculated. If the same amount of oil continues to be moved under the 36,300 kilogram (80,000 lb) maximum GVW scenario as is currently moved, for example, pavement costs will increase by approximately $123,000 per year (total cost for all trucks and all trips) for this scenario, which was the greatest change in pavement costs across all scenarios. The bridge costs assessed against the appropriate vehicles in the 58,100 kilogram (128,000 lb) scenario amounted to only $3,000 annually, when stated as an EUAC. The low magnitude of this cost reflected the expected light use of the largest vehicles allowed under the 58,100 kilogram (128,000 lb) scenario due to maneuverability issues.

5.4.1.3 Economic Impact - Presuming that crude oil presently moved by truck generally continues to be moved by truck, transportation costs for crude oil would be expected to change as the number of trips required to move the same total amount of crude oil changes in each scenario. The calculated cost changes, determined with due consideration of variations in operating costs between vehicle configurations, are presented in Table 5.4.1-2 for each scenario. In the 36,300 kilogram (80,000 lb) scenario, for example, truck transportation costs are expected to increase by 19 percent. Truck transportation costs from the well site to the collector pipeline were estimated to represent 8 to 12 percent of the value of the crude oil at the pipeline. One operator estimated that trucking costs were approximately $12.60 per cubic meter ($2.00 per barrel), which was consistent with the 12 percent value (assuming a crude oil price of $99.37 per cubic meter

($15.80 per barrel), which was the average market price of crude oil for the period 1993 to 1997). Note that crude oil prices can vary dramatically from year-to-year, while transportation expenses remain relatively constant.

Changes in truck transportation costs as a fraction of the value of the crude oil are summarized in Table 5.4.1-2. These values were calculated using the change in truck transportation costs for each scenario given in Table 5.4.1-2 under the assumption that the cost of truck transportation was 10 percent of the value of the oil hauled. These cost changes ranged from an increase of 1.9 percent for the 36,300 kilogram (80,000 lb) scenario to a nominal cost savings of 0.09 percent for the 58,100 kilogram (128,000 lb) scenario. When adjusted to account for the fact that only 38 percent of all oil was assumed to move by truck, the changes in transportation costs were 0.7 and 0.03 percent in the 36,300 and 58,100 kilogram (80,000 and 128,000 lb) scenarios, respectively, across all the crude oil produced.

Several things could happen in response to the cost increase of 1.9 percent calculated for the 36,300 kilogram (80,000 lb) scenario for crude moved by truck:

1) this cost could simply be passed on to the purchasers of crude oil,
2) producers (that use trucks) could absorb the cost internally by reducing their profit, or
3) producers (that use trucks) could cease operations until the price of crude oil reaches a point at which they are comfortable with their profit margin.

In evaluating the likelihood of occurrence of the above outcomes, note that Montana only accounts for 1 percent of the national production of crude oil, that crude oil prices in Montana are already approximately 1.5 percent higher than the national average (at the wellhead), and that current profit margins on production are estimated to be only 3 to 5 percent.

In any event, assuming 954,000 cubic meters (6,000,000 barrels) of crude oil are moved by truck annually, the change in transportation costs ($/yr) associated with moving crude oil from the well sites to the collector pipelines under each scenario are reported in Table 5.4.1-2. The increase in transportation costs under the 36,300 kilogram (80,000 lb) scenario, for example, would be approximately $1.8 million per year. Predicted changes in cost/income ranged from this value to a nominal cost savings (less than $0.06 million per year) for the 58,100 kilogram (128,000 lb) scenario.

5.4.1.4 References -

General

Energy Information Administration (1997)
Oil and Gas Conservation Division (1997)

Direct Interview and/or Survey Response

3 Haulers
1 Producer

Estimated fraction of transportation operation surveyed: 50 percent

5.4.2 Talc

5.4.2.1 Change in Transportation Operations - Montana is the leading producer of talc in the United States. Montana accounts for 1/3 or more of the approximately 1,000,000 metric tons (1,100,000 English tons) of talc mined annually in the United States (average production, 1994 to 1996). This talc is used in items such as ceramics, cosmetics, insecticides, paint, paper, roofing, and plastics. While approximately 20 percent of the talc produced in the United States is exported to other countries, an almost equal amount is imported from other countries, and these imports are expected to gradually increase.

At one major talc operation in Montana, ore is hauled from the mine to a central location, where it is processed and loaded for shipment by truck or rail to industrial clients. Nine axle combination vehicles are used to haul the ore the 120 kilometers (75 miles) from the mine to the processing plant. These vehicles typically operate at a loaded weight of 53,500 kilograms (118,000 lbs) and carry a payload of 36,300 kilograms (80,000 lbs).

The vehicles expected to transport ore from the mine to the processing plant under the various GVW scenarios considered in this study are presented in Table 5.4.2-1. Note that the shipper contacted in researching this case study elected to replace his current vehicles with readily available configurations that he believed would optimize operations under each GVW scenario. Referring to Table 5.4.2-1, the change in the number of trips required to haul the same amount of ore as is presently moved from the mine to the processing plant ranged from an increase of 57 percent under the 36,300 kilogram (80,000 lb) scenario to a reduction of 11 percent under the 58,100 kilogram (128,000 lb) scenario. Rail was not considered as an alternate means to move this product from the mine to processing plant.

5.4.2.2 Infrastructure Impacts - Differences in the damage sustained by the pavement in hauling talc from the mine to the processing plant under the various GVW scenarios were calculated using relative ESAL kilometers (ESAL miles) of travel. The trucks presently used in this operation cause a relatively low amount of damage per unit weight of cargo hauled. This situation results from the large number and specific arrangement of axles used on these vehicles. Thus, pavement damage increased under all of the new GVW scenarios. The changes in pavement costs associated with each scenario were calculated assuming 270,000 metric tons (300,000 English tons) of ore are moved annually a distance of 75 miles (one way). The cost of the increased pavement damage generated using 5 axle combination vehicles under the 36,300 kilometer (80,000 lb) scenario, for example, was estimated to be $190,000 per year (total cost for all trucks and all trips). Smaller impacts were predicted for the other scenarios, with a minimum impact of $28,000 per year calculated for the 47,900 kilogram (105,500 lb) scenario.

5.4.2.3 Economic Impact - The average value of processed talc in the United States in 1996 was estimated at $111 per metric ton ($101 per English ton). Based on estimates provided by one major talc hauler, transportation costs were expected to increase around 44 percent under a 36,300 kilogram (80,000 lb) maximum GVW. Transportation costs from the mine to the processing plant were estimated to represent from 6 to 10 percent of the value of the processed talc. Assuming raw ore transportation costs are 8 percent of total costs, processed talc costs would increase by approximately 3.5 percent under the 36,300 kilogram (80,000 lb) scenario. Changes in transportation costs as a fraction of processed talc price in the remaining scenarios

Table 5.4.2-1. Summary of Case Study Results: Talc

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/ yr (millions)	Change in Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3-2	57	0.19	0	0.19	44	1.06	3.54
39,900 kg (88,000 lb)	4-2	40	0.16	0	0.16	31	0.73	2.44
47,900 kg (105,500 lb)	3-4	19	0.03	0	0.03	10	0.25	0.82
Existing	4S3-2	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	4S3-2	-11	0.04	0.03	0.07	-10	-0.25	-0.82

are presented in Table 5.4.2-1. These changes ranged in magnitude from an increase of 2.4 percent in the 39,900 kilogram (88,000 lb) scenario to a decrease of 0.8 percent in the 58,100 kilogram (128,000 lb) scenario.

Possible actions and outcomes resulting from a 3.5 percent increase in costs under the 36,300 kilogram (80,000 lb) scenario include:

1) The cost increase could be passed on to customers by raising talc prices. Talc is produced in several other states around the country, however, and these producers would not be faced with similar increases in their costs. Thus, in raising prices, Montana could experience a loss of market share to other states. While this effect might be mitigated to some extent by the shear volume of talc Montana supplies to the market, note that Montana talc producers do not just compete against other talc producers in marketing their product. Alternative materials and/or processes (that do not use talc) are available for some of the high volume applications for talc. If the price of talc increases, some of these alternatives may become economically viable, which could substantially reduce demand for talc.
2) The cost increase could be internally absorbed by the talc company. Whether or not this action is practical is related to the current level of profitability of the talc operation and the level of profitability acceptable to the parent company. While the profitability of the current operation in unknown, a change in profit equivalent to 3.5 percent of the value of the product produced would be considered significant in many industries. The talc company indicated that they have been able to retain some clients only by keeping their prices fixed over several years, and that they have been able to survive from a profitability perspective only by optimizing their operation.
3) The cost increase could be shared by the company and the talc consumers.

The eventual result of any of the actions outlined above could be closure of the talc operation due to reduced profitability. This talc operation presently employs 188 people and has an annual pay roll of approximately $7.5 million. The company directly spends around $10 million per year on supplies in Montana. The company annually pays over $1 million in property tax.

In any event, assuming 270,000 metric tons (300,000 English tons) of ore are moved annually, the change in operating costs associated with moving ore from the mine to the processing plant under each scenario are presented in Table 5.4.2-1. Under the 36,300 kilogram (80,000 lb) scenario, for example, transportation costs would increase approximately $1 million per year. A nominal reduction in costs ($0.25 million per year) was calculated for the 58,100 kilogram (128,000 lb) scenario, with results from the other scenarios falling between these values.

5.4.2.4 References -

General

McCartan (1997)

U.S. Geological Survey (1998)

Direct Interview and/or Survey Response

1 freight company that specializes in hauling talc

1 producer of talc

Estimated fraction of transportation operation surveyed: 75 percent or more

5.5 FORESTRY AND WOOD PRODUCTS

5.5.1 Logging

5.5.1.1 Change in Transportation Operations - Logs are typically hauled from the forest to the processing mill using 5 axle tractor, semi-trailers. While large combination vehicles are definitely attractive for this purpose when haul distances are long, they are less well suited to off-road operation at logging sites relative to the 5 axle tractor, semi-trailer. In some long haul situations, facilities have been constructed so that logs hauled from the logging site on 5 axle tractor, semi-trailers can be loaded onto rail cars for shipment to the processing mills. Thus, while the use of large combination vehicles (Rocky Mountain Doubles) to haul logs started to become prevalent 6 or 7 years ago, their use apparently has actually declined over the past 2 to 3 years. It is now estimated that less than 10 percent of all logging trips are made using large combination vehicles.

The estimated percentage of trips made by each configuration, average trip length (one-way), maximum gross vehicle weight, and payload by vehicle configuration are presented below:

Table 5.5.1-1 Vehicles Currently Used in Transporting Logs from the Forest to the Mill

Configuration	Percent of All Trips	One-way Length of Average Trip, kilometers (miles)	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
5 axle tractor, semi-trailer	90	64 (40)	36,300 (80,000)	24,900 (55,000)
7 axle Rocky Mountain Double	10	160 (100)	49,400 (109,000)	34,900 (77,000)

The loaded weight of these vehicles closely approaches their maximum GVW, and their average loaded weight was therefore simply assumed to be their maximum GVW.

The vehicles that were expected to be used to haul logs under each scenario are listed in Table 5.5.1-2. In this case, 5 axle tractor semi-trailers were expected to be used exclusively in the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. Seven axle Rocky Mountain Doubles were expected to be used in the 47,900 kilogram (105,500 lb) scenario at a nominally reduced GVW. Referring to Table 5.5.1-2, only nominal changes in the number of trips were predicted under all scenarios, in that fully 90 percent of truck transport of logs is already

Table 5.5.1-2. Summary of Case Study Results: Logging

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, \$/yr (millions)	Change in Bridge Cost, \$/ yr (millions)	Change in Infrastructure Cost, \$/yr (millions)	Change in Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	\$/yr (millions)	
36,300 kg (80,000 lb)	3S2	5	0.04	0	0.04	5	3.38	0.95
39,900 kg (88,000 lb)	3S2	5	0.04	0	0.04	5	3.38	0.95
47,900 kg (105,500 lb)	3S2 3S2-2	1	-0.11	0	-0.11	1	0.39	0.11
Existing	3S2 3S2-2	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3S2 3S2-2	-1	0.33	0.13	0.46	-1	-0.66	-0.19
36,300 kg (80,000 lb) with rail	3S2	4	-0.35	0	-0.35	7	4.78	1.34

accomplished on vehicles weighing 36,300 kilograms (80,000 lbs) or less. In the 36,300 kilogram (80,000 lb) scenario, for example, the number of trips required to haul the same quantity of logs as is presently hauled increased by 5 percent.

Given that some logs already move by rail, diversion of logs from truck to rail transport was judged to be possible under the 36,300 kilogram (80,000 lb) scenario. In particular, those logs presently hauled longer distances using 7 axle Rocky Mountain Doubles might travel part of the trip by rail. The simple assumption was made that 50 percent all of the logs presently moved by 7 axle Rocky Mountain Doubles would be hauled an average distance of 64 kilometers (40 miles) by 5 axle tractor, semi-trailer to a rail head, at which time they would be hauled 160 kilometers (100 miles) by rail to a mill.

While precisely predicting the volume of logs that would be shifted from truck to rail transport if a 36,300 kilogram (80,000 lb) maximum weight was adopted was beyond the scope of this investigation, these two scenarios provided some insights into what could happen in this situation. Note that both scenarios presume that the total volume of logs moved in Montana remained unchanged by the imposition of the 36,300 kilogram (80,000 lb) gross vehicle weight. If shipping costs increase, however, it may be uneconomical to transport logs to and from some sources in Montana.

5.5.1.2 Infrastructure Impacts - The relative damage associated with using the various configurations available under each scenario to haul logs was estimated in terms of changes in ESAL kilometers (ESAL miles) of travel. Only nominal changes in pavement damage were predicted across all scenarios without rail diversion, ranging from an increase of 6 percent for the 58,100 kilogram (128,000 lb) scenario to a decrease of 2 percent for the 47,900 kilogram (105,500 lb) scenario with respect to the existing situation. The corresponding costs estimated for these changes in pavement demand ranged from an increase of $330,000 per year for the 58,100 kilogram (128,000 lb) scenario to a decrease of $111,000 per year for the 47,900 kilogram (105,500 lb) scenario. For the 36,300 kilogram (80,000 lb) scenario with rail diversion, a decrease in pavement demands of 8 percent was observed. The cost savings associated with this reduction in pavement demand was $350,000 per year.

The bridge cost assessed against the 58,100 kilogram (128,000 lb) scenario was $131,000 per year.

5.5.1.3 Economic Impact - The change in truck transportation costs under each scenario are presented in Table 5.5.1-2. These changes in cost were assumed to be proportional to the changes in the number of trips under each scenario (for the cases with no rail diversion), with due adjustments for differences in operating costs and assumed trip lengths between vehicle configurations. The resulting change in transportation costs ranged from an increase of 5 percent for the 36,300 kilogram (80,000 lb) scenario to a decrease of 1 percent for the 58,100 kilogram (128,000 lb) scenario. Further assumptions were necessary to evaluate the change in transportation costs for the 36,300 kilogram (80,000 lb) scenario with rail diversion. In this case, the cost of the rail transport was simply set equal to the estimated cost of moving the same amount of logs by truck under current GVW regulations (in this case, the cost of moving logs 160 kilometers (100 miles) by 7 axle Rocky Mountain Doubles). Based on these assumptions, transportation costs increased 7 percent relative to the current costs of moving logs from the forest to the mill. This result indicates that under the assumptions made in these analyses, rail diversion would not occur. The predicted transportation costs for the case including rail nominally exceeded those for the case that used only trucks. This result is not necessarily surprising, in that across several shipping activities, rail appears to only become competitive at trip one-way distances of 320 kilometers (200 miles).

Transportation costs were estimated to represent from 10 to 30 percent of the value of the delivered logs, depending on the quality of the timber and the distance it was transported. The resulting change in the delivered cost of logs under each scenario, calculated using an average transportation cost of 20 percent of the value of the logs, are reported in Table 5.5.1-2. The calculated increases in costs for the 36,300 kilogram (80,000 lb) scenario, with and without rail diversion, and for the 39,900 kilogram (88,000 lb) scenario were all approximately 1.5 percent. A nominal reduction in cost, 0.3 percent, was observed for the 58,100 kilogram (128,000 lb) scenario. Some or all these predicted changes in costs could possibly be absorbed or passed on by the owner of the timber, the hauler, the mill, the wholesaler, etc. With respect to passing on any increase in costs, note that Montana produces less than 4 percent of the nation's softwood lumber. The forested regions of Oregon and Washington supply nearly 30 percent of the nation's lumber, and they are geographically closer to some of the large west coast markets compared to Montana. If increases in costs can not be passed on, it may simply become unprofitable to haul logs from some locations to the nearest mill, resulting in reductions both in logging and mill production.

In any event, transportation costs under the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios increased approximately $3.4 dollars per year (based on a $357 million value for the timber delivered to Montana mills in 1997). A nominal cost savings of $0.66 million was realized under the 58,100 kilogram (128,000 lb) scenario in 1997.

5.5.1.4 Other Considerations - One use discovered for Rocky Mountain Doubles was to haul logs during the spring from locations in eastern Montana which were clear of seasonal route restrictions to mills in central and western Montana. Some operators apparently engage in this activity in an effort to cover some of their fixed costs during the off season. This operation would be cost prohibitive if just 5 axle tractor, semi-trailers could be used.

5.5.1.5 References -

General

Keegan (1998)
Warren (1998)

Direct Interview and/or Survey Response

2 Haulers
1 Association

Estimated fraction of transportation operation surveyed: Uncertain

<u>5.5.2 Wood Chips/Liner Board</u>

5.5.2.1 Change in Transportation Operations - Wood chips produced as a by-product of processing raw logs into lumber are transported from mills around Montana to Missoula, where they are used in the production of liner board. The facility in Missoula takes in approximately

1.5 million metric tons (1.6 million English tons) of chips per year, 80 percent of which travel by truck, 20 percent, by rail. Generally, trucks are used if the haul distance is less than approximately 200 miles. Reportedly, when trucks are used instead of rail, costs associated with rail loading facilities can be avoided, and delivery times can be closely controlled.

Popular vehicle configurations for hauling wood chips are 7 and 8 axle semi-trailers and 9 axle Rocky Mountain doubles. The estimated percentage of chips hauled (as a fraction of all chips hauled by truck), average trip length (one-way), and typical gross vehicle weight by vehicle configuration are presented in Table 5.5.2-1. The loaded weight of these vehicles on any given trip can vary considerably, from 60 to 80 percent of their maximum GVW, up to their maximum GVW. For these calculations, an average loaded weight of 95 percent of the maximum GVW was assumed.

Table 5.5.2-1 Vehicles Currently Used in Transporting Wood Chips from the Lumber Mill to the Liner Board Plant

Configuration	Percent of All Trips	One-way Length of Average Trip, kilometers (miles)	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
7 axle tractor, semi-trailer	30	64 (40)	41,300 (91,000)	25,400 (56,000)
8 axle tractor, semi-trailer	30	64 (40)	45,400 (100,000)	27,700 (61,000)
9 axle Rocky Mountain Double	40	128 (80)	54,400 (120,000)	34,500 (76,000)

The vehicles expected to transport chips on Montana's highways under the various GVW scenarios considered in this study are presented in Table 5.5.2-2. If the maximum allowable GVW is restricted to 36,300 kilograms (80,000 lbs), for example, truck transport of chips would be accomplished using 5 axle tractor, semi-trailers. These trucks were expected to operate at an average loaded weight of 34,500 kilograms (76,000 lbs) (payload of 20,400 kilograms (45,000 lbs)). Additionally, some chips presently transported by truck may have been transported by rail. A major chip hauler and the company that uses the chips in the production of liner board indicated that switching from truck to rail was a possibility at the 36,300 kilogram (80,000 lb) weight. The possibility that such a switch could occur over a relatively short period of time was made more likely by the fact that 20 percent of all chips already are moved by rail, so the process is familiar, and some facilities and equipment are already available. Some lumber mills are already located adjacent to rail lines, as is the liner board plant. For the purposes of this analysis, two scenarios were considered regarding the diversion of chip transport from truck to rail: a) no diversion, and b) 50 percent of the chips hauled by 9 axle Rocky Mountain Doubles will be hauled by rail. The rational for the second scenario is that at the 36,300 kilogram (80,000 lb)

Table 5.5.2-2. Summary of Case Study Results: Wood Chips/Liner Board

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3S2	46	0.34	0	0.34	37	7.49	3.29
39,900 kg (88,000 lb)	3S3 3S4	37	0.06	0	0.06	35	7.12	3.12
47,900 kg (105,500 lb)	4S3 4S4 3S3-2	14	-0.03	0	-0.03	19	3.79	1.67
Existing	4S3 4S4 4S3-2	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	4S3 4S4 4S3-2	-1	0.03	0.07	0.10	0	-0.02	0
36,300 kg (80,000 lb) with rail	3S2	12	0.01	0	0.01	24	4.86	1.78

vehicle weight limit, rail would become cost effective (presuming that it is also physically available) for some longer hauls currently done with the 9 axle Rocky Mountain Doubles. Switching from 7 and 8 axle tractor semi-trailers to rail seemed less likely than switching from Rocky Mountain Doubles to rail as a) these vehicles already are apparently used predominantly on short hauls and b) imposing an 36,300 kilogram (80,000 lb) maximum gross vehicle weight will have a smaller impact on these vehicles compared to Rocky Mountain Doubles, as these vehicles already operate at lower weights than Rocky Mountain Doubles.

While precisely predicting the volume of chips that would shift from truck to rail transport if an 36,300 kilogram (80,000 lb) maximum weight was adopted was beyond the scope of this investigation, these two scenarios provided some insights into what could happen in this situation. Note that both scenarios presumed that the total volume of chips shipped to Missoula remained unchanged by the imposition of the 36,300 kilogram (80,000 lb) GVW limit. If shipping costs increase, however, it may be uneconomical to transport chips from some sources to Missoula.

Based on the information and assumptions presented above, the change in the number of trips required to haul chips was calculated for each scenario. These changes are listed in Table 5.5.2-2. Under the 36,300 kilogram (80,000 lb) weight limit, for example, the number of trips increased by 46 percent for the scenario with no rail diversion, and it increased by 12 percent for the scenario with rail diversion. A 1 percent decrease in trips was calculated for the 58,100 kilogram (128,000 lb) scenario. These values bracket predicted changes in trips under the other scenarios.

5.5.2.2 Infrastructure Impacts - Differences in pavement costs in hauling wood chips from sawmills to the liner board plant under the various GVW scenarios are summarized in Table 5.5.2-2. Changes in pavement costs ranged from a maximum increase of $335,000 per year under the 36,300 kilogram (80,000 lb) scenario (no rail diversion) to a decrease of $34,000 per year under the 47,900 kilogram (105,500 lb) scenario. For the 36,300 kilogram (80,000 lb) scenario with rail diversion, the total cost of the increased pavement damage was estimated to be only $7,000 per year. The bridge costs assessed against the appropriate vehicles in the 58,100 kilogram (128,000 lb) scenario amounted to $73,000 annually, when stated as an EUAC, producing a total annual infrastructure cost for this scenario of $104,000.

5.5.2.3 Economic Impact - The change in truck transportation costs under each scenario are presented in Table 5.5.2-2. These changes in cost were assumed to be proportional to the changes in the number of trips under each scenario (for the cases with no rail diversion), with due adjustments for differences in operating costs and assumed trip lengths between vehicle configurations. The resulting change in transportation costs ranged from an increase of 37 percent for the 36,300 kilogram (80,000 lb) scenario to a neutral situation for the 58,100 kilogram (128,000 lb) scenario.

Further assumptions were necessary to evaluate the cost impacts in the 36,300 kilogram (80,000 lb) scenario with diversion of chips from truck to rail transport. Again, detailed analysis of this situation was beyond the scope of this study. For this analysis, the transportation cost of hauling chips by rail was simply set at the estimated maximum average cost of shipping chips short distances by truck, as represented by the cost to ship chips using 8 axle tractor, semi-trailers. Following this approach, and again assuming that the increase in chip transportation costs was proportional to the increase in the number of trips required to haul the same amount of chips (with adjustments for differences in vehicle operating costs and trip distances), transportation costs would increase by 24 percent for the situation with rail diversion.

Approximately 1/3 of the cost of the liner board produced in Missoula is attributable to the cost of the wood chips used in the production process. Additionally, approximately 1/3 of the cost of wood chips is attributable to their transportation costs from the various lumber mills to the Missoula liner board facility. Therefore, 1/9 of the cost of liner board is attributable to wood chip transportation costs. An increase in average liner board production costs (for wood chips hauled by truck), for example, of 4.1 percent was calculated under the 36,300 kilogram (80,000 lb) scenario (no rail diversion), in response to a 37 percent increase in truck transportation costs. The average cost of finished liner board would increase by approximately 2.2 percent under the 36,300 kilogram (80,000 lb) scenario with rail diversion. When adjusted to reflect that only 80 percent of wood chips are shipped by truck, these values reduce to 3.3 and 1.8 percent, respectively.

If costs increase as predicted above, several things could happen:

1) this cost could simply be passed on to the customer,
3) the company could absorb the cost internally by reducing its profit,
3) only chips with low transportation costs might be used, and plant production and chip consumption would go down, and
4) the plant could go out of business. (The Missoula facility directly employs 700 people and has an average annual payroll of approximately $38 million.)

With respect to the first outcome, the liner board market appears to be fairly competitive. Approximately 8 pulp/paper mills in Oregon and Washington reportedly produce liner board in direct competition with the Montana mill. Large pulp/paper mills that produce liner board apparently are also located throughout the southern United States. Thus, a cost increase on the order of magnitude of 2 to 3 percent probably cannot be easily passed on to customers. The ability of the liner board company to internally absorb these increases in transportation costs (second outcome) is related to the magnitude of the cost increase, the current profitability of this operation, and the acceptable profitability of this operation. Note that the Missoula operation is one of 13 paperboard, paper, and pulp facilities within a larger corporation. With respect to the third outcome, the plant in Missoula apparently is already challenged with respect to getting enough chips to supply its needs, due to the general reduction in logging operations in Montana and the Pacific Northwest. Finally, this increase in costs related to transportation could result in the company closing its Missoula facility. Whether this outcome is realized, depends again on the current and acceptable profitability of this operation.

In any event, increased truck transportation costs under the 36,300 kilogram (80,000 lb) scenario were estimated to be $7.5 and $4.9 million per year, for the cases with and without rail diversion, respectively. Cost impacts under the other scenarios, lower in magnitude than the $7.5 million per year for the basic 36,300 kilogram (80,000 lb) scenario, are reported in Table 5.5.2-2.

5.5.2.4 Other Considerations - It is interesting to note that truck transportation costs were predicted to remain unchanged from current costs under the 58,100 kilogram (128,000 lb) scenario for this industry. The industry already tends to run vehicles with GVWs considerably lower than 58,100 kilograms (128,000 lbs). This case study would indicate that efficiencies realized by hauling more freight per trip on the few long combination vehicles presently in use would be closely balanced by the increased operating costs for these vehicles.

5.5.2.5 References -

Direct Interview and/or Survey Response

1 Liner board producer

2 Chip haulers

Estimated fraction of transportation operation surveyed: Greater than 50 percent

5.6 CONSTRUCTION

5.6.1 Sand and Gravel

5.6.1.1 Change in Transportation Operations - Construction activities in Montana consumed an estimated 8,850,000 metric tons (9,760,000 English tons) of sand and gravel in 1996 (generally excluding railroad ballast and crushed stone). This sand and gravel was used in applications such as concrete aggregates, asphalt pavement aggregates, road base material, road chip seal material, and general fill material. At least 95 percent of this sand and gravel is believed to have been transported by heavy trucks (defined as a 3 axle single unit or larger vehicle). Popular vehicle configurations for hauling sand and gravel include 3 and 4 axle single units; 3 and 4 axle straight trucks pulling 2, 3, or 4 axle full trailers; 5 and 6 axle tractor, semi-trailers; and 8 and 9 axle Rocky Mountain Doubles. Factors that effect the vehicle configuration used for a particular job include the size of job, the distance to be driven, the ease of access to the job site, and the equipment that is available.

The characteristics of the heavy vehicles used to haul sand and gravel are presented in Table 5.6.1-1. Based on data available in TIUS (U.S. Dept. of Commerce, 1995) and information provided directly by vehicle operators, 3 and 4 axle single units account for approximately 50 percent of the sand and gravel trips made by heavy trucks and 33 percent of the weight of sand and gravel hauled by heavy trucks. These vehicles operate at gross weights below 36,300 kilograms (80,000 lbs), and thus their operation will be unchanged under the GVW scenarios considered in this study. The remaining 50 percent of the sand and gravel trips made by heavy truck (accounting for 67 percent of the weight of sand and gravel hauled by heavy trucks in Montana) are made using the various combination vehicles listed in Table 5.6.1-1, operating at weights that in many instances would be affected by the GVW scenarios considered herein. Based on a limited survey of sand and gravel haulers within the state, the various combination units are used in approximately equal proportion (by number of trips).

The vehicles which were expected to be used under each GVW scenario to haul sand and gravel are indicated in Table 5.6.1-2. If the maximum gross vehicle weight was restricted to 36,300 kilograms (80,000 lbs), for example, sand and gravel presently hauled on combination vehicles would be shifted to 3 axle trucks pulling 2 axle trailers and 5 axle tractor, semi-trailers. The estimated payload for both of these vehicles (each operating at a gross weight of 36,300 kilograms (80,000 lbs)) was 21,800 kilograms (48,000 lbs). Based on this payload capacity, 20 percent more trips were required under the 36,300 kilogram (80,000 lb) scenario to move the same amount of sand and gravel as is presently hauled on large combination vehicles. A 4 percent reduction in trips was calculated for the 58,100 kilogram (128,000 lb) scenario. Changes in the number of trips in the other scenarios were bracketed by these values. Based on the nature of these trips (gravel pit to job site), it was unlikely that this commodity would be moved by any other mode of transportation.

Table 5.6.1-1 Vehicles Currently Used in Transporting Sand and Gravel from the Mine to the Construction Site

Configuration	Percent of All Truck Trips	Percent of Sand and Gravel Hauled by Weight	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
Single Units	50	33		
3 axle single unit	25	15	22,700 (50,000)	11,800 (26,000)
4 axle single unit	25	18	26,300 (58,000)	13,600 (30,000)
Combination Units	50	67		
3 axle truck, 2 axle trailer	4.5	5	38,100 (84,000)	23,600 (52,000)
3 axle truck, 3 axle trailer	4.5	6	41,700 (92,000)	25,900 (57,000)
3 axle truck, 4 axle trailer	4.5	7	46,300 (102,000)	29,000 (64,000)
4 axle truck, 2 axle trailer	4.5	5	39,000 (86,000)	22,700 (50,000)
4 axle truck, 3 axle trailer	4.5	6	43,500 (96,000)	28,900 (57,000)
4 axle truck, 4 axle trailer	4.5	6	47,600 (105,000)	28,600 (63,000)
5 axle tractor, semi-trailer	4.5	5	36,300 (80,000)	21,800 (48,000)
6 axle tractor, semi-trailer	4.5	6	39,900 (88,000)	24,000 (53,000)
8 axle Rocky Mtn Double (2 configurations)	9	13	49,400 (109,000)	29,500 (65,000)
9 axle Rocky Mtn Double	4.5	7	52,200 (115,000)	30,800 (68,000)

Table 5.6.1-2 Summary of Case Study Results: Sand and Gravel

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3-2 3S2	20	0.21	0	0.21	12	2.63	3.98
39,900 kg (88,000 lb)	3-2, 3-3 4-2 3S2,3S3	13	0.16	0	0.16	10	2.13	3.22
47,900 kg (105,500 lb)	3-2,3-3 3-4,4-2 4-3,4-4 3S2,3S3 3S2-2,4S2-2	1	0.02	0	0.02	1	0.19	0.28
Existing	3-2, 3-3 3-4, 4-2 4-3, 4-4 3S2,3S3 3S2-2,4S2-2 4S3-2	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3-2, 3-3 3-4, 4-2 4-3, 4-4 3S2, 3S3 3S2-2,4S2-2 4S3-2	-4	0.14	0.03	0.17	-3	-0.55	-0.83

5.6.1.2 Infrastructure Impacts - Demands placed on the pavement in hauling sand and gravel from the pit to the job site were expected to change under the different vehicles operating in each GVW scenario. The magnitudes of these changes were calculated using the relative ESAL kilometers (ESAL miles) of travel under each scenario, assuming an average trip length of 16 kilometers (10 miles) (one-way). Under the 36,300 kilogram (80,000 lb) scenario, for example, pavement demands increased by 30 percent compared to the demands under the current traffic stream, as measured by relative ESAL miles of travel. This increase was the largest change in pavement damage calculated across all scenarios. The relative costs associated with the changes in pavement demand under each scenario are presented in Table 5.6.1-2. The greatest observed change in pavement costs across all scenarios was an increase under the 36,300 kilogram (80,000 lb) scenario of $212,000 per year (total cost for all trucks and all trips). The bridge costs assessed against the appropriate vehicles in the 58,100 kilogram (128,000 lb) scenario amounted to $29,000 annually, which resulted in a net change in infrastructure costs for this scenario of $170,000 per year.

5.6.1.3 Economic Impact - Changes in transportation costs under each scenario are presented in Table 5.6.1-2. These values were calculated based on the changes in the number of trips required under each scenario to move the same amount of sand and gravel as is currently shipped on the system, with adjustments for differences in the operating costs of the various vehicle configurations involved. The calculated changes in transportation costs with respect to the current situation steadily moved from a 12 percent increase under the 36,300 kilogram (80,000 lb) scenario to a 3 percent decrease under the 58,100 kilogram (128,000 lb) scenario. Based on information provided by a major supplier of sand and gravel, for a 10 mile travel distance (one-way), approximately one-half of the cost of sand and gravel delivered to the job site is attributable to the costs of transporting it between the gravel pit and the job site. The order of magnitude of this cost was verified using national construction cost data. Changes in the cost of sand and gravel at the job site, calculated using the above values, are presented in Table 5.6.1-2. Under the 36,300 kilogram (80,000 lb) scenario, for example, sand and gravel costs increased by 6 percent (presuming heavy trucks were used). Averaged across all sand and gravel delivered in the state (recall that 33 percent of the sand gravel is already carried on vehicles with gross weights less than 80,000 pounds), sand and gravel costs increased by 4 percent. Increased costs (steadily decreasing in magnitude) were predicted for the 39,900 and 47,900 kilogram (88,000 and 105,500 lb) scenarios. A nominal cost savings of 0.8 percent was calculated across all sand and gravel relative to existing costs in the 58,100 kilogram (128,000 lb) scenario.

Possible impacts of these changes in sand and gravel costs on construction activity are uncertain. Sand and gravel are typically only part of the cost of a construction activity. The relative importance of sand gravel costs varies with the nature of the construction activity under consideration. In constructing a gravel road, for example, basic sand and gravel costs are a major part of the total contract price. In building a steel frame building, sand and gravel costs can be only a small fraction of the total project costs. Thus some impacts might be felt in heavy civil construction areas (such highway construction projects, in which sand and gravel costs range up to 50 percent of the project cost), while other types of construction would be relatively unaffected (such as residential housing construction, in which sand and gravel costs are on the order of magnitude of 1 percent of the project cost). In general, the cost changes calculated herein could be absorbed or passed on by the producer, transporter, or end consumer. In this regard, it seems unlikely that in the competitive sand and gravel market in Montana, that a producer or transporter could absorb cost increases (reductions in income) on the order of magnitude of 6 percent, without facing financial difficulties.

In any event, the increase in transportation costs associated with imposing a 36,300 kilogram (80,000 lb) maximum gross vehicle weight were approximately $2.6 million per year. A cost savings of $0.55 million per year was calculated for the 58,100 kilogram (128,000 lb) scenario. Changes in costs associated with the various other scenarios, presented in Table 5.6.1-2, were bracketed by these values.

5.6.1.4 References -

General

United States Geological Survey (1996)
R.S. Means (1997)

Direct Interview and/or Survey Response

9 Companies that produce and/or haul sand and gravel

Estimated fraction of transportation operation surveyed: 33 percent

5.6.2 Portland Cement

5.6.2.1 Change in Transportation Operations - Construction activities in Montana consumed an estimated 272,000 metric tons (300,000 English) tons of Portland cement in 1996. The primary use of cement in Montana is in ready mixed concrete, which accounts for approximately 80 percent of the cement consumed. Primary domestic sources for this cement consist of manufacturing plants in Three Forks and Helena, and a rail terminal in Missoula (all operated by different companies). Cement is shipped from these locations to consumers spread across the state. An estimated 90 percent of this cement is transported by truck, based on national data on the shipment of cement by mode of transportation. The predominant vehicle configurations for hauling cement are 7, 8, and 9 axle Rocky Mountain doubles. These vehicles were assumed to haul 75 percent of the cement shipped by truck, with the remaining 25 percent shipped on 5 and 6 axle tractor, semi-trailers, and on 8 axle trucks pulling full trailers. The average trip distance from source to destination was estimated to be 190 kilometers (120 miles) for these vehicles, based in part on information provided by vehicle operators in the state. In general, larger configurations tend to be used for longer distance trips.

Some of the characteristics of the various vehicles listed above that are used to haul cement are presented in Table 5.6.2-1. Also shown in the table are the estimated percentages of trips made by the various vehicles, and an average trip length.

The types of vehicles that were expected to be used under each GVW scenario to transport cement are listed in Table 5.6.2-2. If the maximum allowable gross vehicle weight on Montana's highways was restricted to 36,300 kilograms (80,000 lbs), for example, truck transport of cement would predominantly be accomplished using 5 axle tractor, semi-trailers, and these trucks were expected to operate at their maximum GVW when loaded. Additionally, some cement presently transported by truck may be transported by rail. A major cement producer indicated that switching from truck to rail was a possibility at the 36,300 kilogram (80,000 lb) weight. Many consumers of cement in Montana are both small in size and widely dispersed

Table 5.6.2-1 Vehicles Currently Used in Transporting Cement

Configuration	Percent of All Trips	One Way Length of Average Trip, kilometers (miles)	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
5 axle tractor, semi-trailer	15	95 (60)	35,400 (78,000)	20,900 (46,000)
6 axle tractor, semi-trailer	5	95 (60)	38,600 (85,000)	22,200 (49,000)
8 axle straight truck and full trailer	5	95 (60)	47,600 (105,000)	30,400 (67,000)
7 axle Rocky Mtn Double	30	190 (120)	49,900 (110,000)	31,800 (70,000)
8 axle Rocky Mtn Double	40	190 (120)	52,600 (116,000)	33,100 (73,000)
9 axle Rocky Mtn Double	5	190 (120)	56,200 (124,000)	34,500 (76,000)

geographically, so any new rail service would probably consist of the establishment of terminals near larger metropolitan areas, with final delivery of the cement to the customer still accomplished by truck. For the purposes of these analyses, two scenarios were considered regarding the diversion of cement transport from truck to rail: a) no diversion, and b) 100 percent of the cement hauled by 7, 8, and 9 axle Rocky Mountain Doubles will be hauled by rail for part of its travel (assumed average rail travel distance of 240 kilometers (150 miles)), at which time it will be loaded on trucks for final delivery. For the second scenario, the average trip length for all truck transport will be reduced to 48 kilometers (30 miles) (one-way).

While precisely predicting the volume of cement that will be shifted from truck to rail transport if a 36,300 kilogram (80,000 lb) maximum weight is adopted (and all the attendant changes in the characteristics of truck transport that would occur) was beyond the scope of this investigation, these two scenarios provided some insights into what could happen in this situation. Note that both scenarios presumed that the total volume of cement shipped to consumers remained unchanged by the imposition of the 36,300 kilogram (80,000 lb) gross vehicle weight. In general, few substitutes are available for the applications in which cement is used in Montana (i.e., building applications at and below grade), and thus demand would be expected to remain strong, even if its cost increased.

Based on the information and assumptions presented above, the change in the number of truck trips made by cement haulers ranged from an increase of 45 percent under an 36,300 kilogram (80,000 lb) weight limit to a decrease of 5 percent under a 58,100 kilogram (128,000 lb) weight limit (Table 5.6.2-2). Note that the same number of trips was predicted under the 36,300 kilogram (80,000 lb) scenario for the situations with and without diversion to rail. The

Table 5.6.2-2. Summary of Case Study Results: Cement

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, \$/yr (millions)	Change in Bridge Cost, \$/yr (millions)	Change in Infrastructure Cost, \$/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	\$/yr (millions)	
36,300 kg (80,000 lb)	3S2	45	0.04	0	0.04	31	1.05	4.16
39,900 kg (88,000 lb)	3S2 3S3	42	-0.01	0	-0.01	30	1.03	4.10
47,900 kg (105,500 lb)	3S2 3S3 3S2-2 3S2-3	15	-0.10	0	-0.10	12	0.40	1.61
Existing	3S2 3S3 3S2-2 3S2-3 3S2-4	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3S2 3S3 3S2-2 3S2-3 3S2-4	-5	0.06	0.04	0.10	-2	-0.08	-0.33
36,300 kg (80,000 lb) with rail	3S2	45	-0.25	0	-0.25	31	1.05	4.16

difference between the scenarios was the assumed average trip length, which was unchanged for the case of no diversion of cement from truck to rail, but was reduced to 48 kilometers (30 miles) for all truck trips under the scenario with rail diversion.

5.6.2.2 Infrastructure Impacts - Expected changes in pavement demands under each GVW scenario were calculated based on the relative ESAL kilometers (ESAL miles) of travel under each scenario. The maximum increase in pavement demand of 15 percent was predicted for the 58,100 kilogram (128,000 lb) scenario without rail diversion; the maximum decrease in pavement demand of 67 percent was calculated for the 36,300 kilogram (80,000 lb) scenario with rail diversion. The cost of the changes in pavement damage under each scenario are presented in Table 5.6.2-2. Under the 36,300 kilogram (80,000 lb) scenario without rail diversion, the estimated increase in pavement costs is $40,000 per year. If cement is shipped by rail to terminals around the state and then loaded on 5 axle tractor, semi-trailers for delivery to its ultimate destination, pavement costs were found to decrease by $251,000 per year. Bridge costs assessed against vehicles operating under the 58,100 kilogram (128,000 lb) scenario were $41,000 per year, resulting in total infrastructure costs for this scenario of $101,000 per year.

5.6.2.3 Economic Impact - Approximately 15 percent of the cost of cement is related to its delivery by truck to the end user (based on an average haul distance of 95 to 190 kilometers (60 to120 miles)). If the increase in cement transportation cost was directly related to the increase in the number of trips required to haul the same amount of cement (with appropriate adjustments for differences in operating costs and trip distances between vehicle types), transportation costs would increase by 31 percent for the situation without rail diversion. The attendant cost of the delivered cement would increase by 4.7 percent. Across all the cement used in Montana (recognizing that only 90 percent of cement hauled is moved by truck), the change in the cost of cement would be 4.2 percent. Changes in the cost of cement under the other scenarios, listed in Table 5.6.2-2, were lower in magnitude than those mentioned above.

Further assumptions were necessary to evaluate the cost impacts in the scenario in which cement traveled part of the way to its destination by rail. Again, detailed analysis of this situation was beyond the scope of this study. For this analysis, the transportation cost of hauling cement by rail was simply set at the estimated average cost of shipping cement by truck over a 240 kilometer (150 mile) distance. This distance is consistent with the assumed rail shipping distance to terminals around the state. While this distance is 25 percent less than the current point at which rail becomes competitive with trucks (320 kilometers (200 miles)), it may be consistent with the distance at which rail becomes competitive under a 36,300 kilogram (80,000 lb) GVW limit. Following this approach, and again assuming that the increase in cement transportation cost is related to the increase in the number of trips required to haul the same amount of cement, transportation costs were found to increase identical to the situation without rail diversion.

If costs increase as predicted above, several things could happen:

1) Some or all of the increase in production costs could simply be passed on to the customer. In this case, customers include both the companies that use the cement in their manufacturing processes (e.g., ready mix concrete company), or the purchasers of the resulting manufactured products.

2) The companies that manufacture cement could absorb some or all of the increased transportation costs for their product.
3) The companies that manufacture cement could pull out of more distant markets, which would reduce their level of production.
4) The companies that haul cement from the manufacturer to the market could absorb or pass on some or all their increased costs.

In evaluating the likelihood of these various outcomes, note that few substitutes are available for the end applications in which cement is used in Montana (e.g., building and hydraulic applications at and below grade, shear walls in structures, etc.), and thus demand is expected to remain strong, even if prices increase. As was observed for sand and gravel, cement is typically only one element of a construction project, and the significance of changes in cement costs vary with the type of project.

In any event, truck transportation costs of cement were estimated to increase by $1.1 million per year under the 36,300 kilogram (80,000 lb) scenario. A nominal cost savings of $0.08 million per year was predicted for truck transportation costs under the 58,100 kilogram (128,000 lb) scenario. Other changes in truck transportation costs are given in Table 5.6.2-2.

5.6.2.4 Other Considerations - One cement manufacturer was as concerned with simply moving enough cement to satisfy customer demands as with any changes in production costs that might result under reduced GVW regulations. In their opinion, the use of larger heavy trucks allows for less congestion and more rapid delivery of cement to the job site.

5.6.2.5 References -

General

United States Geological Survey (1996)

Direct Interview and/or Survey Response

3 Cement haulers
1 Cement producer
Estimated fraction of transportation operation surveyed: ~ 33 percent

5.7 RETAIL

5.7.1 Retail Food

5.7.1.1 Change in Transportation Operations - Grocery stores in Montana generally receive their stock by truck. Depending on the nature of the specific operation, up to 65 percent of the items sold by a store pass through grocery distribution centers (warehouses) on their way to the supermarket shelves. Approximately 35 percent of the products sold at grocery stores are delivered directly to the stores by producers and/or distributors that handle only certain types of commodities. This case study focuses on the 65 percent of grocery items that are handled through central warehouses, and on the travel of these goods from the warehouse to individual stores. These grocery items are generally shipped using vehicles with GVWs at or above 36,300 kilograms (80,000 lbs). With a few exceptions, the remaining 35 percent of grocery items are moved using vehicles with GVWs at or below 36,300 kilograms (80,000 lbs).

Approximately 65 percent of the grocery stores in Montana are supplied by distribution centers located in cities in Montana (e.g., Great Falls and Billings). The remaining 35 percent of the grocery stores are supplied from distribution centers located in major cities in other states (notably, Salt Lake City and Spokane). For companies that have multiple stores, these distribution centers may be operated by the company, itself. Independent stores use distribution centers operated by third parties. In either case, commodities generally arrive at the distribution center from the producer or broker by the truckload. At the distribution center, these commodities are used to fill orders from individual stores. The orders, consisting of a variety of items (mixer loads), are sent out by truck, with each truck traveling to a single destination. Note that one chain store in Montana apparently dispatches some trucks from the warehouse containing a single commodity (or type of commodity), and the trucks make deliveries of that single commodity to several stores along their route.

A variety of vehicle configurations are used to haul wholesale groceries from distribution centers to individual stores. Most operations use 5 and 6 axle tractor, semi-trailers, and 7 and 8 axle Rocky Mountain Doubles. The vehicle used for a given delivery is dependent on the size of the order to be filled, the distance to be traveled, the accessibility of the store, and the time of year. As might be expected, Rocky Mountain Doubles tend to be used for large loads and long travel distances. The estimated percentage of trips made by each type of vehicle and average trip distances are presented in Table 5.7.1-1.

Independent of the vehicle used, limits on the volume a truck can carry rather than its weight capacity can control its payload, and loads apparently are often planned so that the vehicles are close to both their weight and volume capacities. Typical operating characteristics of loaded vehicles are presented in Table 5.7.1-1.

Table 5.7.1-1 Vehicles Currently Used in Transporting Grocery Items from Distribution Centers to Individual Stores

Configuration	Percent of Trips	One Way Average Trip Distance, kilometers (miles)	Maximum Typical Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
5 axle tractor, semi-trailer	40	95 (60)	34,900 (77,000)	20,900 (46,000)
6 axle tractor, semi-trailer	20	130 (80)	38,600 (85,000)	23,100 (51,000)
7 axle Rocky Mountain Double	10	160 (100)	48,500 (107,000)	31,800 (70,000)
8 axle Rocky Mountain Double	30	160 (100)	50,800 (112,000)	32,700 (72,000)

The various vehicles that were expected to be used in transporting groceries under each GVW scenario are listed in Table 5.7.1-2. If the maximum allowable gross vehicle weight on Montana's highways is restricted to 36,300 kilograms (80,000 lbs), for example, groceries transported on 6 axle tractor, semi-trailers and on 7 and 8 axle Rocky Mountain Doubles would be moved instead using 5 axle tractor, semi-trailers. These 5 axle tractor, semi-trailers were expected to operate at an average actual GVW of 34,900 kilograms (77,000 lbs), as it seems unlikely that all deliveries could be exactly planned to achieve a truck weight of 36,300 kilograms (80,000 lbs). Based on the relative payload capacities of the 6 axle tractor, semi-trailer and of the 7 and 8 axle Rocky Mountain Doubles versus the 5 axle tractor, semi-trailer, a 24 percent increase in trips would be necessary to carry the same volume of groceries using 5 axle tractor, semi-trailers. Changes in the number of trips calculated across all scenarios ranged from the 24 percent increase mentioned above for the 36,300 kilogram (80,000 lb) scenario to a 3 percent decrease for the 58,100 kilogram (128,000 lb) scenario. Due to the timeliness required in making deliveries to individual stores, it seemed unlikely that modes of transportation other than truck would be used for this purpose.

5.7.1.2 Infrastructure Impacts - Changes in the damage inflicted on the pavement in moving groceries from the warehouse to the retail store were calculated based on the relative ESAL kilometers (ESAL miles) of travel determined in each scenario. The maximum increase in pavement damage of 6 percent was observed for the 36,300 kilogram (80,000 lb) scenario; the maximum decrease of 15 percent, for the 47,900 kilogram (105,500 lb) scenario. Assigning precise costs to the changes in pavement damage predicted under each scenario was difficult, in that this cost was related to the specific weight carried by each particular vehicle on each delivery. To establish the order of magnitude of this cost, it was estimated that 340 million kilograms (750 million pounds) of freight moves from grocery warehouses to retail stores each year in Montana. The average loaded trip distances for the 5 axle, tractor semi-trailer, the 6 axle tractor, semi-trailer, and for the 7 and 8 axle Rocky Mountain Doubles were assumed to be 90, 130, and 160 kilometers (60, 80, and 100 miles), respectively. Rail was not considered as an alternate means to move this freight. Changes in the cost of pavement damage sustained in each scenario under these assumptions are given in Table 5.7.1-2. The cost of the increased pavement damage under the 36,300 kilogram (80,000 lb) scenario, for example, was estimated to be $160,000 per year (total cost for all trucks and all trips). Pavement costs decreased by $151,000 per year under the 47,900 kilogram (105,500 lb) scenario. The bridge costs assessed against the appropriate vehicles in the 58,100 kilogram (128,000 lb) scenario amounted to $74,000 annually, when stated as an EUAC, resulting in a total infrastructure cost for this scenario of $266,000 per year.

5.7.1.3 Economic Impact - The assumption was made in these analyses that transportation costs would change in proportion to the change in the number of trips required to move the same volume of groceries under each scenario, with due adjustments for vehicle operating costs and trip lengths. Changes in truck transportation costs, given in Table 5.7.1-2, ranged from an increase of 17 percent under the 36,300 kilogram (80,000 lb) scenario to a decrease of 2 percent under the 58,100 kilogram (128,000 lb) scenario.

Transportation costs from warehouse to retail store were reported by one major chain store to be less than 2 percent of the value of the transported goods. Thus, under the 36,300

Table 5.7.1-2. Summary of Case Study Results: Retail Food

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/yr (millions)	Change in Total Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3S2	24	0.16	0	0.16	17	2.79	0.22
39,900 kg (88,000 lb)	3S2 3S3	20	0.03	0	0.03	15	2.55	0.20
47,900 kg (105,500 lb)	3S2 3S3 3S2-2 3S2-3	5	-0.15	0	-0.15	6	0.93	0.07
Existing	3S2 3S3 3S2-2 3S2-3	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	3S2 3S3 3S2-2 3S2-3	-3	0.19	0.07	0.26	-2	-0.27	-0.02

kilogram (80,000 lb) scenario, for example, a 17 percent increase in transportation costs represented a 0.3 percent increase in the costs associated with those items supplied through central warehouses, and a 0.2 percent increase in operating costs across all grocery items. This cost increase could be shared or absorbed by the distributor, retailer, or consumer. Assuming annual retail grocery sales in Montana of $1.3 billion per year, the increase in transportation costs associated with moving groceries from the warehouse to the store would be approximately $2.8 million per year. At the other end of the scenarios, the nominal decrease of 2 percent in the transportation costs for the 58,100 kilogram (128,000 lb) scenario translated into a cost savings of $0.3 million per year.

Note that these analyses do not address shipment of grocery items to the distribution center. Any such shipments made to distribution centers located inside Montana, that are accomplished by heavy vehicles, could be impacted by the various GVW scenarios considered in this study. This affect may be nominal in magnitude, however, in that many of these deliveries reportedly are already made using 5 axle tractor, semi-trailers.

5.7.1.4 Other Considerations - A major grocery distributor in Montana commented that they have not raised their transportation rates since 1980. They have been able to keep their rates constant despite inflation by improving efficiency, first by adopting 53 foot trailers, and more recently by shifting into 8 axle Rocky Mountain Doubles.

5.6.1.5 References -

General

CEIC (1998)

Direct Interview and/or Survey Response

3 Grocery store chains

1 Grocery distributor

Estimated fraction of transportation operation surveyed: 75 percent

<u>5.7.2 Retail Motor Fuel</u>

5.7.2.1 Change in Transportation Operations - The final step in delivering motor fuel to be sold at retail gas stations in Montana is generally accomplished using trucks. Motor fuel typically travels by pipeline from the refinery to the general geographic area in which it will be consumed. Once in the area, it is picked up by truck and hauled to its final destination. All of the major metropolitan areas in Montana are served directly by pipeline. Thus, much of the motor fuel sold in the state travels only short distances by truck in moving from the pipeline distribution point to a retail station.

Popular vehicle configurations for hauling motor fuel are listed in Table 5.7.2-1. These vehicles include a mixture of straight trucks pulling full trailers; tractor, semi-trailers; and Rocky Mountain Doubles. These vehicles, estimated to haul 95 percent of all retail fuel, typically operate at their maximum allowable gross vehicle weight when filled with motor fuel. The maximum gross weight of these vehicles is generally constrained by the Federal bridge formula, rather than the weight allowed on the individual axle groups used in the configuration. Some of the operating characteristics of the vehicles used in hauling motor fuel are given in Table 5.7.2-1.

Table 5.7.2-1 Vehicles Currently Used to Haul Motor Fuel to Retail Gas Stations

Configuration	Percent of All Truck Trips	Typical Maximum Operating Weight, kilograms (lbs)	Typical Payload, kilograms (lbs)
5 axle truck, semi-trailer	10	36,300 (80,000)	24,000 (53,000)
6 axle truck, semi-trailer	10	39,900 (88,000)	26,300 (58,000)
8 axle truck and full trailer	25	49,900 (110,000)	35,400 (78,000)
7 axle Rocky Mountain Double	25	50,800 (112,000)	34,900 (77,000)
8 axle Rocky Mountain Double	15	53,100 (117,000)	36,300 (80,000)
9 axle Rocky Mountain Double	15	54.400 (120,000)	36,700 (81,000)

The remaining 5 percent of the retail motor fuel sold in Montana is hauled on 3 and 4 axle straight trucks operating at gross vehicle weights at or below 36,300 kilograms (80,000 lbs), on 7 axle truck/full trailers, and on other configurations.

The vehicle configurations expected to be used to haul fuel under each GVW scenario are listed in Table 5.7.2-2. Under the 36,300 kilogram (80,000 lb) scenario, for example, 5 axle vehicles operating at 36,300 kilograms (80,000 lbs) were expected to be used to haul motor fuel. Forty percent more trips would be required using these vehicles to haul the same amount of motor fuel as is moved using the current vehicle fleet. A 4 percent reduction in trips was calculated for the 58,100 kilogram (128,000 lb) scenario relative to existing weight limits. The change in trips for the other scenarios are bracketed by these values.

5.7.2.2 Infrastructure Impacts - Changes in pavement damage were calculated in terms of relative ESAL kilometers (ESAL miles) of travel under each scenario. These changes ranged from an increase in pavement damage of 13 percent under the 36,300 kilogram (80,000 lb) scenario, to a decrease in pavement damage of 23 percent in the 58,100 kilogram (128,000 lb) scenario. To establish the order of magnitude of the costs associated with these changes in pavement damage, it was simply assumed that 95 percent of all taxable gallons of fuel sold in the state travel an average distance of 8 kilometers (5 miles) in heavy trucks as it is moved from the pipeline distribution point to the retail service station. In the 36,300 kilogram (80,000 lb) scenario, the cost of the increased pavement damage generated at this level of operation was approximately $10,000 per year. The savings in pavement costs predicted under the 47,900 kilogram (105,500 lb) scenario were approximately $20,000 per year. The bridge costs assessed against the appropriate vehicles in the 58,100 kilogram (128,000 lb) scenario amounted to $10,000 annually, resulting in total infrastructure costs for this scenario of $20,000 per year.

Table 5.7.2-2. Summary of Case Study Results: Retail Fuel

Scenario	Vehicle Configuration	Change in No. of Trips, %	Change in Pavement Cost, $/yr (millions)	Change in Bridge Cost, $/yr (millions)	Change in Infrastructure Cost, $/yr (millions)	Change in Truck Transportation Cost		Change in Cost as a Fraction of Commodity Value, %
						%	$/yr (millions)	
36,300 kg (80,000 lb)	3-2 3S2	40	0.01	0	0.01	40	2.28	0.47
39,900 kg (88,000 lb)	3-2 3S2 3S3	30	-0.00	0	-0.00	30	1.74	0.36
47,900 kg (105,500 lb)	3-4 3S2, 3S3 3S2-2 3S2-3 3S3-2	15	-0.02	0	-0.02	15	0.85	0.17
Existing	4-4 3S2, 3S3 3S2-2 3S2-3 4S3-2	0	0	0	0	0	0	0
58,100 kg (128,000 lb)	4-4 3S2, 3S3 3S2-2 3S2-3 4S3-2	-4	0.01	0.01	0.02	-4	-0.21	-0.04

5.7.2.3 Economic Impact - Economic activity in the retail motor fuel sector of the state's economy would be affected by the change in vehicle configurations predicted above in response to the imposition of new maximum allowable GVWs. The majority of the fuel consumed in the state already travels by pipeline to the immediate area in which it is sold, as previously mentioned. It is unlikely that shipment from the pipeline distribution point to local service stations would be accomplished by any means other than truck. Thus, transportation costs for motor fuel were expected to change commensurate with changes in the number of truck trips predicted in each scenario. Based on discussions with a few fuel transport companies, changes in transportation costs were expected to be nominally the same as changes in the number of trips.

The cost of hauling fuel from a pipeline distribution point to an individual service station is dependent on the distance between the pipeline and the station. For short hauls (up to 9 miles), the cost of transporting gasoline is approximately $0.003/liter ($0.01/gallon). The majority of fuel used in the state falls into this category. Over some of the longer hauls that may be encountered in Montana, the cost of transporting fuel can be as high as $0.026/liter ($0.10/gallon). One major transport company estimated their average transportation costs across all their clients was $0.008 to $0.011 per liter ($0.03 to $0.04 per gallon). If the maximum weight limit was reduced to 36,300 kilograms (80,000 lbs), transportation of gasoline in Montana would have a minimum cost of $0.053/liter ($0.014/gallon), an average cost of $0.011 to 0.016 per liter ($0.04 to $0.06 per gallon), and a maximum cost of $0.037/liter ($0.14/gallon), depending on the delivery distance. Note that the cost of transporting diesel fuel figured on a per gallon basis is generally nominally higher than that of gasoline, as diesel fuel has a higher unit weight than gasoline. A single cost (the cost for gasoline) has been used in these analyses for both types of fuel. Changes in fuel costs for other scenarios were calculated using the trip information presented in Table 5.7.1-2. In the case of the 58,100 kilogram (128,000 lb) scenario, for example, average fuel transportation costs would decrease by less than 4 percent.

Changes in the cost of transporting motor fuel to retail service stations was expected to be passed onto the consumer. The profit margin on retail gasoline sales is low, on the order of magnitude of a cent on a dollar. Given the slim margin, gasoline retailers would likely try to pass on to consumers any increase in transportation costs. They would likely be successful in doing so, due to the relatively inelastic demand for gasoline. The average number of taxable gallons of motor fuel sold in Montana per year is 2.29 billion liters (605 million gallons) (based on the combined gallons of taxable gasoline and diesel fuel sold in Montana from 1994 to 1996). The annual increase in the cost of this fuel to the consumer can be conservatively estimated as the expected cost increase for a local delivery times the number of gallons sold (2.29 billion liters (605 million gallons)) times the share of all fuel presently hauled with large vehicles (0.95), assuming consumers do not subsequently change their demand for gasoline. The resulting cost changes ranged from an increase of $2.3 million per year for the 36,300 kilogram (80,000 lb) scenario to a decrease of $0.21 million per year in the 58,100 kilogram (128,000 lb) scenario.

5.7.2.4 Other Considerations: Apparently there is some debate within the motor fuel transport industry regarding the relative merits from a safety perspective of using small versus large vehicles to haul fuel. This debate centers on the potentially devastating consequences of accidents involving vehicles that haul motor fuel. Naturally, in this debate, the attractiveness of minimizing the consequences of individual accidents by hauling less product on small vehicles is weighed against the increased number of accidents that may occur under this scenario as more trips are required to haul the same amount of fuel as is presently carried by the large vehicles.

5.7.2.5 References -

General

MDT (1998b)

Direct Interview and/or Survey Response

1 Hauler
1 Trailer Manufacturer
1 Producer and Hauler

Estimated fraction of transportation operation surveyed: 33 percent

5.8 DISCUSSION OF RESULTS

5.8.1 General Remarks

Presented in Table 5.8-1 are selected results from the case studies listed by GVW scenario. In general, these results are consistent with intuitive expectations, in that

1) with respect to commodity type, heavy and bulky commodities currently shipped on heavy trucks (such as milk, sugar beets, talc, wood chips, cement, and motor fuel) experienced the greatest impacts in transportation operations and costs across all scenarios,
2) with respect to scenarios, the greatest impacts were consistently predicted for the lowest GVW scenario of 36,300 kilograms (80,000 lbs) and they consisted of increased trips and costs, while a nominal decrease in trips and costs was generally found for the highest GVW scenario of 58,100 kilograms (128,000 lbs),
3) with respect to the infrastructure, only nominal impacts were calculated for all industries and all scenarios, with the greatest increase in costs for the 36,300 and 58,100 kilogram (80,000 and 128,000 lb) scenarios and the greatest decrease in costs for the 47,900 kilogram (105,500 lb) scenario,
4) with respect to economic significance, the greatest impacts were expected for those situations in which transportation operations were significantly affected by the GVW scenario and truck transportation costs were a significant part of total commodity costs (such as sugar beets, talc, wood chips, wheat, etc., under the 36,300 kilogram (80,000 lb)).

5.8.2 Changes in Transportation Operations

The greatest increase in the number of truck trips required to haul the same amount of commodity as is presently transported on the highway system was observed in the 36,300 kilogram (80,000 lb) scenario. The changes in trips for this scenario ranged from 5 to 57 percent, depending on the commodity involved. The greatest changes were observed for heavy commodities presently hauled on large combination vehicles (e.g., milk, sugar beets, talc, wood chips, retail fuel). The smallest changes were generally observed for commodities already shipped on some trips using vehicles with GVWs less than or equal to 36,300 kilograms (80,000 lbs) (e.g., cattle, logs).

Table 5.8-1 - Range of Results Obtained for Each Scenario Across All Case Studies

Case Study Result		Range in Result by Scenario				
		36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	105,500 kg (47,900 lb)	Exist	58,100 kg (128,000 lb)
Change in No. of Trips, %		5 to 57	1 to 51	0 to 28	0	0 to -11
Change in Total Infrastructure Cost, \$/yr (millions)		0.34 to -0.20	0.16 to -0.19	0.03 to -0.58	0	0.46 to 0
Change in Truck Transportation Cost	%	54 to 3	51 to 1	25 to 0	0	0 to -10
	\$/yr (millions)	7.49 to1.01	7.12 to 0.16	3.79 to 0	0	0 to -0.66
Change in Cost as a Fraction of Commodity Value, %		4.16 to 0.20	4.10 to 0.05	2.98 to 0	0	0 to -0.83

Changes in the number of trips for the 39,900 kilogram (88,000 lb) scenario were slightly lower in magnitude (typically only 1 or 2 percent) than those predicted for the 36,300 kilogram (80,000 lb) scenario. The similarity in values resulted to a large degree from the absence of vehicles in the existing fleet capable of taking advantage of an 39,900 kilogram (88,000 lb) weight limit. Many operators currently use long combination vehicles that consist of a 5 axle tractor, semi-trailer with a second trailer attached. The majority of these operators were assumed to simply run the five axle tractor, semi-trailer portion of these vehicles under both the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. Some operators did indicate that they would immediately modify their equipment to create 6 axle, tractor, semi-trailers, and some allowance was made for such modifications.

Changes in the number of trips predicted under the 47,900 kilogram (105,500 lb) scenario ranged from zero to a 28 percent increase. Some industries already predominantly use trucks operating at GVWs below 47,900 kilograms (105,500 lbs) (cattle, crude oil, logging, sand and gravel), and thus are relatively unaffected by this and other high GVW scenarios. Cattle, for example, are currently moved on tractor, semi-trailer trucks with maximum GVWs below 47,900 kilograms (105,500 lbs). Reasons given for why larger vehicles are not used in this industry included loading difficulties and maneuvering problems. Similarly, only a small percentage of logs are hauled on long combination vehicles, also apparently due to maneuverability problems. Changes in truck trips for these industries under the 47,900 kilogram (105,500 lb) scenario were less than 1 percent. Those industries that experienced the greatest changes in trips under the 47,900 kilogram (105,500 lb) scenario were those that involved heavy commodities consistently hauled at the maximum allowable weights under current regulations (e.g., milk, sugar beets). Several other industries use long combination vehicles at weights near to nominally above 47,900 kilograms (105,500 lbs) (crude oil, wheat, wood chips, sand and gravel, retail food, and retail fuel), and thus were not as impacted by this scenario (5 to 15 percent increase in trips).

The number of trips predicted under the 58,100 kilogram (128,000 lb) scenario to move the same total quantity of freight as is presently moved on the highway system decreased in almost every industry considered. The greatest reduction in trips (4 to 11 percent) was predicted for those industries that currently and exclusively use the heaviest vehicles (e.g., milk, sugar beets, talc). Typical trip reductions in other industries were only 1 percent. As commented above, several industries already use smaller vehicles for some deliveries than are currently allowed by law, typically due to customer imposed constraints on the size of the order, or maneuverability problems at the delivery site (e.g., retail food, retail fuel, crude oil, logging). Correspondingly, these industries were not expected to realize dramatic advantages from increases in allowable vehicle size and weight.

5.8.3 Impacts on the Infrastructure

The greatest infrastructure impacts were typically predicted for the 36,300 kilogram (80,000 lb) scenario. Pavement costs increased for the 36,300 kilogram (80,000 lb) scenario compared to the existing situation in all but one of the case studies. These increases ranged from $0.04 to $0.34 millions per year, depending on the number of trips involved, length of trip, and specific types of vehicles. Under the 36,300 kilogram (80,000 lb) scenario, freight typically was shifted from 6 axle and greater combination vehicles to 5 axle tractor, semi-trailers operating at or near 36,300 kilograms (80,000 lbs). Due to their payload capacity, the number of axles used, and limits imposed on the individual axle weights by the bridge formula, many of these 6 axle and greater combination vehicles cause less pavement damage per 45,500 kilograms (100,000 pounds) of freight carried than a 36,300 kilogram (80,000 lb) 5 axle tractor, semi-trailer. The one exception to this situation was for the movement of wheat from the farm to the grain elevator. For this movement, calculated pavement costs decreased by $0.20 million per year for the 80,000 pound scenario compared to the existing situation (despite a 27 percent increase in the number of trips required to move the same amount of wheat). A relatively large amount of wheat was believed to presently be shipped on 7 axle Rocky Mountain Doubles (30 percent of all trips). Of all the combination vehicles with 6 axles or more, the 7 axle Rocky Mountain Double is one of the few configurations that does more damage per 45,500 kilograms (100,000 lbs) of freight hauled than is done by a loaded 5 axle tractor, semi-trailer.

Infrastructure impacts under the 39,900 kilogram (88,000 lb) scenario were similar to, and typically slightly less than, those observed for the 36,300 kilogram (80,000 lb) scenario. A greater fraction of the freight on the system was hauled on 6 axle tractor semi-trailers instead of 5 axle units under the 39,900 kilogram (88,000 lb) scenario. Due to its axle configuration, a 6 axle tractor semi-trailer is more pavement friendly than a 5 axle tractor, semi-trailer.

Infrastructure impacts dropped dramatically in magnitude in the 47,900 kilogram (105,500 lb) scenario relative to the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. An actual reduction in pavement costs was predicted in most cases compared to the existing situation. In the 47,900 kilogram (105,500 lb) scenario, freight was typically hauled on the same vehicles that are presently used, simply operating at lower weights. The attendant reduction in axle loads at which these vehicles operated produced a net reduction in pavement damage, despite the increase in the number of trips necessary to move the same amount of freight as is presently carried on the system. The greatest reduction in infrastructure costs was $0.58 million per year for wheat movements.

Pavement costs generally increased in the 58,100 kilogram (128,000 lb) scenario relative to the existing situation. Contrary to the 47,900 kilogram (105,500 lb) scenario, the operating weights of existing vehicle configurations used in the various scenarios were simply increased in the 58,100 kilogram (128,000 lb) scenario relative to their current values. The resulting increase in the axle loads at which these vehicles operated produced a net increase in pavement damage, despite the decrease in the number of trips necessary to move the same amount of freight as is presently moved on the system. This scenario also included bridge impacts. The maximum cost assessed for bridge replacement was $0.2 million per year (for wheat). While the highest infrastructure cost of $0.46 million per year was a combined pavement and bridge cost calculated for the 58,100 kilogram (128,000 lb) scenario, other scenarios (notably the 36,300 kilogram (80,000 lb) scenario) had the highest infrastructure costs for approximately 50 percent of the case studies considered.

5.8.4 Changes in Trucking Costs

The percent change in trucking costs predicted for each scenario closely follow the percent change in the number of trips for each scenario. Differences between these values reflect, as appropriate, expected differences in operating costs and trip distances between vehicle configurations used in the various scenarios. The greatest changes in transportation costs were observed for the 36,300 kilogram (80,000 lb) scenario for all industries. Costs increased by 3 to 54 percent for this scenario, depending on the commodity involved. The greatest cost increases were expected for industries that currently use the heaviest trucks for most of their transportation operations (e.g., milk, sugar beets, talc, wood chips, cement). The lowest cost increases were predicted for industries that already extensively use trucks with GVWs at 36,300 kilograms (80,000 lbs) in their operations (e.g.,cattle, logging). These results are consistent with those obtained by other investigators. Based on information presented by Middendorf and Bronzini (1994), moving from Rocky Mountain Doubles operating at a maximum GVW of 52,200 kilograms (115,000 lbs) to single trailers operating at 36,300 kilograms (80,000 lbs) should have resulted in a 25 to 37 percent increase in transportation costs. Based on information presented in the Turner truck study performed by TRB (TRB 1990b), shifting bulk and high density goods from large combination Turner trucks to 5 axle tractor, semi-trailers should have resulted in a 7 to 47 percent increase in transportation costs, depending on the commodity and truck configurations involved.

Increases in transportation costs steadily declined, as would be expected, in moving from the 36,300 kilogram (80,000 lb) to the 39,900 and 47,900 kilogram (88,000 and 105,500 lb) scenarios. Transportation costs were typically predicted to decrease for all industries in the 58,100 kilogram (128,000 lb) scenario. Maximum savings in transportation costs of 4 to 10 percent were realized by industries that currently and exclusively use the largest trucks (e.g., milk, sugar beets, talc). Transportation cost savings expected in most industries, however, were in the range of 1 to 2 percent.

These various changes in transportation costs were also expressed in terms of absolute dollars of cost per year experienced by each industry. Naturally, expressed in this fashion, differences in transportation costs between industries reflect both differences in types of transportation activity (vehicle types and trip distances) as well as in the level of this activity (total number of trips). The largest cost increases were for the 36,300 kilogram (80,000 lb) scenario, and ranged from $1 to $7 million per year across the case studies. The only transportation cost reductions were predicted for the 58,100 kilogram (128,000 lb) scenario. Cost reductions up to $0.66 million per year were expected for this scenario across the various industries.

In general, the increased transportation costs cited above were an order of magnitude larger than the associated infrastructure costs for each scenario. This result reinforces the need to consider more than just infrastructure costs in investigating truck size and weight issues. Further note that for the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios considered in this study, not only did truck transportation costs increase, but infrastructure costs also generally increased.

5.8.5 Economic Implications of Changes in Transportation Costs

The significance and implications of changes in truck costs for any given industry are affected by several factors, including the percent of the value of the commodity related to truck transportation, the geographic market for the commodity, the level of competition in the industry, the current profitability of the industry, the relative elasticity of customer demand, etc. In some situations, based on these various factors, changes in costs can be passed on to the customer. Such a situation would exist, for example, if little competition existed and customer demand was inelastic, or alternatively, if all producers were faced with the same cost increase (say in one local geographic market), and customer demand was inelastic. In other instances, changes in costs must be absorbed by the producer (and thus become lost income). Such a situation would exist, for example, if customers could purchase the commodity in question from other producers that were not faced with price increases (say from an out-of-state source). If cost increases were too high to be absorbed internally, a producer could simply close down. Such an occurrence depends on the existing profit situation for the producer. Naturally, many situations fall between the two cases described above, that is, some part of a cost increase can be passed on the customer, while the remainder is absorbed by the producer.

The case studies conducted herein were divided into two groups with respect to assessing the types of outcomes listed above for each industry, namely, industries engaged in activities primarily related to products consumed in the state, and industries engaged in activities related to products that primarily are exported from the state. The first group was assumed to include sand and gravel, cement, retail food, and retail fuel. In these cases, the increased transportation costs under the various scenarios were judged more likely to be passed on to consumers in the state. To a large extent, suppliers of these products serve a local geographic market, and all the suppliers in the market would be faced with the same cost increases. Therefore, changes in costs in these areas were expected to be passed on to the consumer. Furthermore, the changes in transportation costs represented sufficiently small percentages of the value of the these products (maximum of 4 percent), that significant and immediate reduction in product demand were not expected to occur. These increased costs to the consumer would result in a net reduction in their disposable income, which would potentially have long term impacts on the state's economy (which would be addressed by the state-wide economic model). Note that to a certain extent, raw milk might also be placed in this category, although significant competition from out-of-state producers and potential elasticity in product demand could influence the ability of producers to pass costs on to consumers.

The second group of case studies, that is, industries involved in producing commodities primarily for export from the state, was assumed to include wheat, cattle, sugar beets, crude oil, talc, logging, and wood chips/liner board. The implications of transportation cost increases in these areas of economic activity are more difficult to predict than for those of the first group of case studies. In general, cost changes are more difficult to pass on to customers in these cases, as these producers compete in a national market place, and their competitors may not necessarily be faced with similar increases in costs. The alternative would be to absorb some or all of the increase in costs internally. This alternative is feasible if these costs are small relative to the value of the commodity. In the case of beef cattle, for example, increased transportation costs are estimated under the 36,300 kilogram (80,000 lb) scenario to amount to only 0.2 percent of the market value of the cattle. Thus, major changes in the cattle industry are not expected due to changes in maximum allowable GVW.

The situation is different, however, for items such as talc and wood chips/liner board, in which changes in costs associated with switching to a 36,300 kilogram (80,000 lb) maximum GVW were estimated to be around 3.5 percent of the product value. This cost is sufficiently high that producers of such commodities may be unable or unwilling to absorb it. Wheat and crude oil fall between the above two examples (with an estimated increase in the exported product cost of 0.7 percent). Impacts of the increases in transportation costs calculated for sugar beets and logging were even less definitively known. In the case of sugar beets, the cost of beets delivered to the processing plant were expected to increase by 2.7 percent under the 36,300 kilogram (80,000 lb) scenario. As the costs of the sugar beets were estimated to make up approximately 50 percent of the value of the sugar produced from them, sugar costs would increase by 1.3 percent. Once again, this cost increase is sufficiently high that the processing plants may be unable or unwilling to accept them. While log prices at the mill are expected to increase by 0.8 percent, the fraction of the value of finished timber made up by the raw log cost is unknown.

In general, cost impacts calculated in the 39,900 kilogram (88,000 lb) scenario were similar to those in the 36,300 kilogram (80,000 lb) scenario, and therefore would have similar economic implications to those reported above. Impacts in the 47,900 and 58,100 kilogram (105,500 and 128,000 lb) scenarios were smaller in magnitude than those determined for the 36,300 kilogram (80,000 lb) scenario, and their effects would be proportionally less. Note that the cost impacts in the 58,100 kilogram (128,000 lb) scenario were also typically determined to be cost savings. These savings, however were nominal in magnitude (typically less than 0.5 percent of the value of the commodity) and were not expected to dramatically stimulate economic activity.

5.8.6 Cases with Rail Diversion

In general, the simple rail diversions considered in this study yielded transportation costs similar in magnitude to trucking costs. The primary difference between scenarios with and without rail diversion was in the calculated change in infrastructure damage. Highway infrastructure costs were consistently and significantly lower if rail was involved in part of the freight movements ($0.04 per year increase, for example, without rail diversion, versus a $0.25 million per year savings, with rail involved in part of the movements).

6. STATEWIDE ECONOMIC IMPACTS

6.1 GENERAL REMARKS

The primary goal of this study was to estimate the statewide economic impacts of changes in allowable GVW regulations. Such impacts are the macroeconomic counterparts to the sectoral impacts demonstrated in the case studies of Chapter 5. The purpose of the statewide economic model was twofold. First, it provided a more comprehensive view of the impacts on the state's economy by considering all sectors, rather than selected sectors, as was done in the case studies. Although the sectors chosen for case study scrutiny were those thought to be important to the state's economy, thus representing the greater portion of impacts, running a statewide economic model insured that there was no bias in the guesswork of sectors chosen for consideration. Second, interdependencies exist among sectors of the economy. A judiciously chosen statewide model would be capable of estimating the indirect and induced effects that changes in GVW limits would have on all sectors of the state's economy through the sectoral interdependencies.

6.2 STATEWIDE ECONOMIC MODEL

6.2.1 Description

The statewide economic impacts were calculated using a model developed by Regional Economic Modeling, Inc. (REMI) of Amherst, Massachusetts (Treyz, 1993). They developed a model called the Economic and Demographic Forecasting and Simulation (EDFS) model which can be used to describe any regional economy in terms of 53 distinct industries (each, an aggregation of sub-industries). The region used in this study was the state of Montana. The philosophy underlying the EDFS model is that variations in how regional economies respond to a particular policy are due more to differences in the structure of the regional economies, than to differences in behavioral responses across regional economies. REMI uses data for the entire United States to estimate behavioral parameters, producing parameter estimates that are more reliable than those that might be estimated for the state of Montana alone. These parameters are then combined with data for the state economy to create a custom regional economic model. The calibrated model generates a comprehensive view of the state economy on an annual basis, and is used to forecast to the year 2035.

The EDFS model is run twice to estimate the economic impacts of a given policy change. The first run is a baseline forecast to 2035 with no policy changes implemented. The model outputs a set of variables describing the state economy, both in aggregate terms and in sectoral detail. Assumptions made about the U.S. economy (which are beyond the scope of this discussion; for example, the rate of inflation) drive year-to-year differences in the baseline forecast. The second run is a policy simulation, including inputs that characterize the policy change in question. This simulation includes as outputs the values of the very same set of variables describing the state economy as the baseline forecast. The economic impacts of the policy change are then determined by differences between the baseline forecast and policy scenario simulation, either in absolute or percentage change form.

A significant task in the process of running the model is identifying the appropriate policy input variables, as there are 1500 such input variables from which to choose. The appropriate set of policy inputs is the most compact set of inputs that fully characterizes the policy; at the same time, caution must be exercised so as to not include as policy inputs changes in variables not directly the result of the policy in question. That is, the results of model runs will describe the effects of the policy scenario if and only if all other variables are held constant. Variables expected to be affected indirectly by the policy scenarios should not be entered as policy inputs, but they rather should be generated as changes predicted by the model, or model outputs. For example, changes in truck weight limits may be expected to have an impact on sales in the lumber sector, but sales in lumber is a dependent variable (whose value should be predicted by the model) rather than an independent variable (whose value is entered as a policy input). As shall be demonstrated below, the production of lumber is affected through the cost of trucking lumber, and is the type of direct effect of the policy entered into the model that produces an affect on value added in lumber.

The basic structure of the model is shown in Figure 6.2.1-1 as five main blocks. Each block has equations, parameters and data that determine the value of certain internal variables based on external changes (policy inputs) that are dictated by the policy scenarios. The equations are based upon economic and accounting relationships specific to that block. For example, the value added in an industry must equal payments to all the factors of production (labor, capital, profits, etc.) in the output block, and the equilibrium wage rate will cause the quantity of labor demanded to be equal to the quantity of labor supplied in the wages, prices, and profits block. While there are not direct linkages between certain of the blocks in Figure 6.2.1-1, all of the blocks are interdependent in that they are solved simultaneously; changing a policy variable in the market shares block can have an effect on all variables in other blocks, whether directly (output) or indirectly (e.g., labor and capital demand).

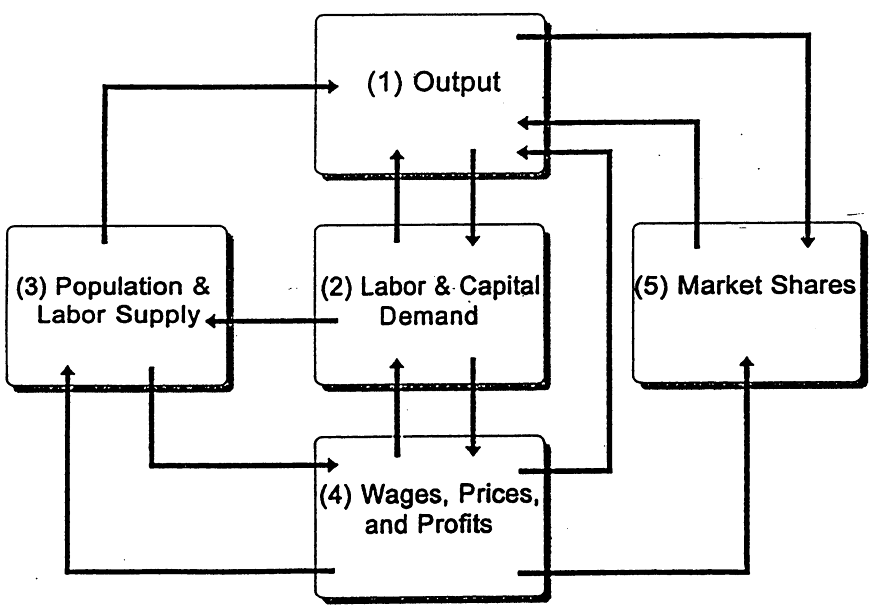


Figure 6.2.1-1 Structure of the REMI Model

To get an idea of how the EDFS model works, the blocks are briefly discussed in turn. In the output block, gross and net output of the regional (or local) economy are derived as the sum of the components of demand, where the components are determined by the economic agents purchasing the output: personal consumption (households), investment (businesses, households and government), government, and net exports (international and interstate). Personal consumption expenditures depend upon real income; investment depends upon relative factor prices and expected output; government demand is a function of local population. Each expenditure category is translated into industry-specific local output for local consumption. Labor and capital demand are determined by output (inputs necessary to produce outputs), and by relative costs of the factors of production via cost-minimization of a Cobb-Douglas production function. Labor demand is also calculated by occupation. The supply of labor depends upon population, which in turn depends upon economic migration (a function of expected income). Expected income is in turn determined by the probability of being employed, the real wage rate and the mix of industries. Non-economic migrations (retirement, military, and international) are also included in this block, as well as general demographic changes (birth and death rates by age and race cohorts).

The wages, prices and profits block is where the equilibrium wages, sales prices and profitability are calculated. There is a distinction made in this block between industries which are regional–selling more than 50 percent of their production in-state–and those which are national, where the distinction is determined for an industry using national averages over all states, rather than by how an industry operates in Montana alone. Note that in general, regional industries will sell some of their output outside the state and national industries will sell some of their input within the state. Liner board manufacturers are part of a national industry while retail food is a regional industry. Regional industries have locational advantage over competition from elsewhere, implying that their ability to pass on production cost increases in the form of higher prices is *greater* than that of a national industry (assuming the national industry is not a monopoly). If this point seems counterintuitive, it is perhaps due to associating national industries with firms having market power (perhaps through larger firm size). A more accurate view focuses on the competition firms face, rather than firm size itself. That is, production cost increases affecting a national industry in a region generally imply lower profitability for production in that region, as these industries must compete and sell at the national or world price in a national or world market. Regional industries face less competition from firms outside the region, and have more market power in terms of ability to pass cost increases on to their consumers. Whether national industries locate or remain in a state depends upon relative profitability. Thus, consumer prices in the state may differ from consumer prices at the national level, according to the proportion of GSP in regional versus national industries. In the market shares block, the proportion of local and external markets that are supplied by local production is calculated. Again, the distinction between regional and national industry is critical. Market shares are instrumental in determining how local production responds to a change in local demand.

The EDFS model is essentially an augmented input/output model (Leontief, 1986). A key component of the standard input-output model is the use table, which shows how an increase of $1 of output of one industry causes indirect increases in output of other industries that the first industry purchases intermediate inputs from (Miernyk, 1965). The use table begins from a square table with a row and a column for each industry or sector the economy is comprised of (e.g., a 53 × 53 matrix), with detailed data on industry purchases from other industries (columns). The square table is supplemented with rows and columns for other national income and product accounts data such that the table balances according to the national income accounting identities (e.g., output equals payments to factors of production, including profits). In adding these rows and columns, gross domestic product (GDP) for the U.S. appears as both a row total and a column total. The U.S. Department of Commerce periodically updates the input/output model of the U.S. economy, roughly every ten years (the current I/O table is for 1987). The relative infrequency is due to the massive data requirements, as the national economy is divided into 526 industries. REMI uses more aggregated sectors in the EDFS model to simplify the process of creating a regional model from a national one. The industries employed in the 53-industry version of the EDFS model are given in Table 6.2.1-1. REMI has also developed 14-sector and 214-sub-industry versions of the EDFS model. The 53-industry version includes trucking and warehousing as an industry. Although more costly to run, the 214-sub-industry version is no more disaggregate with respect to trucking. The 14-sector version contains trucking not separated from other industries in the transportation and public utilities sector.

The augmentation of the standard I/O model that comprises the EDFS model is the inclusion of the blocks in Figure 6.2.1-1 regarding population and labor supply; wages, prices and profits; and market shares. The market shares block deserves particular attention in this regard. There are two approaches to creating an input/output model of a regional economy. The first is the survey method that is used to produce the U.S. model, but is prohibitively expensive for regional modeling. The second approach, called the nonsurvey method, involves modifying the I/O table for the U.S. so that it is representative of a regional economy. There is a significant literature on nonsurvey methods, including the regional purchase coefficient method that is the basis of the market shares block of REMI's EDFS model (Polenske, 1980; Miller and Blair, 1985; Crihfield and Campbell, 1991). The regional purchase coefficient method is particularly useful when the policy being modeled implies changes in the sectoral structure of the regional economy by affecting various sectors differently. Changes in truck weight limits were anticipated to be precisely this kind of policy change.

6.2.2 Discussion of Model Inputs

It was important in choosing the policy inputs for the EDFS model to fully characterize the policy scenarios. Although it may be reasonable to suggest that additional impacts could result from truck weight limit changes, two distinct effects required attention in each scenario: physical and economic effects. First, changes in infrastructure impacts in each scenario were expected to have an effect on state and local government spending on road construction. This additional spending could occur without a budget-balancing revenue increase, because truck user fee and gas tax revenue would implicitly generate the revenue to cover any change in this spending level. This assumption may not be precisely true, but was reasonable in the absence of the detailed data necessary to show how user fee and gas tax revenue might have differed. Even if more detailed revenue calculations were undertaken as a part of this study, it would not necessarily be representative of realistic changes in road maintenance expenditures. In light of the level of infrastructure costs calculated, the potential for significantly different results from a different version of this assumption was quite limited.

Second, the economic effect of the reconfigured traffic streams in each scenario required attention. That is, while the new traffic streams were used to generate the infrastructure costs in

Table 6.2.1-1 Sectors in REMI's 53 Sector EDFS Model (page 1 of 2)

Major Sector (4 total)	Sub Sector (14 total)	Industries (53 total)
Manufacturing	Durable Goods	Lumber and wood products Furniture and fixtures Stone, clay and glass products Primary metal industries Fabricated metal products Machinery and computer equipment Electronic equipment, except computer equipment Motor vehicles and equipment Transportation equipment excluding motor vehicles Instruments and related products Miscellaneous manufacturing industries
	Nondurable Goods	Food and kindred products Tobacco products Textile mill products Apparel and other textile products Paper and allied products Printing and publishing Chemicals and allied products Petroleum and coal products Rubber and miscellaneous plastics products Leather and leather products
Nonmanufacturing	Mining	Mining
	Construction	Construction
	Transportation and Public Utilities (T & PU)	Railroad transportation Trucking and warehousing Local and interurban passenger transit Transportation by air Other transportation and transportation services Communications Electric, gas, and sanitary services

Table 6.2.1-1 Sectors in REMI's 53 Sector EDFS Model (page 2 of 2)

Sector	Area	Industry
	Finance, Insurance, and Real Estate (FIRE)	Depository and non-depository credit institutions Insurance carriers, agents, brokers, and services Security and commodity brokers and investment services Real estate
	Retail Trade	Eating and drinking places Other retail trade
	Wholesale Trade	Wholesale trade
	Services	Hotels and other lodging places Personal and miscellaneous repair services Private household services Auto repair, services and parking Business services Amusement and recreation services Motion pictures Health services Legal, engineering and management, and miscellaneous services Educational services Social services, membership organizations, and museums, etc.
	Agricultural Services, Forestry, Fisheries, and Other	Agricultural services, forestry, fisheries, and other
Government	State and Local	State and local
	Federal, Civilian	Federal, civilian
	Federal, Military	Federal, military
Farm	Farm	Farm

Chapter 4, these costs represented only the physical effects associated with changing truck weight limits. The economic effects can be characterized as the additional (reduced) costs associated with hauling the same cargo via more (fewer) truck trips. That is, additional (fewer) resources would be required to produce a similar level of transportation services, implying lower (higher) productivity. These production costs would be real, and they would have to be borne by either producers, consumers or both, unless these parties collectively decided via trade decisions to produce, ship and consume less cargo with the same number of trips and same total transportation costs as prior to the change in weight limits. However, such changes in behavior would be driven by changes in prices and profitability, which were precisely the kind of predicted effects the model solves for and reports as results. The economic effects of changing truck weight limits affected the 53 industries in one of two distinct ways, leading to the economic direct effects entered into the model as inputs. First, the 49 private nonfarm sectors were affected via the production process. The farm sector effect was modeled via net farm income, a concept closely related to value added in the farm sector. The government sectors (federal civilian, military, and state and local government) were assumed to be unaffected, except indirectly.

In the analysis to follow, the impact of changes in allowable GVW on the 49 private nonfarm sectors was handled as a change in productivity. The production process of the 49 private nonfarm sectors could have been altered in one of two ways to reflect the changes in conditions in each GVW scenario. First, an increase (decrease) in the number of trips required to transport the same cargo could have been considered to be an increase (decrease) in the costs of production associated with trucking. Alternatively, an increase (decrease) in the number of trips required to transport the same cargo could have been considered to be a decrease (increase) in productivity. The latter approach was believed to be most appropriate for this study. An increase in production costs would reduce the profitability of national industries (relative to those outside the state), while increasing sales prices for regional industries. Reduced profitability would have the effect of reducing the share of local consumption that was locally produced, as well as the state's share of out-of-state (and international) markets, while increased sales prices for regional industries would increase local consumer prices. As the state's share of the local and external markets decreased, local output would fall, *ceteris paribus*. As local consumer prices rose, real disposable income would fall, and in turn, consumption would fall, having a further dampening effect on output. As output of the state fell, so too would employment. Note however, that this line of reasoning would apply to all affected industries, including trucking. However, it was expected that employment in the trucking sector would increase, at least in the short run, as lower weight limits would require more truck trips and higher levels of employment in the trucking sector. In this case, a more complete view of the economic impact would require separately estimating the increase in employment in the trucking industry–an effect which one would expect to occur endogenously as a result of the policy inputs.

Viewing an increase in truck trips as a decrease in productivity resulted in additional economic impacts. The reduction in productivity would require more employees per dollar of value added in an industry–and consequent adjustments in capital in the industry–such that employment would increase if industry output were held constant. Of course, output was not held constant. The reduction in productivity had a similar effect on costs of production, as above, which in turn reduced output. Thus, there are counteracting effects on employment: lower productivity increases employment, while lower output (from lower profitability or higher prices) decreases employment. The magnitude of these opposing effects determined whether the net effect was growth or decline for each industry. Also, entering the effects of changing truck weight limits as a change in productivity allowed the direction of change to differ by industry, and allowed the model to determine the impacts objectively. Note that this approach did not require separate estimation of the employment effects in the trucking sector, but produced them as the result of running the model. Because the range of possible results would be much richer in taking the productivity approach, it was deemed to be the more correct approach and hence, the approach employed.

The farm sector could not be treated in the same fashion as the 49 private nonfarm sectors because the US Department of Commerce does not have the detailed information necessary to include the farm sector as an industry in the US input/output table. Thus, the farm sector could not be separately represented in a regional model of the Montana economy. The impacts of changing truck weight limits on the farm sector had to enter the model in some fashion other than a decrease in productivity. However, it was deemed to be prudent to derive the impacts on the farm sector from the same basis as that used for the 49 nonfarm sectors, that is, using a change in productivity due to changing truck weight limits. Because the farm sector was comprised of many small producers relative to the market, farmers were thought of as price takers with respect to the price they sell their output for. Thus, a decrease in productivity would lead to an increase in the farmer's production costs, which in turn would result in lower net farm income.

Value added in the farm sector is defined as the total value of agricultural output, less intermediate consumption outlays (e.g., feed used on farm), plus net government transactions (farm program payments less taxes), less capital consumption (depreciation). Net farm income is derived from value added by subtracting payments to factors of production, that is, employee compensation, land rent, and interest paid (Economic Research Service, 1997b). Farm transportation expenses are included in the intermediate consumption outlays category of value added, although trucking expenses alone are not separately accounted for. Thus, an increase of \$1 in trucking costs, translates into a \$1 decrease in both value added and net farm income. As shall be seen below, limitations on data available for the agricultural sector implied that a change in trucking costs in the sector could not be used to produce separate predictions for changes in net farm income and value added. The effects were seen through net farm income, which was referred to in the EDFS model as labor and proprietor's income in the farm sector.

6.2.3 Derivation of Model Inputs

Having determined how the GVW policy scenarios enter the statewide economic model, attention was turned to the derivation of the specific input values. First, the change in infrastructure costs was calculated (see Chapter 4). This effect was entered into the EDFS model via a change in state and local government spending on highways (translator variable 342), which is, in the parlance of input/output analysis, a change in final demand for this commodity. The effect was measured in nominal dollar units.

Second, the change in net farm income was derived. This effect was entered into the EDFS model via a change in proprietors' and other labor income for the farm sector (policy variable 1309). The effect was measured in nominal dollar units. The value used to change proprietors' income for the farm sector was derived from the net farm income changes determined in the case studies. Case studies were conducted for beef cattle, dairy, wheat and sugar beets, which comprise 80 percent of cash receipts from farm marketings. The case study for wheat was extended to barley, another important crop that would extend the coverage of cash receipts from farm marketings to 87 percent. The change in net farm income from barley due to changing truck weight limits was estimated by applying the same percent change in net farm income in wheat to barley. The changes in net farm income from these five commodities were summed to calculate the change in proprietors' income. This estimate potentially understates the impact on the agricultural sector, in that roughly14 percent of marketed commodities were not represented. However, the determination of commodities for which to conduct additional case studies was based on the degree to which shipments occur at vehicular weights affected by the changes under study. Thus the agricultural commodities most affected are included, with the possible exception of hay. In this sense, more than 86 percent of the impact on the farm sector may well have been included. Several estimates of 100 percent of the change in farm proprietors' income were calculated. These estimates produced changes that were from $0.5 to $1.8 million greater than the estimate used for the 36,300 kilogram (80,000 lb) scenario (which consisted of a loss of $11.56 million per year). That these estimates do not differ dramatically implied that a conservative approach was to consider only those changes in net farm income that had been estimated via case study.

Finally the change in factor productivity for the 49 private nonfarm sectors was determined. The changes in productivity were derived using data from two sources, with different industry definitions, hence requiring a matching up of industry definitions for input calculations. The two data sources were TIUS (U.S. Department of Commerce, 1995), conducted in conjunction with the quinquennial Census of Transportation, and the Transportation Satellite Accounts (TSA), developed jointly by the Bureau of Transportation Statistics and the Bureau of Economic Analysis (Fang et al., 1998). The TIUS data provided information on trucks registered in Montana, giving the joint distribution of products carried and operating weights.

The TSA is a satellite account to the U.S. input/output table. The standard I/O use table shows how the value of an industry's output is allocated as payment to factors of production, where intermediate inputs purchased are broken out by the industry providing them. One factor of production often purchased is transportation services, whether via the mode of rail, truck, air, water, pipeline, or other. Although the I/O use table has long broken out expenditures on for-hire transportation services by modal industry, it has treated the value of firms' in-house transportation expenditures as a purchase of inputs from their own industry, thus understating the importance of the transportation industries. As firms which undertake transportation expenditures in-house for their own account are more likely to have trucking operations, the I/O table entries for trucking understate the importance of trucking in the U.S. economy.

The TSA shows a more comprehensive view of expenditures on transportation, by including separate entries for own-account transportation. This breakdown is particularly useful in I/O analysis of any policy which may involve firms deciding to contract out transportation services previously undertaken in-house, or vice versa. Using the standard I/O tables, a firm's decision to contract out its trucking activity would result in an increase in the output of the trucking industry, whereas with the TSA supplementing the I/O table, no change in trucking output is observed. The TSA table of commodity-by-industry direct requirements shows the expenditures per dollar of industry output on both motor freight and own-account transportation. By assuming that own-account transportation is chiefly by truck mode, information was thus available on how trucking expenditures per dollar of output vary by industry (other possibilities for own-account expenditures include bus operations, wherein employees are transported from the site they report for duty at to another site to work, as sometimes occurs in large construction projects). Although this information was available only at the national level, it was the only source of industry variation in trucking expenditures on a consistently measured basis.

In the TSA industry definitions, there were 101 industries in the private sector, and these had to be matched to the 23 nonservice sectors of the EDFS model. For example, the EDFS sector, Petroleum Products, was comprised of the I/O sectors for crude petroleum and natural gas, and petroleum refining and related products. The trucking expenditures per dollar of industry output for the EDFS sectors were calculated as the weighted average of the appropriate I/O industries, where the weights were the total output by industry. An implicit assumption involved in using this information was that if Montana firms are different from their overall industry in the U.S. with respect to expenditures on trucking, such differences occur in a random rather than a systematic fashion.

The TIUS data gave the joint distribution of products carried by trucks and the operating weights of these trucks. An algorithm similar to that described in Chapter 3 (in particular, section 3.2.3) was employed to generate the percent increase (decrease) in truck trips required to carry the same cargo of a particular commodity, given the configuration of trucks the commodity was carried on. The only distinction here (versus the analysis performed in Chapter 3) was that the diverting algorithm was applied on a commodity-by-commodity basis. The cargo on each affected truck was diverted to another truck configuration, and the results by truck configuration were combined to produce an overall change in truck trips by commodity. Information on 23 commodity categories was then matched to the 23 nonservice sectors of the private nonfarm economy, though the matching was not a one-to-one matching. For example, in the EDFS model, paper and printing were separate industries, while in TIUS both were part of the paper products industry. The TIUS data was thus applied to both the paper and printing industry in the EDFS model.

Note that the TIUS vehicle configuration and commodity-carried data used in these analyses were for vehicles *registered* in Montana, as previously mentioned. However, the most appropriate data for this study would be configuration and commodity-carried data for trucks *operating* in Montana. This type of information is not systematically collected, nor is it possible to determine such information from data that are available (such information, for example, cannot be obtained from the results of the Commodity Flow Survey (BTS, 1996)). Only gross estimates of geographical area of vehicle operation can be made from data available in TIUS. Thus, the vehicle fleet represented in the Montana TIUS data may not precisely match the fleet of vehicles that actually operates on Montana's highways. In this case, heavy trucks may be proportionally under represented in the registered fleet relative to the actual fleet operating in Montana. Vehicles that are registered in Montana that are used to haul commodities outside of the state will operate at lower weights than vehicles that are operating exclusively within Montana. These lower weight out-of-state trips serve to lower the apparent average operating weight of the vehicles used to haul a given commodity. Correspondingly, when the TIUS data is used to represent the situation in Montana, the operating fleet appears to include more light vehicles (which would be less affected in moving to a reduced GVW scenario) than actually operate on Montana's highways. Thus, changes predicted in vehicle operations for a given commodity from the TIUS data could be understated for the reduced GVW scenarios.

Consistent with the above described situation, the productivity changes estimated in the case studies were consistently greater than those estimated from the TIUS data for the same industries. The TIUS data, however, was expected to more comprehensively represent complete sectors of the economy compared to the specific industries analyzed in the case studies. Therefore, the decision was made to proceed with the TIUS-based productivity changes in formulating inputs for the statewide economic model. The expected conservative nature of the TIUS-based projections of changes in trucking operations was offset, to some extent, by subsequently directly using these changes in truck trips as changes in productivity (independent of any possible differences in operating costs between vehicles used in each scenario).

In any event, the change in trucking productivity was combined with the fraction of production costs associated with trucking (for-hire and own-account) to produce an overall productivity change. The TIUS data covered for-hire and own-account trucking, so that combining these two data sources was quite reasonable. The inputs to the EDFS model relating to the four truck weight limit scenarios are shown in Table 6.2.3-1. Although there were 49 private nonfarm sectors in the EDFS model, only 24 sectors are shown in Table 6.2.3-1 as having changes in productivity. The other sectors are service sectors that do not employ the heavier vehicles that were affected by changing truck weight limits and were faced with no direct productivity effects. Note that some of the sectors listed are not very large sectors of the state's economy; when a sector was not large, the impact on the state's economy of affecting that sector would be smaller than when a larger sector was similarly affected. All sectors are shown for completeness.

6.3 RESULTS OF THE STATEWIDE ECONOMIC MODEL

6.3.1 General Remarks

As was described earlier, analyzing the GVW policies involved comparing the runs of the EDFS model done for each GVW scenario to the baseline run of the EDFS model. In the discussion of results to follow, efforts were made to abstract the results from the baseline forecast, by focusing on changes relative to the baseline. Thus, a statement such as "output fell" implies not that output fell in an absolute sense, only that it fell relative to the baseline forecast. Indeed, output under the baseline and 36,300 kilogram (80,000 lb) scenario could both have risen. Even so, output was lost in the sense that it was potential output that was not realized.

The inputs introduced to the EDFS model took effect beginning in 1999 and occurred every year thereafter as well, as they represented permanent rather than transitory changes. The EDFS model produced a forecast of the state's economy for each year through 2035. Caution should be exercised in interpreting the values forecast that far into the future. Were any of these scenarios to actually become policy, firms–particularly trucking firms–would likely find innovative ways to improve their productivity. Short of anticipating these innovations, or at least their time trend, they could not be incorporated as inputs (including magnitude and direction as well as timing) in the EDFS model. It is, however, safe to say that by 2035, some sort of productivity enhancing innovation would occur. Thus, the more distant the time frame, the more caution that should be exercised in interpreting the results. None the less, results are presented out to the year 2035 in what follows, as they are illustrative of underlying economic trends.

In the following sections, the results of the 36,300 kilogram (80,000 lb) scenario are presented in some detail, with a subsequent comparison and discussion of the results of all four scenarios. The 36,300 kilogram (80,000 lb) scenario was chosen for detailed focus because the input values were greatest in magnitude for that scenario. As such, it represented the scenario

Table 6.2.3-1 Exogenous Policy Inputs for EDFS Model

Sector/Demand	Variable ID	Scenario: 36,300 kg (80,000 lb)	39,900 kg (88,000 lb)	47,900 kg (105,500 lb)	58,100 kg (128,000 lb)
		Millions $			
Farm	1309	-11.560	-10.780	-5.335	1.014
State and local highways	673	1.51	0.85	-0.58	1.61
		Percent Change in Productivity[a]			
Lumber	1001	-0.139811	-0.125017	-0.000574	0.117830
Furniture	1002	-0.074126	-0.071513	-0.003146	0.128981
Stone, clay, glass	1003	-0.583243	-0.568921	-0.008246	0.051764
Primary metals	1004	-0.037638	-0.037440	0.000000	0.149774
Fabricated metals	1005	-0.010201	-0.007638	-0.000344	0.086506
Non-electrical machinery	1006	-0.202031	-0.145051	-0.007274	0.033713
Electrical equipment	1007	-0.092362	-0.066292	-0.003322	0.015393
Motor vehicles	1008	-0.276764	-0.228860	-0.055925	0.032425
Rest of transport equipment	1009	-0.125389	-0.103658	-0.025306	0.014665
Instruments	1010	0.000000	0.000000	0.000000	0.000982
Miscellaneous manufacturing	1011	-0.083925	-0.083925	0.000000	0.049333
Food	1012	-0.170758	-0.153561	-0.002749	0.082559
Tobacco	1013	-0.035217	-0.031666	-0.000566	0.016993
Textiles	1014	-0.049366	-0.048472	0.000000	0.043105
Apparel	1015	-0.040505	-0.039771	0.000000	0.035361
Paper	1016	-0.500063	-0.477304	0.000000	0.097398
Printing	1017	-0.298236	-0.284636	0.000000	0.057948
Chemicals	1018	-0.272997	-0.270174	-0.007913	0.016862
Petroleum Products	1019	-0.207995	-0.188831	-0.011967	0.004118
Rubber	1020	-0.127307	-0.127307	0.000000	0.081102
Leather	1021	0.000000	0.000000	0.000000	0.000000
Mining	1022	-1.226032	-1.005483	-0.018551	0.160573
Construction	1023	-0.604795	-0.589947	-0.008552	0.053689
Trucking	1025	-6.385210	-5.648058	-0.103998	1.169934

[a] negative values are a reduction in productivity; positive values, an increase in productivity

where industry differences were likely to be the greatest, and therefore the most interesting scenario for which to consider industry breakdowns.

Each model run produced over 3200 variables (the large number of variables was due in part to the reporting of many concepts at the industry level). Direct discussion is presented for relatively few of these variables in this analysis. Particular attention was given to three main categories of economic variables: output, employment and income.

Before introducing the results of these calculations, it may be useful to provide some benchmark values for the state's economy. The 1996 level of Montana's real GSP was $20.6 billion, projected to rise to $20.9 billion in 1997 and $21.3 billion in 1998, all in 1992 dollars. Employment in 1996 was 503 thousand, projected to be 508 thousand in 1997 and 513 thousand in 1998. Real disposable income in 1992 dollars was $15.5 billion in 1997, projected to rise to $16.0 billion in 1997 and to $16.3 billion in 1998. Population in 1996 was 868 thousand, projected to decline slightly to 867 thousand for 1997 and 1998.

Gross state product (GSP) is defined as the total value added in production in the state. In this sense, it is a net concept–total output net of input purchases, with the adjective "net" implied in the phrase value added. Gross state product may be exceeded by some of the other economic concepts produced by the model that are expressed in gross terms (e.g., exports). As many inputs used in local production are purchased from outside the region, it is appropriate to look at GSP for analyzing impacts of a regional policy. The terms output, local output, value added, and GSP are used synonymously below.

6.3.2 Results for the 36,300 Kilogram (80,000 lb) Scenario

6.3.2.1 Overall Effects - Output was predicted to decline for the scenario with an 36,300 kilogram (80,000 lb) GVW limit. That is, although there were increased state and local road construction demands, these increases were not large enough to compensate for the reduction in output due to decreased productivity and lower net farm income. The impacts of reduced productivity resulted in unequivocally lower profitability for national industries and higher prices for regional industries, direct effects that served to diminish output (even if the impact on employment alluded to in section 6.2.2 is uncertain). Lower net farm income resulted in lower consumption for those households, placing a further damper on output produced for local consumption. Indeed, Figure 6.3.2-1 shows–in real 1992 dollar changes–the results for output by broad sector, which declined relative to the baseline beginning in the first year (1999) of the 36,300 kilogram (80,000 lb) weight limit. The decline in GSP grew in magnitude with time. Figure 6.3.2-2 shows the same GSP changes in percentage units. The $21 million decline in GSP in 1999 was a 0.1% decrease. As the long run shows, although the dollars of lost GDP grew in magnitude, the percentage change in GDP approached 0.5%. Even though these dollars are in real terms, caution should be exercised in adding up values across years; the annual values should be discounted using a real interest rate if cumulative effects are to be expressed. Using a 4% real discount rate, the 17-year cumulative effects reached $1 billion in 1992 dollars, approaching $2 billion in 35 years.

As alluded to above, a reduction in productivity in trucking (not just the trucking sector) might have been expected to result in a short run increase in employment in the trucking industry, as the increase in truck trips required to ship the same amount of cargo would likely require more truck drivers. Over time, as firms adjusted to the 36,300 kilogram (80,000 lb) weight limit, employment in trucking was expected to fall off. Employment in other industries

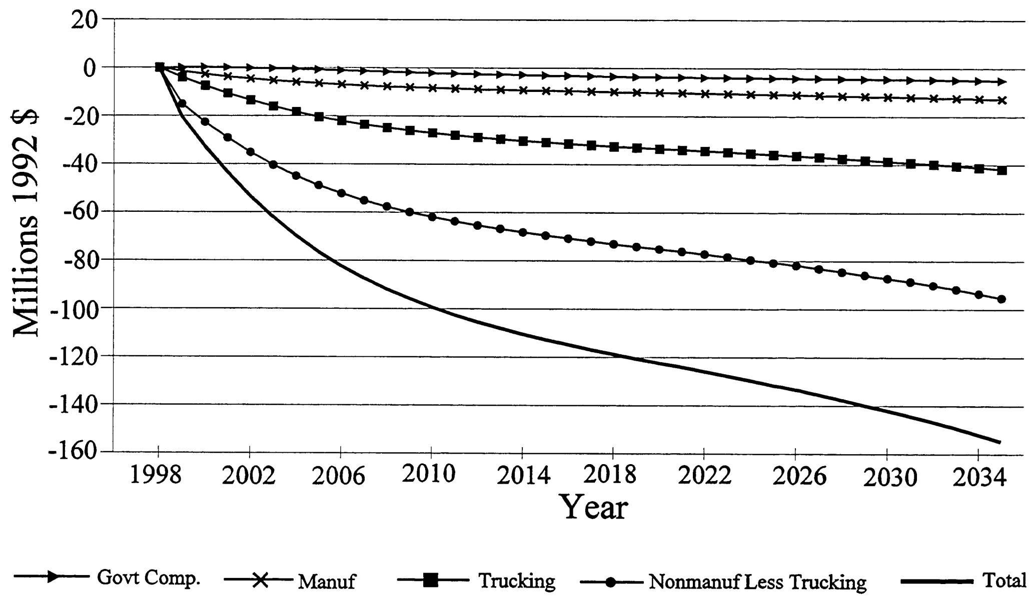


Figure 6.3.2-1 Change in GSP (Value Added) by Sector, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Dollars

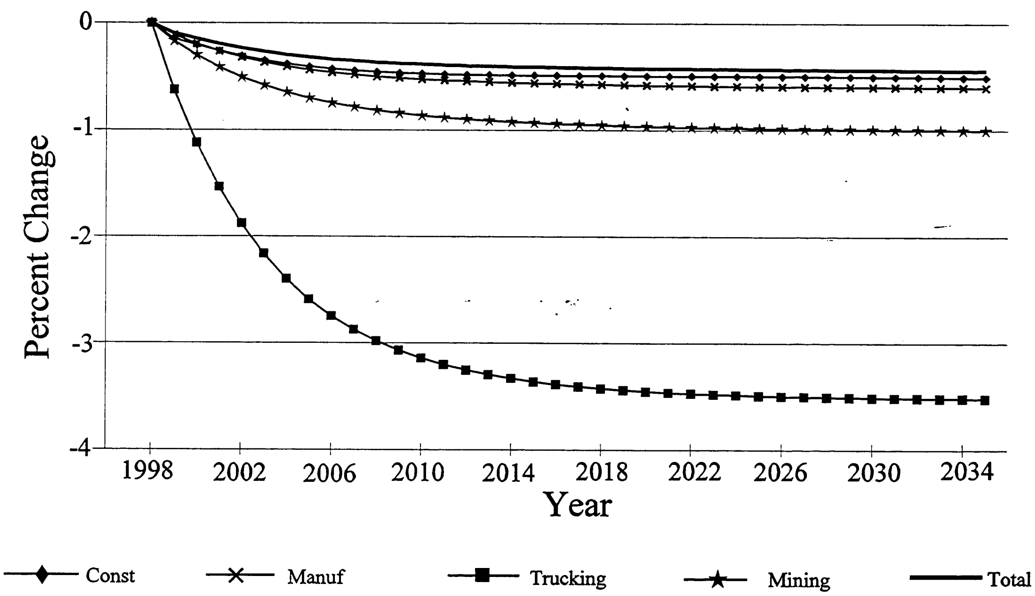


Figure 6.3.2-2 Percent Change in GSP (Value Added) by Sector, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline

may well decline from the outset of the policy if the decline in output outweighs the increase in employees per dollar of output resulting from lower productivity. While the magnitude of these opposing effects determined the net effect, changes in employment in trucking were not expected to completely dominate changes in all other sectors. The total employment for the state predicted by the EDFS model was in concert with these anticipations as shown in Figure 6.3.2-3; total employment rose relative to the baseline through 2001, whereupon total employment began to decline relative to the baseline, with the decline growing larger in time. In percentage terms, as shown in Figure 6.3.2-4, the change was not great: even in the out years, the percent change in total jobs was a decline of 0.2%.

The effect on income is a combination of the effects on output and employment noted above. Output must equal payments to factors of production, the largest of which is payments to labor, which is likewise the largest component of income; income would be expected to vary directly with output, *ceteris paribus*. At the same time, income would vary directly with employment, *ceteris paribus*. However, employment rose in the short run before falling, while output declined, as noted, and so the impact on income was unclear *a priori*. Personal income, defined as wage and salary income plus proprietors' income plus nonlabor income (*e.g.*, interest income) corrected for place of residence, rose through the year 2002 (although the increase was very small in 2002), declining relative to the baseline thereafter. Disposable income (personal income less taxes) followed a similar pattern, although the magnitudes of change were slightly smaller than for personal income. However, as the personal consumption expenditure price index (analogous to the more familiar Consumer Price Index, or CPI) rose, and rose by a greater proportion, real disposable income, as shown in Figure 6.3.2-5, fell relative to the baseline by 21 million dollars in the first year of imposing the 36,300 kilogram (80,000 lb) truck weight limit, continuing to decline thereafter. The first year decrease was 0.13 percent. Real disposable personal income also fell when viewed on a per capita basis.

Another variable of interest is population. Population in the state was predicted to rise slightly through 2001, and to decline thereafter, as shown in Figure 6.3.2-6, with the reduction reaching one thousand persons by 2010. Population is a function of economic migration (people moving to the state if economic conditions are good and vice-versa), as well as general demographic trends regarding births and deaths. In large part, the decline in population observed was driven by economic migration which was positive for two years, then negative thereafter. Although the migration out of the state peaked in 2005 at 130 persons, the ultimate impact on state population was much greater in that the migratory effects cumulate, as well as affecting the level of births in the state.

6.3.2.2 Sectoral Effects - The EDFS model was based on 53 sectors, of which trucking and warehousing was its own sector. The trucking sector is considered separately in the following discussions, as appropriate. Presenting detail on all 52 sectors was judged to be of nominal value, and so other sectors were aggregated in the following discussion into either 14 or 4 broad sectors, as described in Table 6.2.1-1. Trucking and warehousing is part of transportation and public utilities (T&PU) in the 14-sector aggregation, which is in turn a part of nonmanufacturing in the 4-sector aggregation (manufacturing, government and farm are the other three sectors). When trucking is isolated, trucking effects have been subtracted from the large sector it is a part of, as in T&PU less trucking or nonmanufacturing less trucking. In a few cases, variables were not estimated at the 53-sector level of detail, but only at the 14-sector level, such that trucking

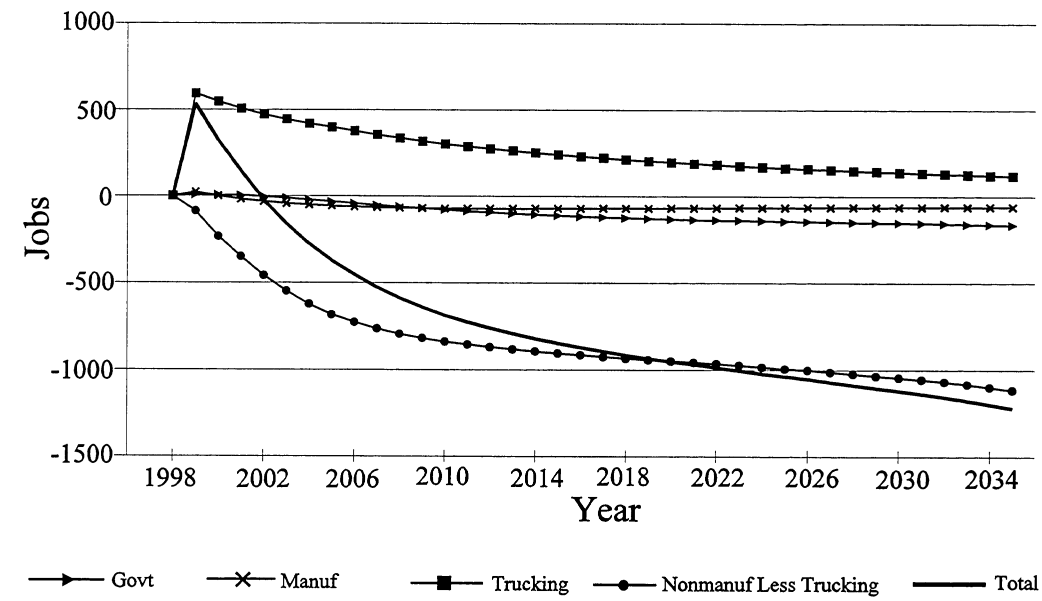


Figure 6.3.2-3 Change in Non-farm Employment by Sector, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Jobs

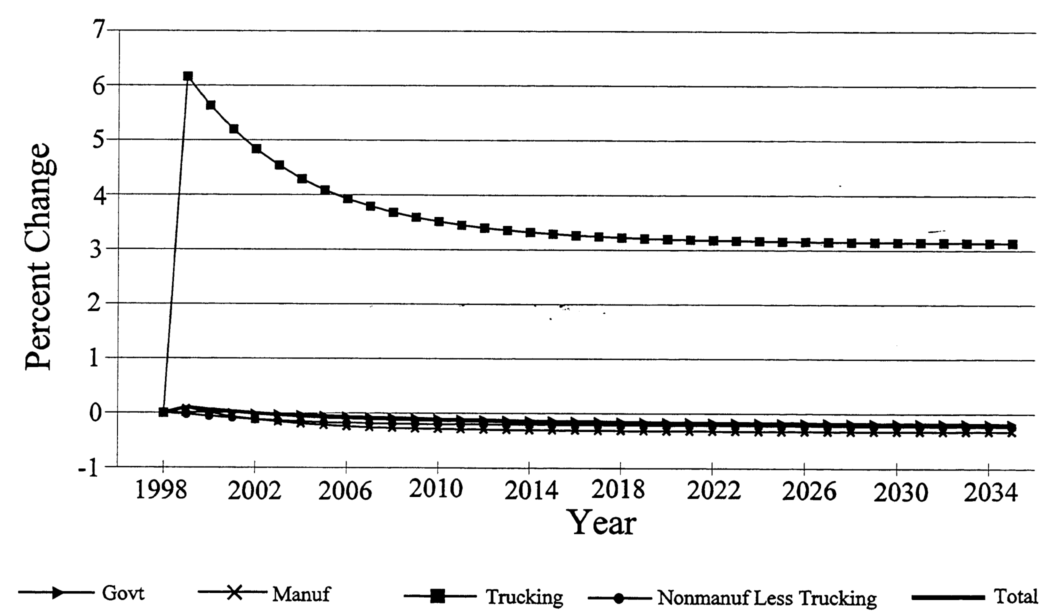


Figure 6.3.2-4 Percent Change in Non-farm Employment by Sector, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline

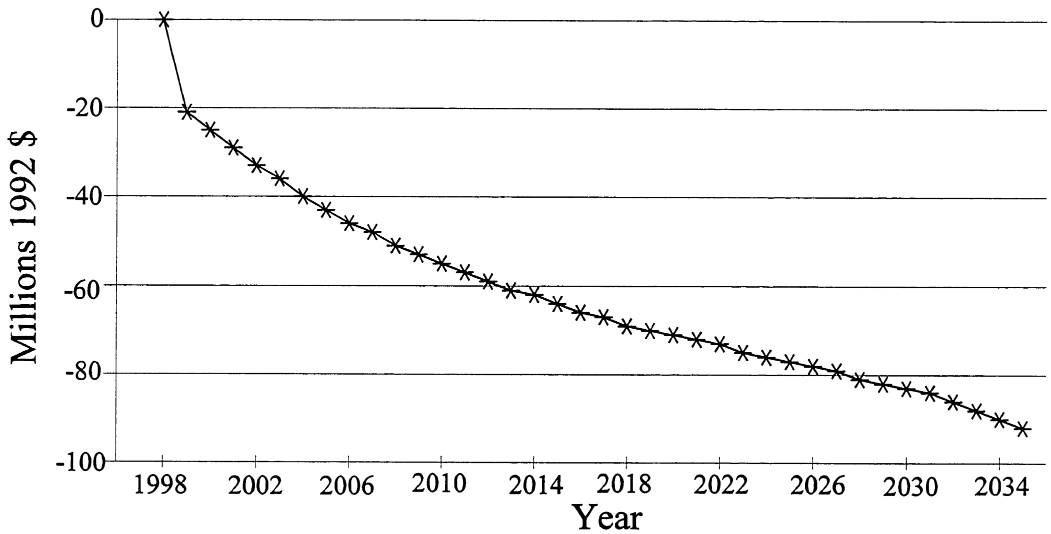


Figure 6.3.2-5 Change in Real Disposable Personal Income, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Dollars

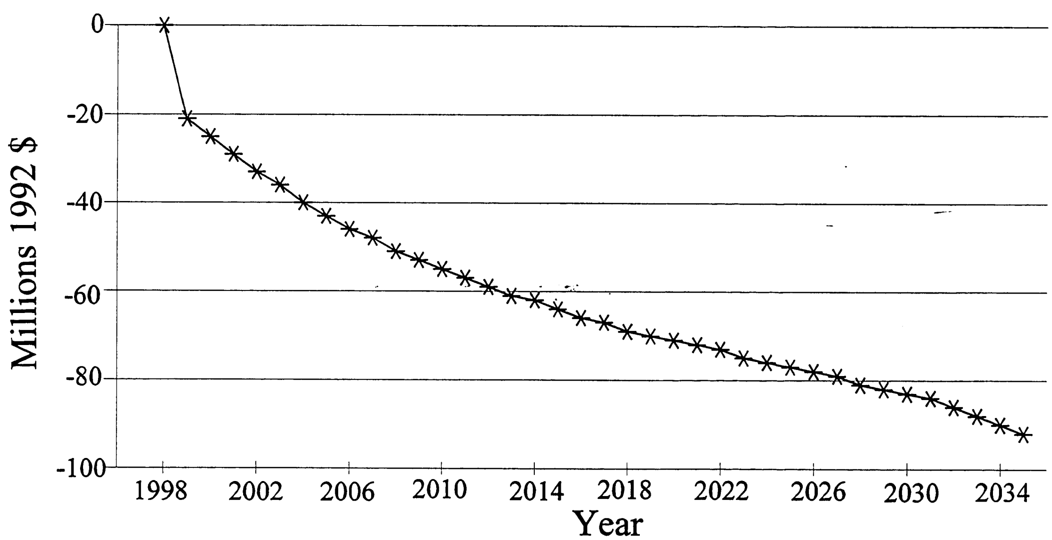


Figure 6.3.2-6 Change in Population, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Number of People

cannot be isolated. In these cases, T&PU and nonmanufacturing less T&PU are shown as separate sectors.

Some detail regarding sectoral response to the imposition of an 36,300 kilogram (80,000 lb) GVW is presented in Figures 6.3.2-1 through 6.3.2-4 above. The magnitude of indirect and induced effects can be noted in Figure 6.3.2-1, where the most affected sector in dollar terms is the nonmanufacturing less trucking sector, due in large part to the size of this sector, including services as it does. As presented in percentage terms in Figure 6.3.2-2, mining was the most affected sector after trucking, with manufacturing and construction representing the other two sectors with changes of magnitude greater than the total effect. The indirect and induced effects can also be seen in the nonmanufacturing less trucking sector in employment in Figure 6.3.2-3.

Although the increase in trucking sector employment was positive throughout, after 2002 the impacts on the nonmanufacturing less trucking sector were alone enough for the employment impact of the 36,300 kilogram (80,000 lb) weight limit to be negative. In percentage terms in Figure 6.3.2-4, the trucking sector was most affected, where the initial increase in trucking jobs of 6.2 percent mainly reflected the 6.4 percent decrease in productivity.

Labor and proprietors' income is shown in Figures 6.3.2-7 and 6.3.2-8. Recall that labor and proprietors' income includes all labor related income, not adjusted by interest income, or taxes. It is expressed in nominal dollars, and shows patterns somewhat similar to those of employment. Referring to Figure 6.3.2-7, income rose and then fell in dollar terms, as does employment in terms of number of jobs in Figure 6.3.2-3; note that although the year-to-year change in jobs (indicated by the slopes of the curves in Figure 6.3.2-3) became less significant with the passage of time, the same is not true for the year-to-year decline in income, which increases with time. The T&PU sector is the only sector in which income rose; it is fairly reasonable to conclude that the trucking portion of T&PU drove this result, as employment in the non-trucking industries in T&PU changed very little and average wages for the T&PU sector declined (see Figure 6.3.2-9). Again, the nonmanufacturing less T&PU (generally, services) sector was the most affected in terms of lost income, although the farm sector now enters the picture. Decline in the farm sector began with a loss in income of $9.8 million in 1999. This value is smaller in magnitude than the $11.6 million decline in farm income used in the model inputs. This difference is due to the fact that the $11.6 million decline is based on all other things being constant. This of course will not be the case, as the EDFS model had other inputs and solved for the changes in economic variables on the basis of behavioral and accounting relationships with all other things not held constant. The decline in farm income continued over time.

Figure 6.3.2-8 resembles Figure 6.3.2-4, with the exception that the farm sector is shown on the former (it cannot be shown on the latter, as the farm sector isn't modeled in the EDFS model in the same fashion as the manufacturing and nonmanufacturing industries). In percentage terms, the gains in the T&PU sector (again, mainly due to gains in trucking income) were at the expense of lost income in the farming sector. Furthermore, although T&PU income rose as much as 1.75 percent in the first year, the gains thereafter diminished towards 0.4 percent, while the farming sector lost 2.84 percent of income in the first year, with the losses remaining in the range from -3.0 to -3.3 percent from 2002 and beyond.

All of the impacts discussed thus far have been macroeconomic impacts, that is, the sum total effect for the state's economy. The impact on individuals was also important, and the chief effect was via average annual wages. Figure 6.3.2-9 shows the trend of average annual wages in

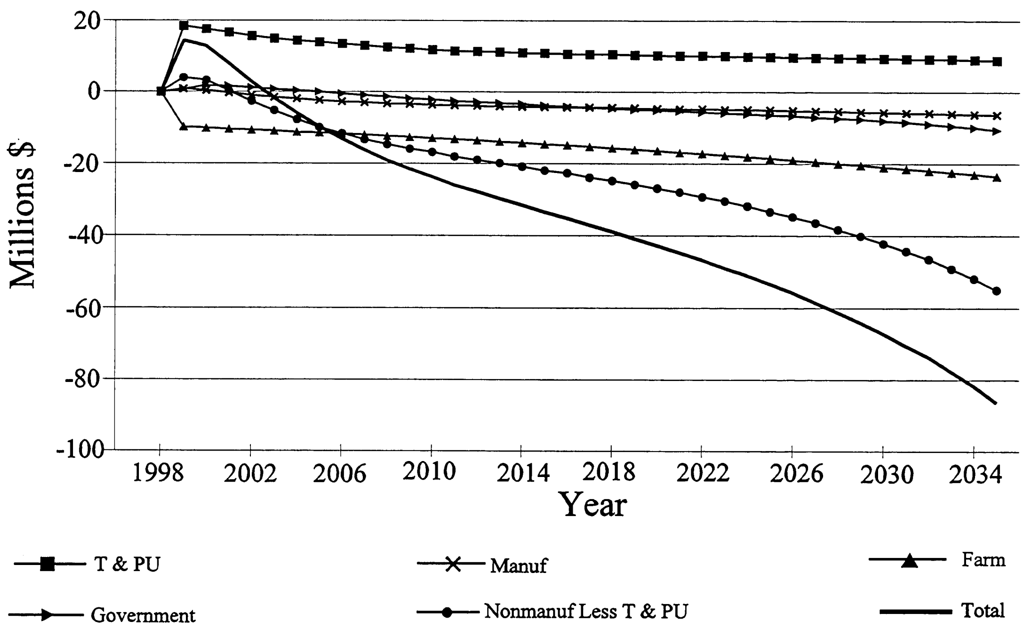


Figure 6.3.2-7 Change in Labor & Proprietor's Income, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Dollars

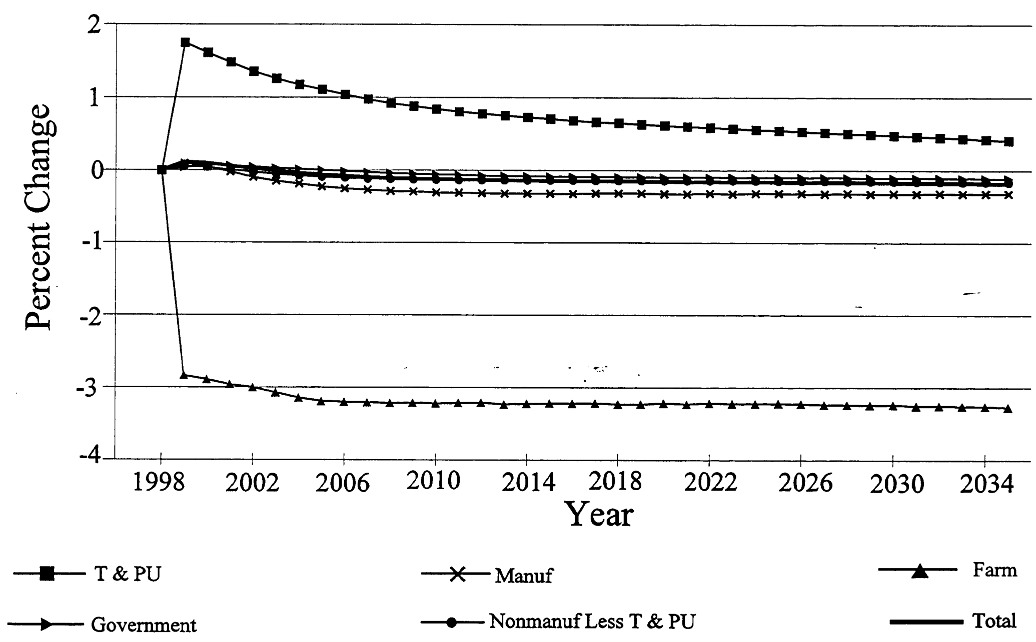


Figure 6.3.2-8 Percent Change in Labor & Proprietor's Income, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline

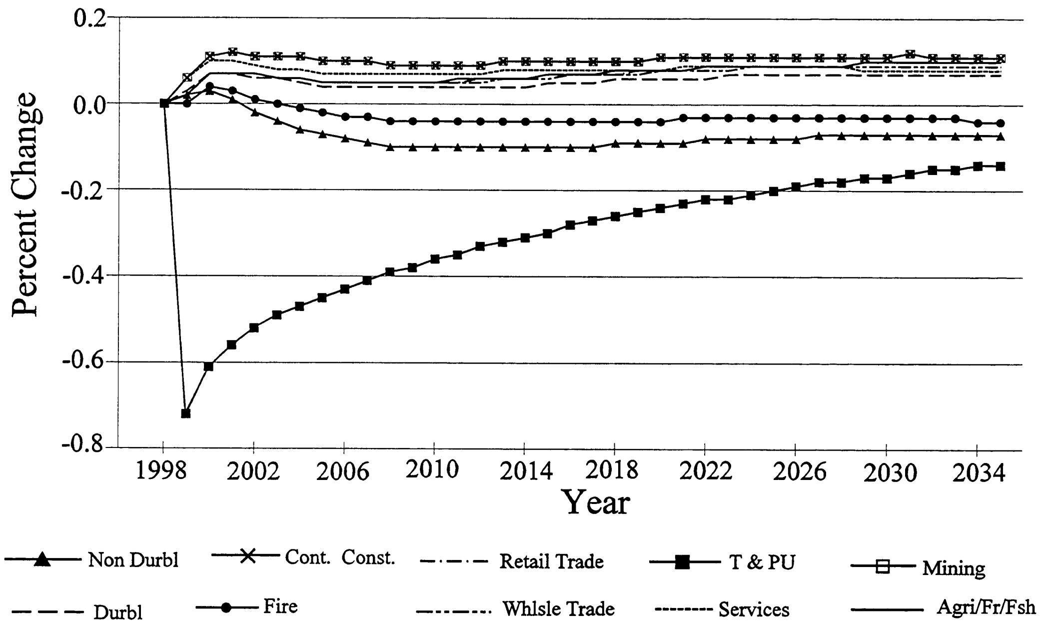


Figure 6.3.2-9 Percent Change in Average Annual Wage Rate by Sector, 36,300 kilogram (80,000 lb) Scenario Compared to the Baseline

ten private nonfarm sectors. Note that although the T&PU sector was the sector that gained the most in aggregate in terms of labor and proprietors' income, this increase was chiefly due to the increase in employment in that sector (Figures 6.3.2-3 and 6.3.2-4), and not due to increases in individuals' earnings. Not only did individual earnings fall for the T&PU sector, as shown in Figure 6.3.2-9, but this was the sector that bore the greatest impact at the individual level.

To summarize the economic impacts of the 36,300 kilogram (80,000 lb) weight scenario, the only positive effects observed were in employment and income for the trucking or T&PU sector. Total employment in the state also increased for the first four years of the forecast period, but subsequently turned negative. Employment in trucking increased throughout the study period (through 2035), as did labor and proprietors' income in the T&PU sector. The increase in labor and proprietors' income in the T&PU sector was, however, only the case when viewed in aggregate for the sector. At the individual level, the impacts were negative as employees in the T&PU sector saw their wages fall. This last effect is best explained as the result of the dramatically lowered productivity in this sector as a result of the decrease in the maximum gross vehicle weight to 36,300 kilograms (80,000 lbs).

The negative effects on the other sectors outweigh those positive effects on trucking, either from the outset in terms of gross state product (or value added), or after only five years in terms of employment and labor and proprietors' income. Of course, not considered in the statewide economic impacts are any benefits that might derive from lower truck weight limits in terms of environmental effects. However, as was discussed in Chapter 4, these effects could not be reliably quantified at this time, due to the lack of data and accepted analysis procedures. The results presented do give an indication of the magnitude that these potential benefits must exceed in order to make a 36,300 kilogram (80,000 lb) weight limit sound policy.

6.3.3 Comparison of Results from All Scenarios

To keep the focus on the larger economic impacts of the various weight limit scenarios, the other three scenarios are not presented and discussed in the same level of detail as was given above to the 36,300 kilogram (80,000 lb) scenario. Figures for the 39,900; 47,900; and 58,100 kilogram (88,000;105,500; and 128,000 lb) scenarios that are analogous to Figures 6.3.2-1 through 6.3.2-9 with regard to sectoral detail are presented in Appendix D (without discussion). In the following discussion, the macroeconomic effects for the scenarios are compared, including the already discussed 36,300 kilogram (80,000 lb) weight limit (which was included for reference).

Figure 6.3.3-1 shows the change in GSP for each scenario. First, note that the 39,900 kilogram (88,000 lb) GVW scenario is closest to the 36,300 kilogram (80,000 lb) GVW scenario in terms of the decrease in GSP, with a very similar shape through time. The 39,900 kilogram (88,000 lb) scenario's decrease in GSP was roughly 90 percent of the decrease in GSP for the 36,300 kilogram (80,000 lb) scenario. That these two scenarios are so similar was to be expected when comparing the model inputs for these scenarios in Table 6.2.3-1. Next, note that the 58,100 kilogram (128,000 lb) scenario, which represents an increase in the GVW limit, had positive economic impacts in terms of higher GSP than would occur with no change in truck weight limits. Although GSP would rise relative to the baseline with increased weight limits, the magnitude of the increase is less than one fifth (in absolute value) of the 36,300 kilogram (80,000 lb) scenario. Though less perceptible than for the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios, the 58,100 kilogram (128,000 lb) scenario shared the pattern whereby the increase in GSP was steepest during the early years, somewhat flatter in the middle years, and slightly steeper again in the later years. Not surprising given the model inputs in Table 6.2.3-1, the 58,100 kilogram (128,000 lb) scenario is a smaller-in-magnitude reflection about the horizontal axis of the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios.

The 47,900 kilogram (105,500 lb) GVW scenario produced the smallest economic impacts of the scenarios considered. Real GSP declined by $2.6 million (1992 dollars) in the first year of imposing weight limits, which became a $4 million decrease by 2035. The change was small and very stable. The change was largely driven by the change in net farm income, as the productivity impacts for this scenario in all of the non-farm sectors are the smallest magnitude of the four scenarios, while the decline in net farm income was half of the decline in the 39,900 kilogram (88,000 lb) scenario. The decrease in infrastructure costs that lead to lower final demand for state and local government highway construction also distinguished this scenario from the others.

Figure 6.3.3-2 shows the total employment effects for each scenario. Again, the 39,900 kilogram (88,000 lb) scenario closely mimics the 36,300 kilogram (80,000 lb) scenario, with a slightly smaller magnitude of effect, first showing an increase in overall employment that became a decrease in employment relative to the baseline after the year 2002. The 58,100 kilogram (128,000 lb) scenario is again a mirror image of the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios, with a much smaller magnitude of change. The 47,900 kilogram (105,500 lb) scenario shows a decrease in employment that is stable through the study period, much as was the case for real GSP.

Figure 6.3.3-3 shows the change in real disposable income for each of the scenarios relative to the baseline. The pattern established in Figures 6.3.3-1 and 6.3.3-2 prevails here, in

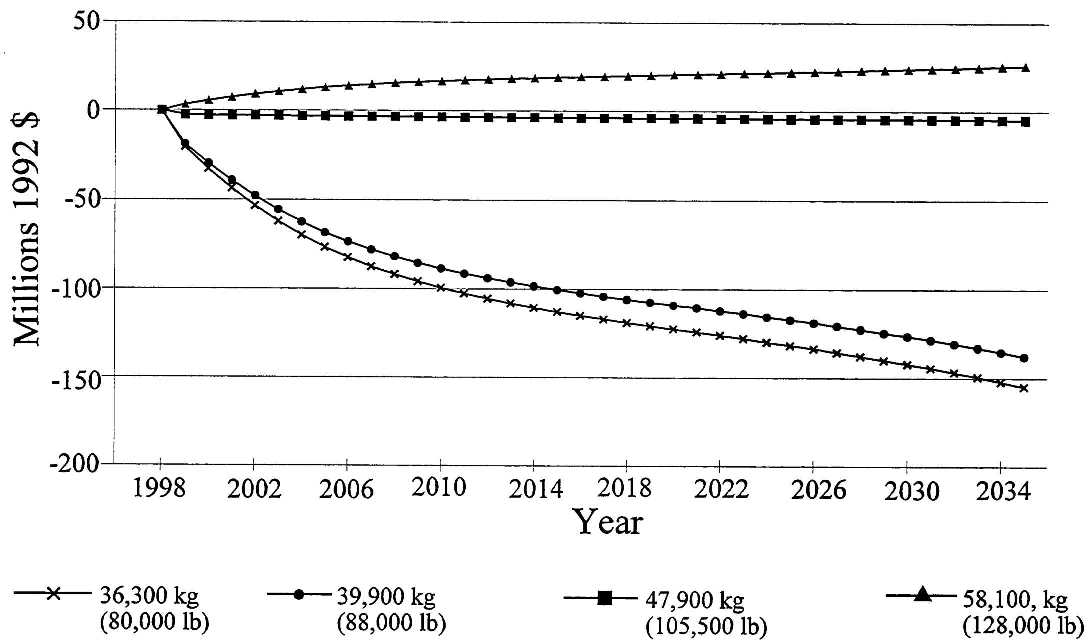


Figure 6.3.3-1 Change in GSP (Value Added) for All Scenarios Compared to the Baseline, Measured in Dollars

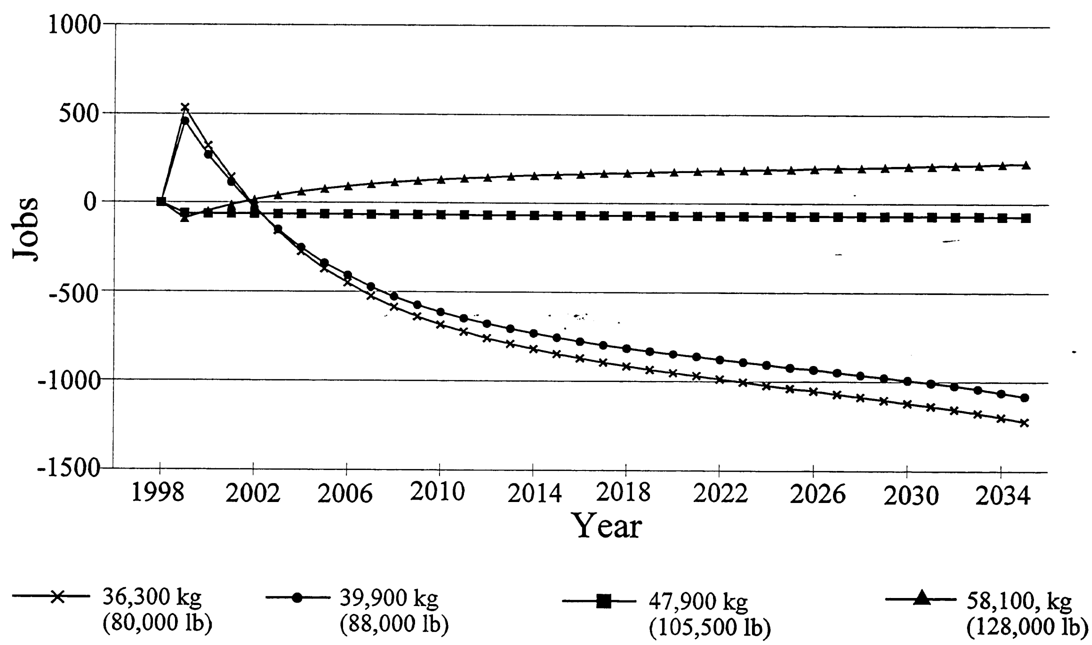


Figure 6.3.3-2 Change in Total Employment for All Scenarios Compared to the Baseline, Measured in Number of Jobs

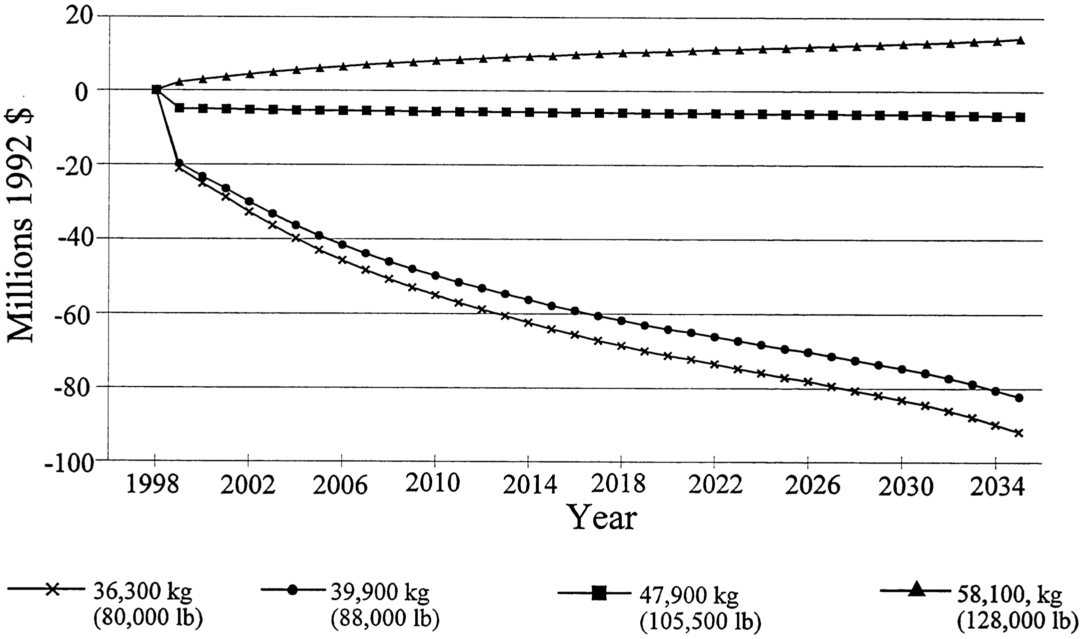


Figure 6.3.3-3 Change in Real Disposable Personal Income for All Scenarios Compared to the Baseline, Measured in Dollars

that the 39,900 kilogram (88,000 lb) scenario closely mimics the 36,300 kilogram (80,000 lb) scenario, while the 58,100 kilogram (128,000 lb) scenario is a mirror image of a smaller magnitude, while the impact on income of the 47,900 kilogram (105,500 lb) scenario is fairly constant.

6.3.4 Discussion

In general, reductions in GVW limits resulted in over-all reductions in state economic activity. This affect was most pronounced for the 80,000 and 88,000 pound scenarios. Evaluated in terms of GSP, economic activity was expected to decrease by at least 50 million dollars per year within 5 years after adoption of 80,000 or 88,000 pound GVW limits. These and other effects were much less pronounced for the 105,500 pound scenario. GSP was actually expected to increase by 15 million dollars per year within five years for the 128,000 pound scenario. From an employment perspective, employment in the trucking industry was expected to increase by up to 6 percent in the short term under the 80,000 pound scenario, leveling off to an increase of around 3 percent in the long term. Total employment was expected to nominally increase in the short term in the 80,000 and 88,000 pound scenarios (approximately 0.2 percent), in direct response to increased employment in the trucking sector (and to some extent in the area of highway construction), but it was expected to subsequently decline as indirect effects generated negative performance in other sectors of the economy. These effects were again less pronounced in the 105,500 pound scenario. Beginning in the year 2002, total employment was expected to increase under the 128,000 pound scenario.

In all cases, results from the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenario were similar in character and magnitude. Two conclusions are apparent from the similarity of the

36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. First, the impact of changing from a 36,300 kilogram (80,000 lb) GVW limit to a 39,900 kilogram (88,000 lb) GVW limit–or vice-versa–are quite small; whether the change from one such limit to the other was justified would depend upon whether the difference between the scenarios in potential benefits not directly measured as a part of this study (e.g., environmental benefits or costs) were sufficient to outweigh the change in GSP between the scenarios. In addition, one could use the scenario comparison to suggest that the 39,900 kilogram (88,000 lb) scenario does not represent much of a compromise between parties that would advocate and oppose a 36,300 kilogram (80,000 lb) GVW limit.

In general, changes in infrastructure costs under each scenario were nominal in magnitude relative to other economic impacts. Notably, in the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios, changes in GSP reached 50 million dollars per year after the first 5 years, compared to changes in annual infrastructure costs an order of magnitude lower. Only in the 47,900 kilogram (105,500 lb) scenario were economic impacts and infrastructure cost impacts similar in magnitude.

7. SUMMARY

7.1 GENERAL REMARKS

The objective of this study was to determine the effects on the state economy of changes in the allowable gross weight of vehicles that operate on the state highway system. Four GVW limits were considered, namely, 36,300; 39,900; 47,900; and 58,100 kilograms (80,000; 88,000; 105,500; and 128,000 lbs). The first three scenarios represent reductions in allowable GVW compared to the existing situation in Montana, while the last scenario represents an increase in allowable GVW. The economic impacts that would result from each scenario were determined using a sectoral I/O model of the statewide economy. The effects of each scenario (with a few exceptions) were introduced into this model via changes in industry productivity associated with the changes in trucking operations predicted under each scenario. In general, reductions in the allowable gross weight of the vehicles operating on the state highway system were found to produce negative impacts on the state's economy, while the increase in allowable gross weight was found to produce a nominal positive impact on the state's economy. Under the 36,300 kilogram (80,000 lb) GVW limit, GSP was found to be consistently 0.4 percent below that expected under existing regulations (baseline case), which translates, for example, into a \$50 million reduction in GSP in the fifth year after the new limits were introduced. Under a 58,100 kilogram (128,000 lb) GVW limit, GSP reached a level consistently 0.08 percent above that expected under existing regulations, which translates, for example, into approximately a \$5 million increase in GSP the fifth year after the new limits were introduced. With respect to the intermediate GVW scenarios, results for the 39,900 kilogram (88,000 lb) scenario were similar in nature and magnitude to those for the 36,900 kilogram (80,000 lb) scenario, while the results for the 47,900 kilogram (105,500 lb) scenario were smaller in magnitude than those for the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios. Many existing vehicles were found to already operate close to or below maximum GVWs of 47,900 kilograms (105,500 lbs), and thus traffic operations in this scenario were similar to the existing situation.

Similar long term trends (5 years and after) to those seen for GSP were observed for statewide employment and real disposable income. Long term reductions were seen in both these areas for those scenarios that were reductions in allowable GVW compared to the current situation. Reductions of approximately 0.2 percent in these areas were observed for the 36,300 kilogram (80,000 lb) scenario. Conversely, nominal increases in employment and real disposable income (0.04 percent) were observed in the one case when GVW limits were increased (58,100 kilogram (128,000 lb) scenario). Note that at the sectoral level, employment increased in the trucking and the transportation and public utilities sectors of the economy in the 36,300 and 39,900 kilogram (80,000 and 88,000 lb) scenarios throughout the simulations. This increase in employment resulted primarily from the reduction in productivity (increase in number of trips required to carry the same amount of commodity) in the trucking industry under these scenarios. In the short term, this increase in employment was sufficient to generate a nominal net increase in total statewide employment. In the long term, as jobs were lost in other sectors of the economy due to the reduced competitiveness of other industries resulting from increased transportation costs, a net decrease was observed in total statewide employment.

Case studies done on specific industries in the areas of agriculture, extractive industries, forestry and wood products, construction, and retail sales revealed a broad range of potential economic impacts, dependent on the specific industry and scenario involved. In general, costs increased for scenarios involving reductions in GVW limits and decreased for scenarios involving increases in GVW limits. The greatest changes in transportation costs were observed for the 36,300 kilogram (80,000 lb) scenario for all industries. Truck trips increased by 3% to 57% for this scenario, depending on the commodity involved. The greatest trip increases were predicted for industries that currently use the heaviest trucks for most of their transportation operations (e.g., milk, sugar beets, talc, wood chips, cement, motor fuel). The lowest trip increases were predicted for industries that already extensively use trucks with GVWs not exceeding 36,300 kilograms (80,000 lbs) in their operations (e.g.,cattle, logging). Expressed as a fraction of commodity value, costs increased by 0.2 to 4.2 percent for this scenario. Correspondingly, expressed as a percentage of commodity value, costs decreased by up to 0.8 percent in the 58,100 kilogram (128,000 lb) scenario. Possible outcomes of these changes in production costs ranged from reductions or increases in consumer disposable income (in response to increases/decreases in prices of commodities) to reductions or increases in plant production (in response to increases/decreases in production costs).

It was found for both the statewide economic model and the case studies that infrastructure costs were only a small part of the net economic effect of changing GVW limits. Extensive analyses were done of changes in infrastructure performance and requirements under each GVW scenario. While these analyses primarily focused on the pavement and bridge elements of the infrastructure, consideration was also given to geometric, capacity, and safety issues. To a large extent, these analyses found that system performance and requirements were similar under all scenarios. The largest increase in pavement costs compared to present expenditures, for example, was 1.2 percent. Interestingly, this increase in cost was calculated for the lowest GVW scenario of 36,300 kilograms (80,000 lbs), which *a priori* might have intuitively been believed to offer the greatest infrastructure savings. For the 36,300 kilogram (80,000 lb) scenario, changes in GSP in the statewide economic model were approximately 20 times the change in the infrastructure costs in the first year alone. Across all scenarios, changes in GSP ranged from 2 to 20 times the changes in infrastructure costs. The changes in transportation costs determined in the case studies were at least an order of magnitude larger than the associated infrastructure costs. Both of these results reinforce the need to consider more than just infrastructure costs in investigating truck size and weight issues.

7.2 RECOMMENDED FUTURE WORK

Further analyses could be performed to improve the quality and determine the sensitivity of the results obtained from the statewide economic model. First, efforts could be made to better define the productivity changes by industry under each GVW scenario. These productivity changes are critical to any results obtained from the model, in that they are the means by which the effects of the GVW scenarios are put into the model. These changes were estimated based on information available in the Montana TIUS data and the national TSA. While this approach was judged to produce useable results, these results were expected to be conservative in nature. Notably, more extreme changes in productivity were consistently observed in the case studies compared to the changes predicted from the TIUS and TSA information.

The reliability and sensitivity of the statewide model could be determined by performing parametric studies in which selected variables are changed and the output analyzed. The 36,300 kilogram (80,000 lb) scenario might be most appropriate for these studies, in that the greatest economic impacts are generally expected for this scenario.

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APPENDIX A

Survey Instrument used with Members of the Montana Motor Carriers Association

This appendix contains a copy of the survey that was developed in cooperation with the Montana Motor Carriers Association (MMCA) to obtain information on the current operations of their members and on how these operations might change under different maximum allowable GVW limits. This survey was sent to all members of the MMCA and 76 replies were received.

Transportation Survey
Truck Weight Limit Study
Montana State University, Bozeman

Julie Hewitt, Agricultural Economics Dept., 406-994-5636
Jerry Stephens, Civil Engineering Dept., 406-994-6113

Survey Objectives:
This survey is being conducted to support a study underway at Montana State University on the economic impacts in Montana of regulatory changes in truck weight limits. The study, commissioned by the Montana Department of Transportation, is being conducted in anticipation of changes regarding truck size and weight limits that may be proposed at the federal level in the near future. While the most obvious effects of changes in truck weight limits are changes in direct shipping costs and highway infrastructure maintenance costs, the intent of this study is to focus on the indirect effects on various sectors of the state economy. Trucks are used to ship a substantial portion of the goods produced and consumed in the state of Montana, and the purpose of the study is to gauge how far-reaching these impacts may be to the state's economy.

Confidentiality of Results:
Confidentiality is assured. Information on individual responses will not be reported in either the study report or to MDT. The contact information below is requested in the event that something in your responses triggers a follow-up question, or if we need further clarification.

Instructions:
Answer as many of the questions below as you can. Please note that an approximate answer is more useful than no answer. Please fax or mail your response by *January 1, 1998*. Fax to Julie Hewitt at (406) 994-4838 or mail to Julie Hewitt, Montana State University, P.O. Box 172920, Bozeman MT 59717-2920. Thank-you for your time and cooperation.

Contact		Phone	
Company		E-mail	
Address			

Is your primary business providing transportation hauling services? No ☐ Yes ☐

If no, what is your primary business? ______

If yes, what percent of your business is: under contract? ____ % as common carrier? ____ %

If under contract, what is the approximate number of clients served? ______

Thinking only of the *trips at loaded weights exceeding 70,000 lbs.* (GVW), what percentage of these trips fall into the following weight categories (in thousands of lbs.)?

70-80	%
80-90	%
90-100	%
100-110	%
110-120	%
120+	%
	100%

What percentage of *all* trips do you operate empty? ____ %

Check the box which bests describes your one-way average haul distance for trips over 70,000 lbs.

0-50 miles ☐ 50-100 ☐ 100-200 ☐ 200-500 ☐ over 500 ☐ Don't know ☐

Check the box which bests describes the average annual mileage for trips over 70,000 lbs.

0-5000 miles	☐	5,000 - 25,000	☐	25,000 - 50,000	☐	50,000 - 100,000	☐	over 100,000	☐	Don't know	☐

Thinking only of the trips at weights over 70,000 lbs., what percent of these trips occur *strictly within* the following regions?

*Intermountain & Pacific NW includes: Montana, Idaho, Wyoming, North and South Dakota, Colorado, Utah, Nevada, Arizona, Oregon and Washington

Montana	%
Intermountain & Pacific NW states*	%
West of the Mississippi River	%
United States	%
Other ____________________	%
	100%

Of the trucks in your fleet that operate at more than 70,000 lbs. (GVW), what percent is each type of rig below? Circle the major axle configuration for each type of rig you use.

Single unit	axles 2 3 4	%
Truck and full trailer	axles 3 4 5 6 7	%
Tractor and semi-trailer	axles 3 4 5 6 7	%
Tractor, semi-trailer and full trailer	axles 5 6 7 8 9	%
Triple trailer	axles 7 8 9	%
Other	axles ____________	%
		100%

What percentage of your trips over 70,000 lbs. are: off-road? [%] on public road? [%]

Thinking only of the trips at weights over 70,000 lbs., what percent of these trips are for the purpose of hauling commodities in the following groups? If possible, note the breakdown within groups.

Agriculture	%	____% Grain ____% Livestock ____% Feed ____% Dairy ____% Other
Mining	%	____% Precious metals ____% Coal ____% Other
Forestry	%	____% Logs ____% Chips ____% Pulp ____% Paper ____% Lumber ____% Other
Chemicals	%	____% Petroleum & fuel products ____% Ag. chemicals ____% Other
Food Products	%	____% Warehouse-to-retail transport ____% Other
Construction	%	____% Gravel & cement ____% Bldg. Matls. ____% Equip. ____% Other
Manufacturing	%	specify ____________________
Other	%	specify ____________________

The following questions regard how your firm would likely respond to changes in truck weight regulations. Please consider how your firm would respond to each of the five maximum GVW limit scenarios in terms of percentage change from your total current operations. Presume that these limits apply to the Intermountain and Pacific NW region, with any existing state maximum GVWs *less* than the scenario below remaining unchanged. For the 128,000 lb. scenario, assume *all* states in the Intermountain and Pacific NW region *raise* their limits on 7-or-more axle combinations to 128,000 lbs.

Would you likely layoff or hire employees, and if so, what percent of your total workforce?

Max GVW	No change	Layoff	Hire	Don't know	1-5%	6-10%	11-15%	16-20%	20-25%	25-35%	35-50%
73,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
80,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
88,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
105,500	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
128,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Would you experience income or cash flow decreases or increases, and if so, what percent of current levels?

Max GVW	No change	Decrease	Increase	Don't know	1-5%	6-10%	11-15%	16-20%	20-25%	25-35%	35-50%
73,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
80,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
88,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
105,500	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
128,000	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Will the products being hauled be shipped by a different transportation mode?

Max GVW	No	Don't know	Yes	If yes, specify (eg., rail).
73,000	☐	☐	☐	______
80,000	☐	☐	☐	______
88,000	☐	☐	☐	______
105,500	☐	☐	☐	______
128,000	☐	☐	☐	______

Will you change the configuration of the trucks you use?

Max GVW	No	Don't know	Yes	If yes, specify (eg., 5 axle tractor, semi-trailer).
73,000	☐	☐	☐	______
80,000	☐	☐	☐	______
88,000	☐	☐	☐	______
105,500	☐	☐	☐	______
128,000	☐	☐	☐	______

If you have any additional comments, please attach a page with your comments.

APPENDIX B

New Vehicle Configurations for the 58,100 kilogram (128,000 lb) Scenario (Canamex Vehicles)

This appendix contains a description of the size and weight limits on the new vehicles allowed under the 58,100 kilogram (128,000 lb) scenario (Canamex limits).

CANAMEX
ROCKY MOUNTAIN DOUBLE
GENERAL CONDITIONS

	A TRAIN CONFIGURATION	C TRAIN CONFIGURATION
Overall Length Overall Height Overall Width	Max. 30m (98 ft. 5 in.) Max. 4.27m (14 ft.) Max. 2.6m (8 ft. 6 in.)	Max. 30m (98 ft. 5 in.) Max. 4.27m (14 ft.) Max. 2.6m (8 ft. 6 in.)
Lead Semitrailer Length (box length)	Min. 12.8m (42 ft.) Max. 16.2m (53 ft.)	Min 12.8m (42 ft.) Max. 16.2m (53 ft.)
Wheelbase	Min. N/A Max. 12.5m (41 ft.)	Min. N/A Max. 12.5m (41 ft.)
Hitch Offset Trailers ≤ 13.7 m (45 ft) Trailers > 13.7 m (45 ft)	Max. 1.8m (6 ft.) Max. 2.8m (9.2 ft.)	Max. 1.8m (6 ft.) Max. 2.8m (9.2 ft.)
Effective Rear Overhang	Max. 35% of WB	Max. 35% of WB
Converter Dolly Drawbar Length Max. No. of Axles	Not Controlled 2	Max. 2.0m*(6 ft. 6 in.) 1
Second Semitrailer or Full Trailer Wheelbase Effective Rear Overhang	Min. 6.5m (21 ft. 4 in.) Max. 35% of WB	Min. 6.5m (21 ft. 4 in.) Max. 35% of WB
WEIGHTS		
Gross Vehicle Weight	Max. 53 500kg (118,000 lb.)	Max. 58 200kg (128,000 lb.)

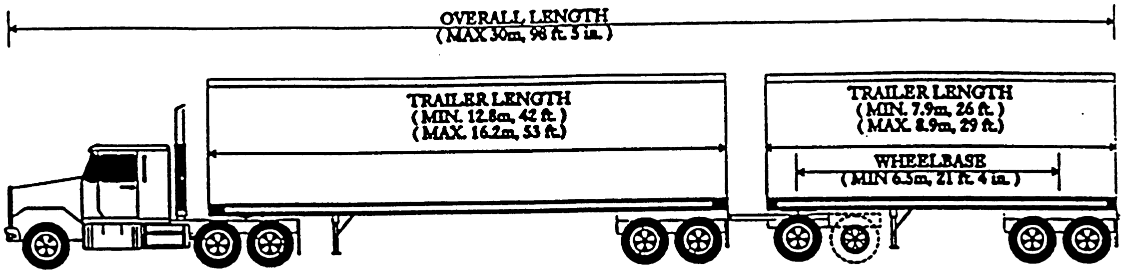
In all cases, the lead semitrailer of the configuration, must be heavier than the second semi-trailer.

***The 2.0 metre (6 ft. 6 in.) maximum drawbar length is applicable to "C" dollies manufactured in 1993 or later in accord with the compliance requirements to the CMVSS under the Motor Vehicle Safety Act, Canada.**

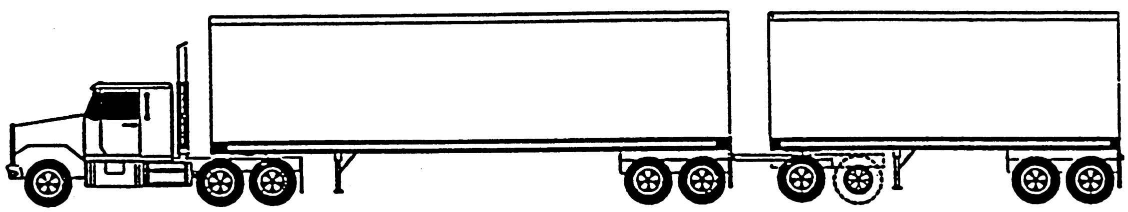
Figure B-1 Canamex Size and Weight Limits Used for the 58,100 kilogram (128,000 lb) Scenario (Alberta Transportation and Utilities, 1994) (page 1 of 3)

CANAMEX
ROCKY MOUNTAIN DOUBLE
A train and C train

DIMENSIONS



WEIGHTS



MAXIMUM AXLE WEIGHTS	STEERING 5 500kg 12000 lb.	SINGLE : 9 100kg/ 20,000 lb. TANDEM : 15 454kg/ 34,000 lb.
COMBINED AXLE GROUP WEIGHTS		SEE TABLE 1

		A TRAIN	C TRAIN
MAXIMUM GROSS VEHICLE WEIGHT	5 AXLE	41 900kg / 92,000 lb.	41 900kg / 92,000 lb.
	6 AXLE	48 200kg / 106,000 lb.	48 200kg / 106,000 lb.
	7 AXLE	53 500kg / 118,000 lb.	54 500kg / 120,000 lb.
	8 OR MORE AXLES	53 500kg / 118,000 lb.	58 200kg / 128,000 lb.

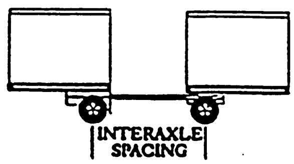
NOTE : Second or rear trailer must be lighter than the lead trailer or lead trailer must be heaviest.
Refer to jurisdictions' transport regulations governing kingpin set back and effective rear overhang.

Figure B-1 Canamex Size and Weight Limits Used for the 58,100 kilogram (128,000 lb) Scenario (Alberta Transportation and Utilities, 1994) (page 2 of 3)

COMBINED AXLE GROUP WEIGHT ALLOWANCE

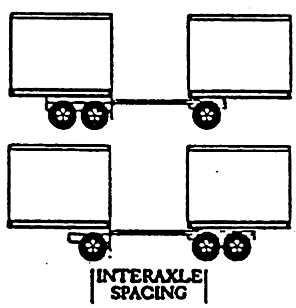
NOTE : The Axle Group Weights shown consist of the lead trailer rear axle group plus the front axle group of the second trailer.

SINGLE-SINGLE



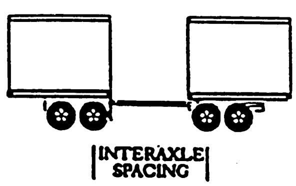
INTERAXLE SPACING	ALLOWED COMBINED WEIGHT
Equal to or greater than 3.0m (10 ft.)	18 200kg/ 40,000 lb.
Less than 3.0m (10 ft.)	15 454kg/ 34,000 lb.

TANDEM-SINGLE SINGLE-TANDEM



INTERAXLE SPACING	ALLOWED COMBINED WEIGHT
Equal to or greater than 3.0m (10 ft.)	24 545kg/ 54,000 lb.
Less than 3.0m (10 ft.) but greater than 2.5m (8 ft. 2 in.)	23 000kg/ 50,600 lb.
Less than 2.5m (8 ft. 2 in.) but greater than 2.0m (6 ft. 6 in.)	21 000kg/ 46,000 lb.

TANDEM-TANDEM



INTERAXLE SPACING	ALLOWED COMBINED WEIGHT
Equal to or greater than 4.3m (14 ft.)	50 900kg/ 68,000 lb.
Less than 4.3m (14 ft.) but greater than 4.1m (13 ft. 6 in.)	29 900kg/ 65,600 lb.
Less than or equal to 4.1m (13 ft. 6 in.) but greater than or equal to 3.8m (12 ft. 6 in.)	28 400kg/ 62,500 lb.

Under no circumstances shall the following be exceeded :

(a) 3 650kg/ 8000 lb. per tire

(b) the capacity of the tire as determined by multiplying the cross section dimension of the tire as stamped on the tire by its manufacturer by : 10kg/ mm width of tire or 560 lb./ inch width of tire

(c) the rated capacity of the tire as stamped on the tire by its manufacturer

whichever is the lesser.

Figure B-1 Canamex Size and Weight Limits Used for the 58,100 kilogram (128,000 lb) Scenario (Alberta Transportation and Utilities, 1994) (page 3 of 3)

APPENDIX C

Bridge Analysis Methodology

Presented in this appendix is a description of the methodology used to assess bridge capacity and adequacy under the various GVW scenarios. A reliability based analysis approach was used for this purpose.

BRIDGE RELIABILITY INDEX

The risk of a vehicle crossing a bridge can be represented by the probability of the load demand from that vehicle exceeding the resistance of the bridge. This risk can be characterized by the reliability index. Simply stated, the reliability index measures the margin of safety between the resistance of a bridge and the load effects applied to it during its lifetime. If the load effects applied to a bridge increase while the resistance of the bridge remains constant, a decrease in the reliability index will occur. Conversely, if the resistance of a bridge is increased while the load effect remains unchanged, an increase will occur in the reliability index (indicating a lesser probability of failure).

For this study, the reliability index for a given bridge was determined from,

$$\beta = \frac{\ln(R_M / S_M)}{\sqrt{Vs^2 + Vr^2}}$$

where,

R_M = mean resistance of bridge

S_M = mean load demand

Vs = coefficient of variation of load demand

Vr = coefficient of variation of resistance

RESISTANCE

Bridge resistance was calculated as the sum of the dead load plus live load capacities of the structure. The live load capacity was determined from the vehicle used in the original design. It was decided to use inventory vehicles, listed in the state bridge inventory, as the vehicles used for design. Each inventory vehicle was run across each bridge, using PCBridge (Murphy, 1992), to determine the live load bending moment capacity (M_{DESIGN}). The final live load member resistance was then calculated using,

$$M_{LR} = D.F.*(1+I)*M_{DESIGN}$$

where,

M_{LR} = live load resistance (ft-kips)

D.F. = distribution factor for total resistance

I = AASHTO live load impact factor (AASHTO, 1983)

M_{DESIGN} = live load bending moment (ft-kips)

It has been shown in previous studies that the dead load effect on a bridge can be directly related to the live load effect and span length. This assumption was validated for bridges in Montana by Stephens and his colleagues (1996). Hansell and Viest (1971) were the first to develop an equation for this relationship. The original equation developed by Hansell and Viest (1971) was modified to exclude the impact factor that had been included in calculating M_{LR}. The final equation to determine the dead load member resistance for steel, wood, reinforced concrete, and prestressed concrete bridges was,

$$M_{DR} = 0.0132*M_{LR}*X$$

where,

X = span length (ft)

M_{LR} = live load member resistance (ft-kips)

M_{DR} = dead load member resistance (ft-kips)

In an investigation done by the Ministry of Transportation of Ontario (1997), an equation for the resistance of non-composite steel girder bridges was developed. The Transportation Research Board (1987) lists the ratio of the mean value to the nominal design value, or bias, for steel members in new condition of 1.10. This bias value was assigned to all structural steel components. Inclusion of this bias produces the final equation for the total mean resistance (R_M) for all steel bridges,

$$R_M = 2.30*(M_{DR} + M_{LR})$$

The National Transportation Research Board (1987) also reported a coefficient of variation for steel members in new condition of 12%. This coefficient of variation was used for the resistance of all steel bridges.

The mean to nominal ratio for flexure of reinforced beams was reported to be in the range of 1.01 to 1.06 (Mirza and MacGregor, 1982). It was decided to assign a bias of 1.04 to all reinforced concrete bridges. This bias was included in a resistance equation, developed by Stephens et.al. (1996) for reinforced concrete beams. The following equation was used to calculate the mean resistance for all reinforced concrete bridges,

$$R_M = 1.87*(M_{DR} + M_{LR})$$

The coefficient of variation for reinforced concrete members ranges from 8% to 12% (Ministry of Transportation of Ontario, 1997). A coefficient of variation of 10% was used for all reinforced concrete bridges.

Mean-to-nominal values for precast prestressed concrete members were determined to be in the range of 1.04 to 1.06 (Mirza and MacGregor, 1982). A bias of 1.05 was used for all prestressed concrete bridges. With inclusion of this bias, the

Ministry of Transportation of Ontario (1997) derived an equation for the mean resistance of prestressed concrete beams. The mean resistance for all prestressed concrete bridges was,

$$R_M = 1.79*M_{DR} + 3.00*M_{LR}$$

The coefficients of variation for precast, prestressed concrete beams range from 4.5% to 9% depending on minimum and maximum amounts of reinforcing steel (Mirza and MacGregor, 1982). A value of 9% was used as the coefficient of variation for all prestressed bridges.

The basic equation for the nominal resistance of timber bridges was based on design equations set in the Standard for Load Factor Design for Engineered Wood Construction (1995). The mean to nominal ratio used was 1.05 (Marx, 1988). As a result, the mean resistance for all timber stringer bridges under all loadings was,

$$R_M = 2.48*M_{DR} + 3.31*M_{LR}*(1+I)$$

The coefficient of variation for timber components is in the range of 10% to 30% (Goodman, 1983). A coefficient of variation of 20% was used for all timber bridges.

LOAD DEMAND

To determine the reliability index for a particular bridge, it is necessary to determine the load effects applied to the bridge during its lifetime. Previous studies have calculated reliability indices based on the entire vehicular population. Although using this approach results in valid reliability indices, it is difficult to determine the effect of a particular vehicle type. Therefore it was decided to focus on individual vehicle types. As a result, the effect a particular vehicle type has on the bridges of Montana could be determined. Ten different vehicle types were chosen. The ten vehicle types, gross weights, and axle spacings are shown in Figure C1. The vehicles considered under each GVW scenario are listed in Table C1.

Table C1 Vehicle Configurations Used in Calculating Moment Demands by Scenario

Vehicle[a]	Scenario				
	36,300 kg (80,000 lbs.)	39,900 kg (88,000 lbs.)	47,900 kg (105,500 lbs.)	Existing	58,100 kg (128,000 lbs.)
3SU	X	X	X	X	X
4SU	X	X	X	X	X
2S2	X	X	X	X	X
3S2	X	X	X	X	X
3S3		X	X	X	X
4-4			X	X	X
3S2-2a			X	X	X
3S2-2				X	X
3S2-3				X	X
C-Train					X

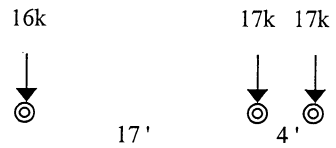
[a]See Figure C1

Essentially a core group of 4 vehicles was used for the 36,300 kg (80,000 lbs.) scenario, with this group being used in the analysis of each subsequent scenario with the addition of larger vehicles with higher GVW's, as appropriate.

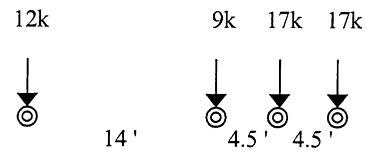
The live load demand (M_{95}) was determined by running each vehicle type over each bridge on the Montana highway system using PCBridge (Murphy, 1992). The live load demand (M_{95}) represents the 95th percentile characteristic value of live load bending moments for the particular vehicle. The final live load member demand was calculated from,

$$M_{LD} = D.F.*(1+I)*H*M_{95}$$

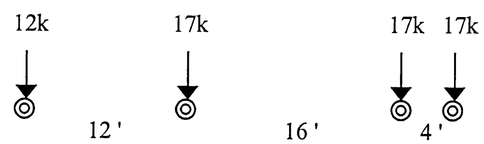
3 Axle Single Unit (3SU) - GVW = 50,000 lbs.



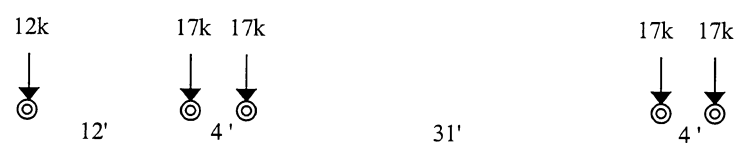
4 Axle Single Unit (4SU) - GVW = 55,000 lbs.



4 Axle Tractor Semi Trailer (2S2) - GVW = 63,000 lbs.



5 Axle Tractor Semi Trailer (3S2) - GVW = 80,000 lbs.



6 Axle Tractor Semi Trailer (3S3) - GVW = 88,000 lbs.

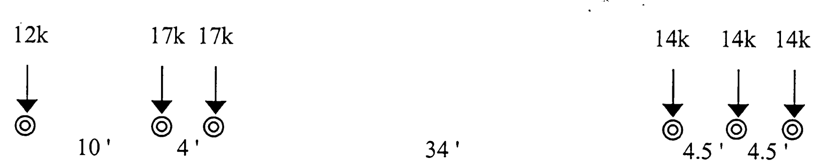
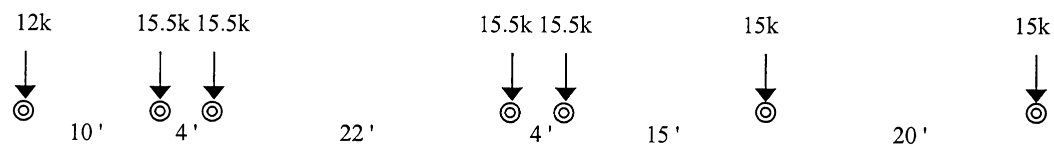


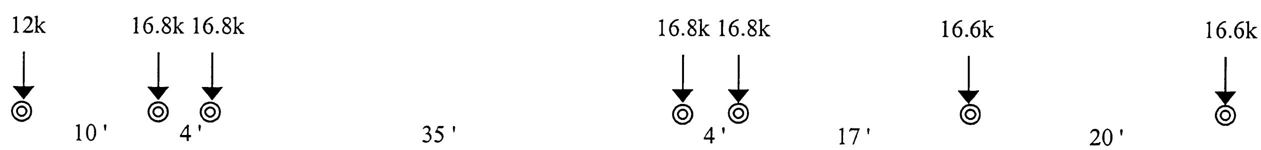
Figure C1 Vehicle Configurations Used in Calculating Moment Demands

8 Axle Truck and Trailer (4-4) - GVW = 105,000 lbs.

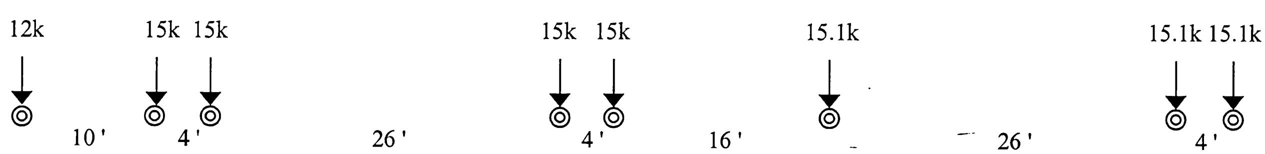
7 Axle A/C Train Combination (3S2-2a) - GVW = 104,000 lbs.



7 Axle A/C Train Combination (3S2-2) - GVW = 112,500 lbs.



8 Axle A/C Train Combination (3S2-3) - GVW = 117,500 lbs.



8 Axle C Train Combination - GVW = 128,000 lbs.

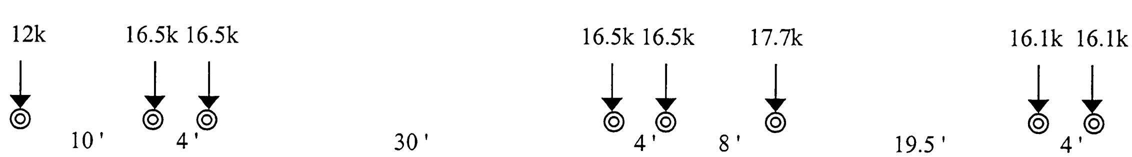
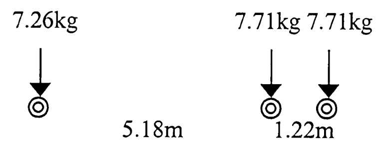
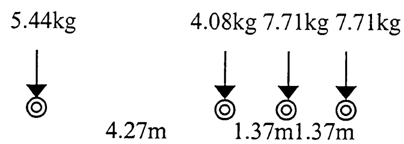


Figure C1 (continued)

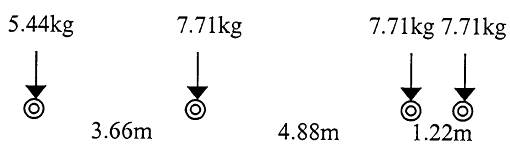
3 Axle Single Unit (3SU) - GVW = 22,700 kg



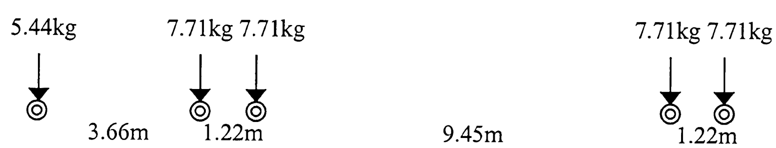
4 Axle Single Unit (4SU) - GVW = 25,000 kg



4 Axle Tractor Semi Trailer (2S2) - GVW = 28,600 kg



5 Axle Tractor Semi Trailer (3S2) - GVW = 36,300 kg



6 Axle Tractor Semi Trailer (3S3) - GVW = 39,900 kg

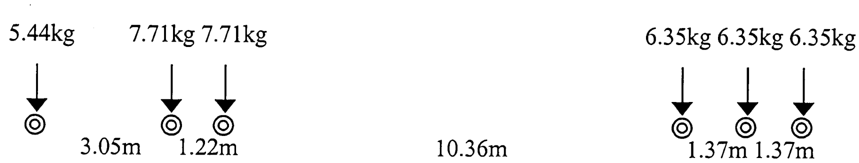
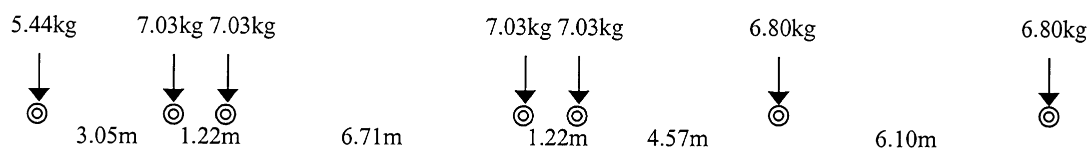


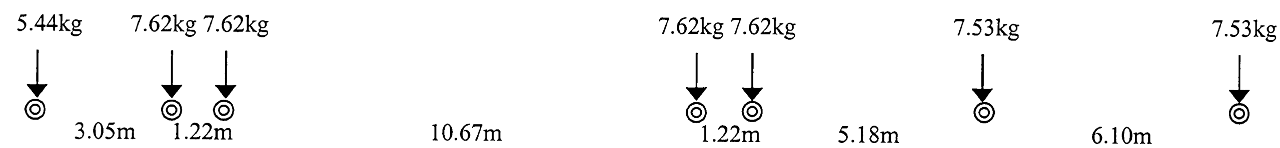
Figure C1 (continued)

8 Axle Truck and Trailer (4-4) - GVW = 47,900 kg

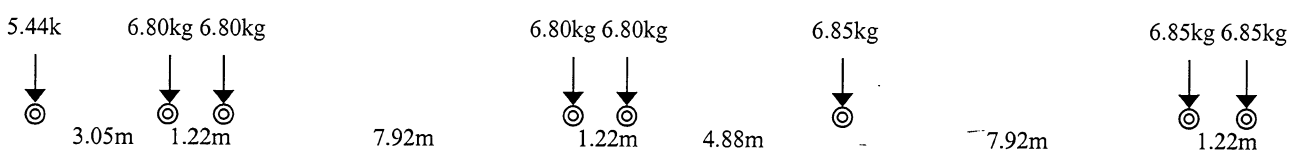
7 Axle A/C Train Combination (3S2-2a) - GVW = 47,200 kg



7 Axle A/C Train Combination (3S2-2) - GVW = 51,000 kg



8 Axle A/C Train Combination (3S2-3) - GVW = 53,300 kg



8 Axle C Train Combination - GVW = 58,100 kg

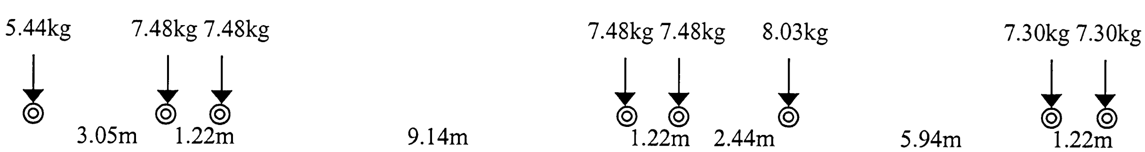


Figure C1 (continued)

where,

D.F. = distribution factor

I = impact factor from field testing done by Billing (1980)

H = headway factor

M_{95} = live load demand (ft-kips)

as described above. As previously discussed, the dead load effect on a bridge can be directly related to the live load effect and span length. This behavior was considered to also be true for load demand. Dead load demand was taken to be independent of the vehicle crossing the bridge. Dead load demand was calculated using the design vehicle moments.

To determine the mean dead load and mean live load demand, coefficient of variation and bias values had to be determined. A bias of 1.0 and coefficient of variation of 10% were used for the dead load (Transportation Research Board, 1987). In addition, after review of numerous studies the live load coefficient of variation of 20% and bias of 1.0 was used.

BETA CALCULATION

Reliability indices, beta values, were subsequently calculated for each bridge using the above described inputs in the reliability equation.

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APPENDIX D

Results from the State Wide Economic Model, All Scenarios

Presented in this appendix are more detailed results for each scenario from the state wide economic model than were presented in the main body of the text. Information of the type presented in the text for the 80,000 pound scenario is presented for the remaining scenarios (without commentary).

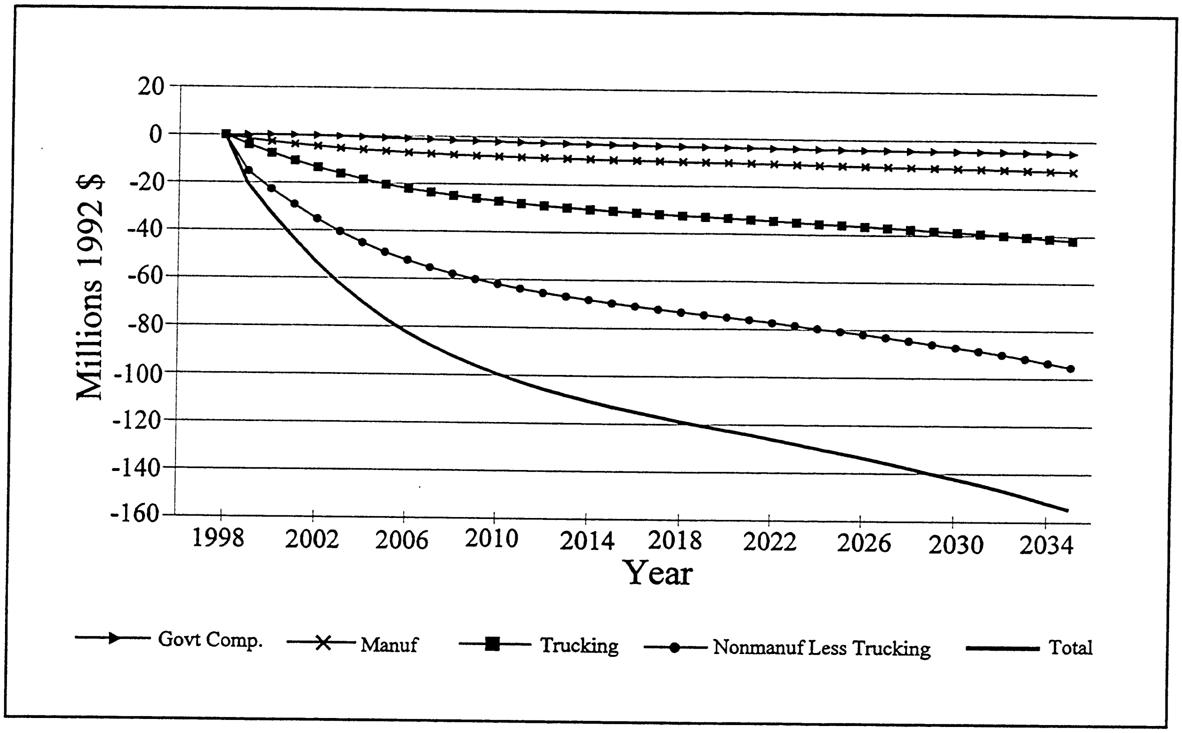

Figure D.1-1 Change in GSP (Value Added) by Sector, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Dollars

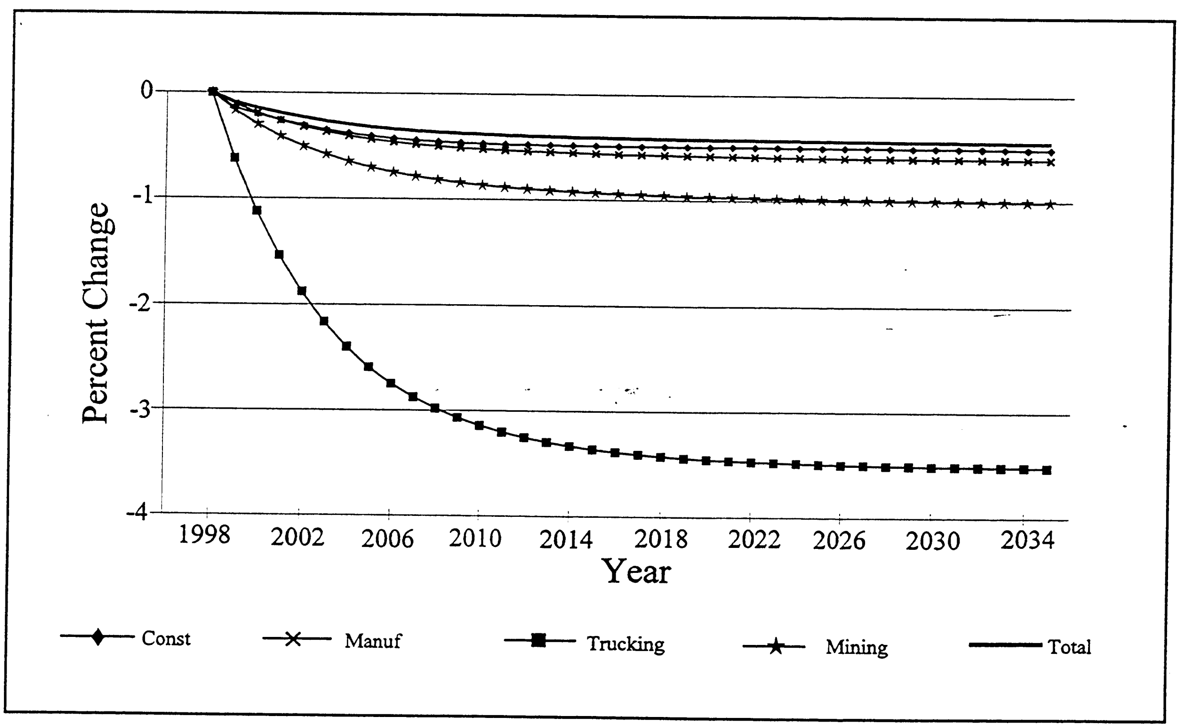

Figure D.1-2 Percent Change in GSP (Value Added) by Sector, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline

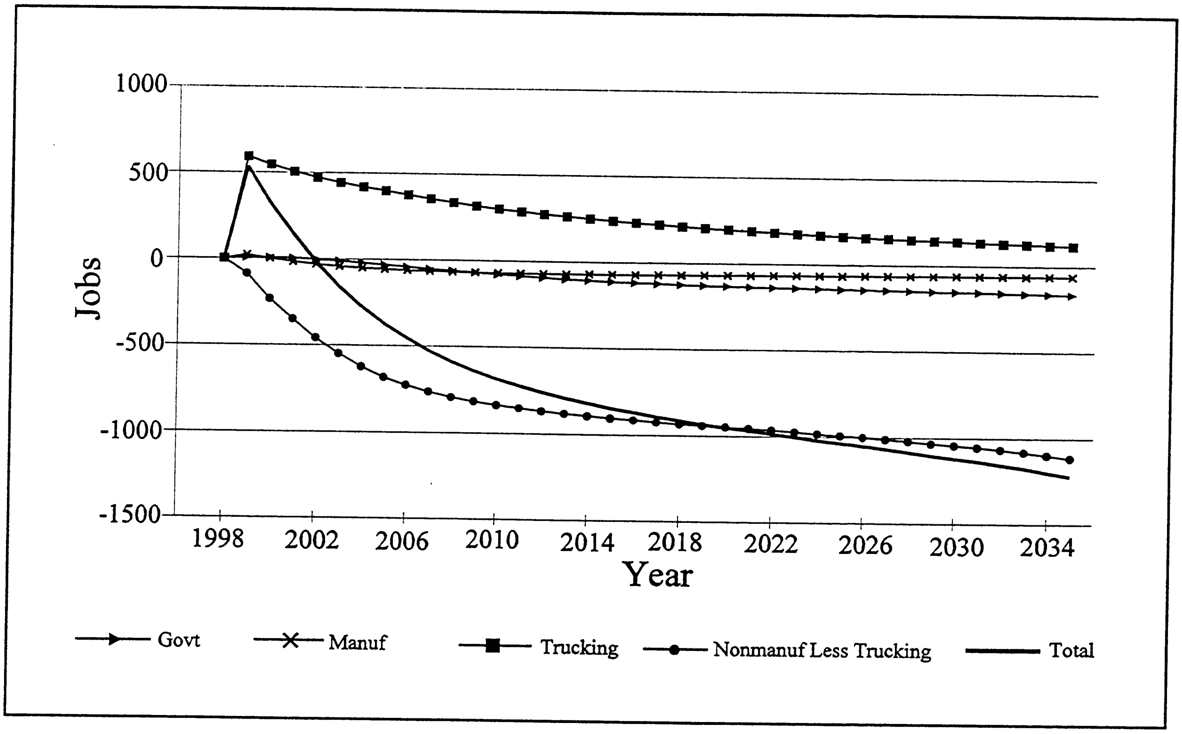

Figure D.1-3 Change in Non-farm Employment by Sector, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Jobs

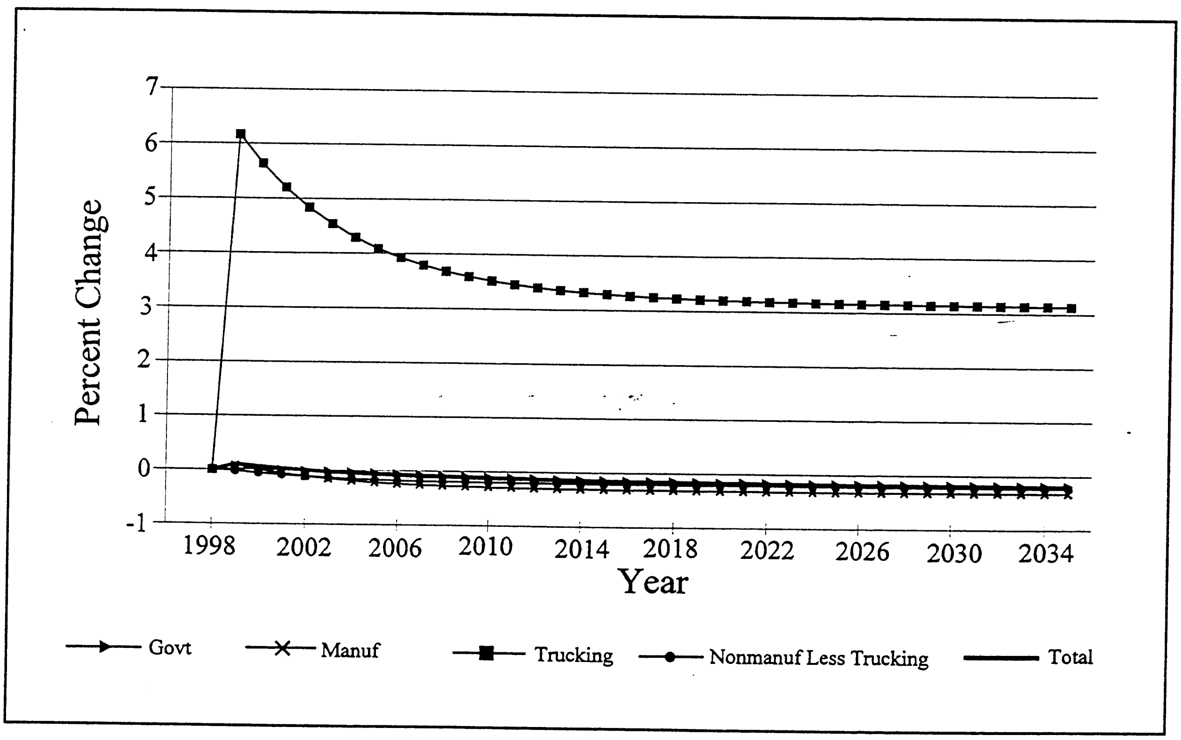

Figure D.1-4 Percent Change in Non-farm Employment by Sector, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline

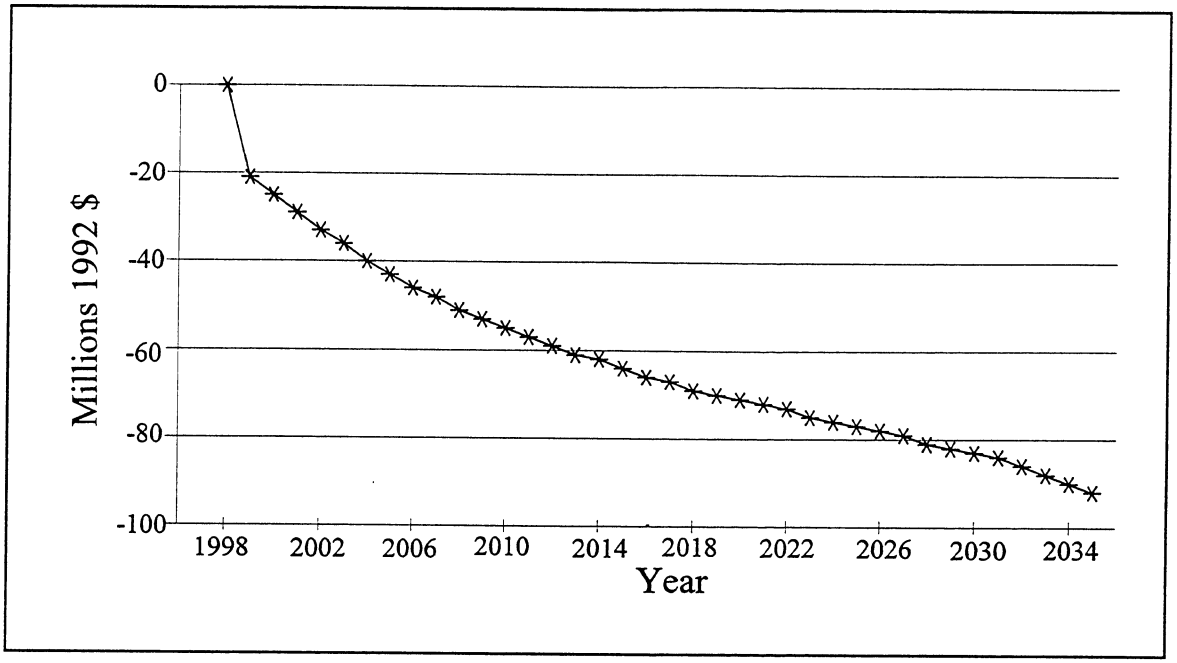

Figure D.1-5 Change in Real Disposable Personal Income, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Dollars

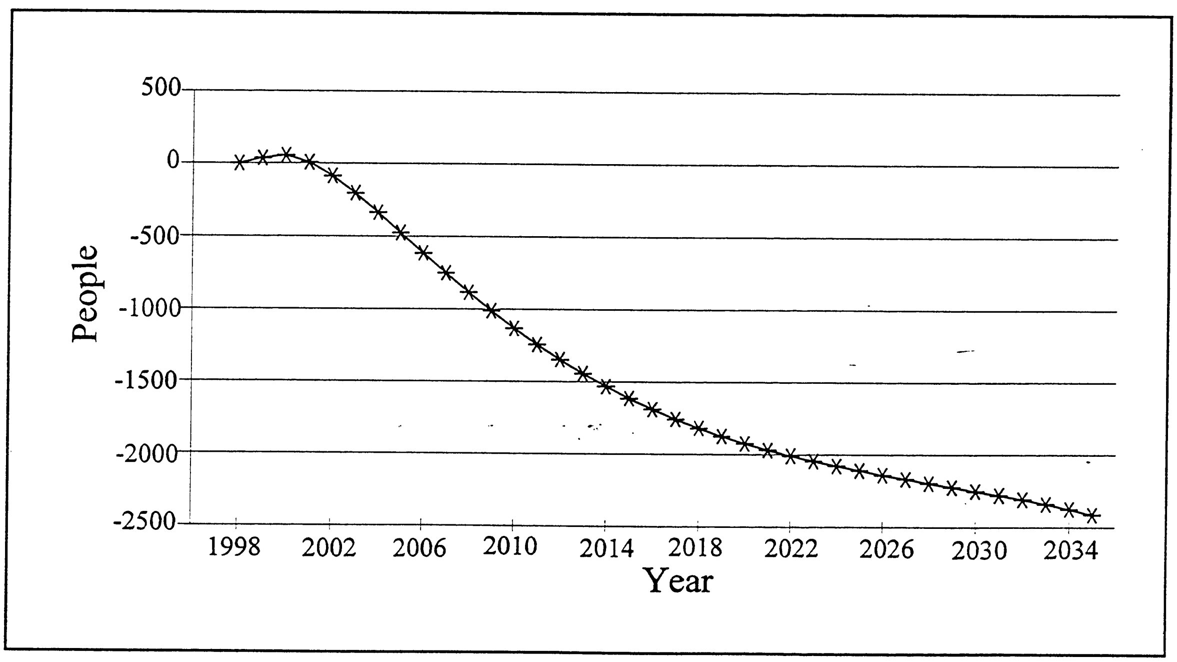

Figure D.1-6 Change in Population, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Number of People

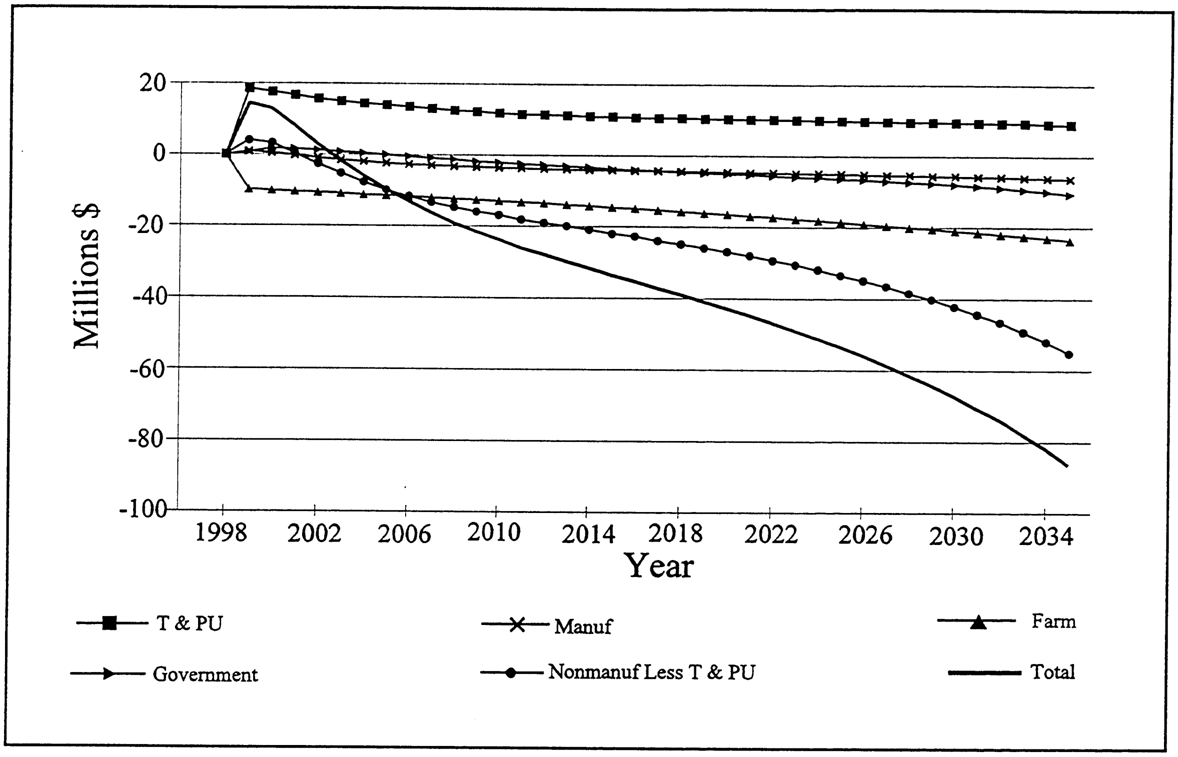

Figure D.1-7 Change in Labor & Proprietor's Income, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline, Measured in Dollars

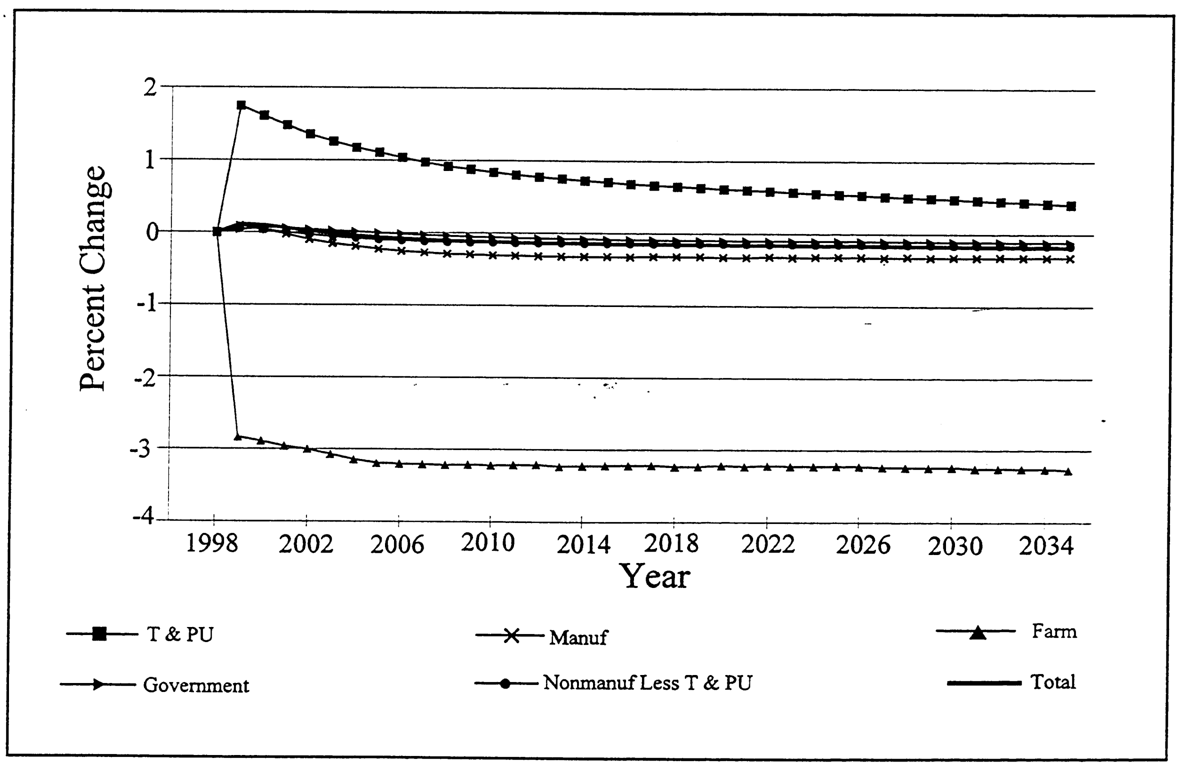

Figure D.1-8 Percent Change in Labor & Proprietor's Income, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline

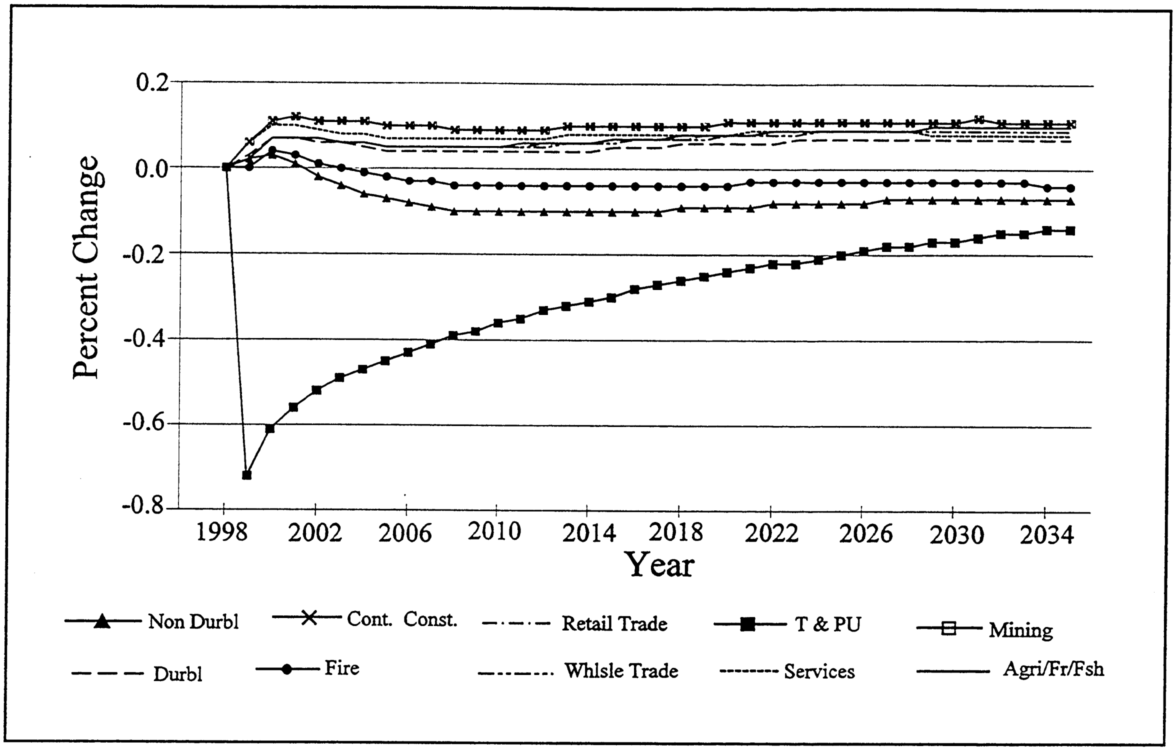

Figure D.1-9 Percent Change in Average Annual Wage Rate by Sector, 36,300 Kilogram (80,000 lb) Scenario Compared to the Baseline

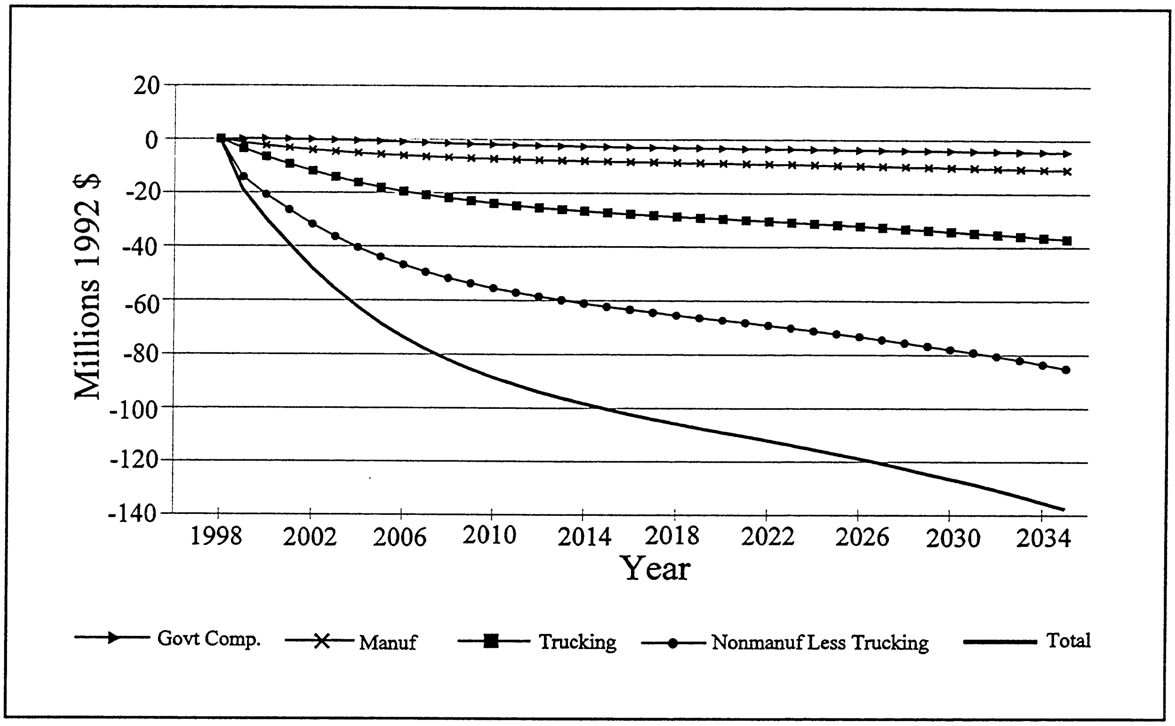

Figure D.2-1 Change in GSP (Value Added) by Sector, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline, Measured in Dollars

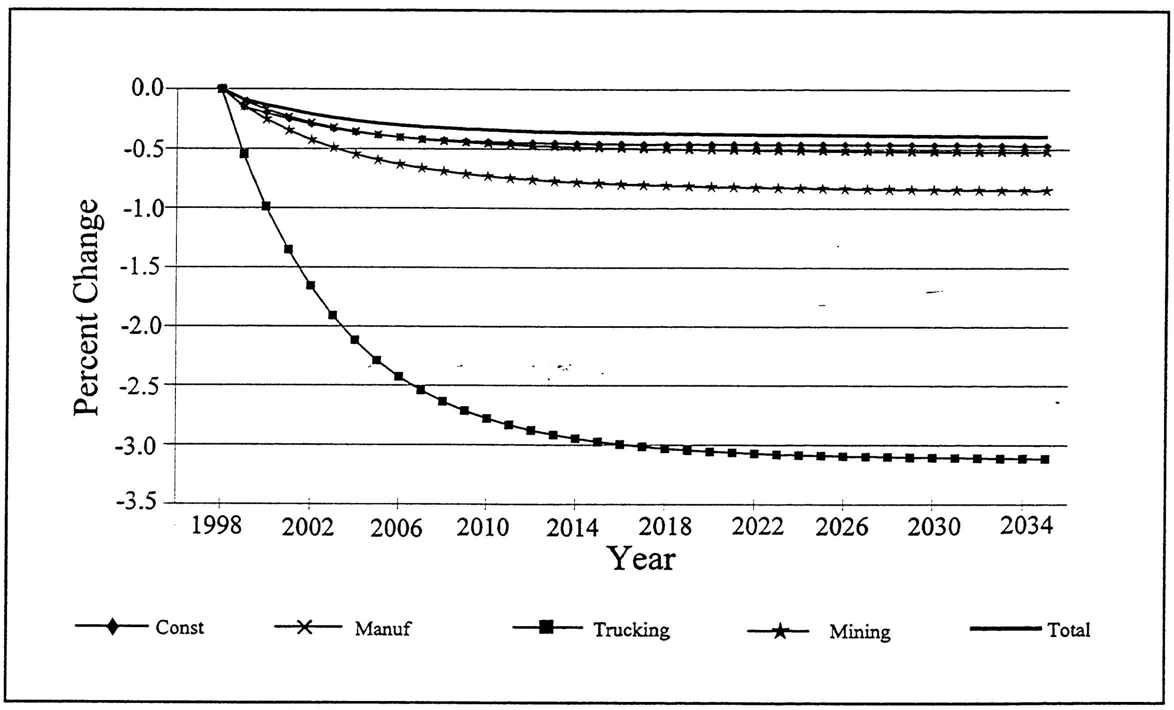

Figure D.2-2 Percent Change in GSP (Value Added) by Sector, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline

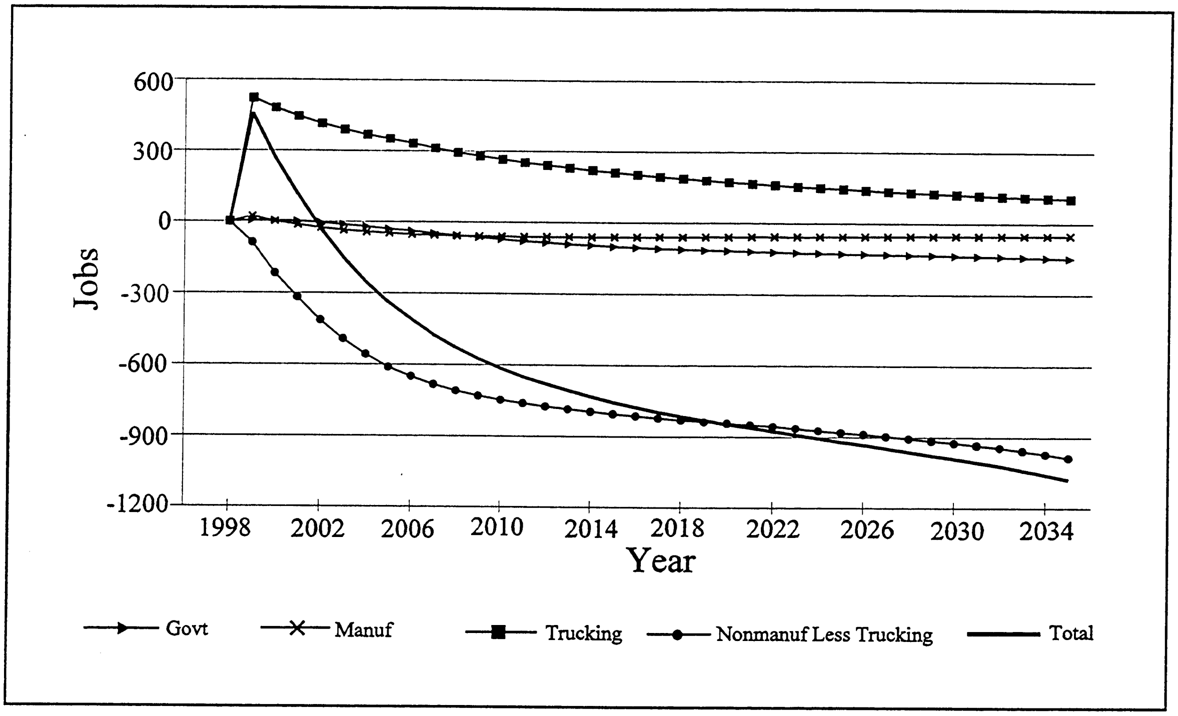

Figure D.2-3 Change in Non-farm Employment by Sector, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline, Measured in Jobs

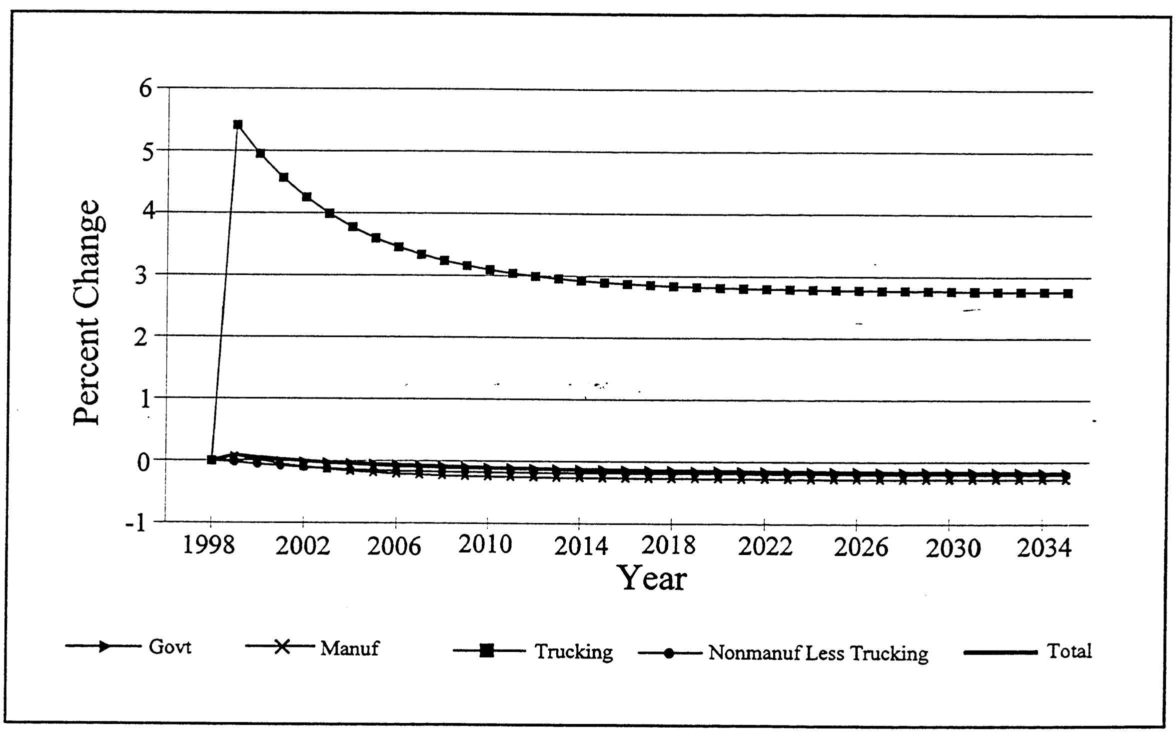

Figure D.2-4 Percent Change in Non-farm Employment by Sector, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline

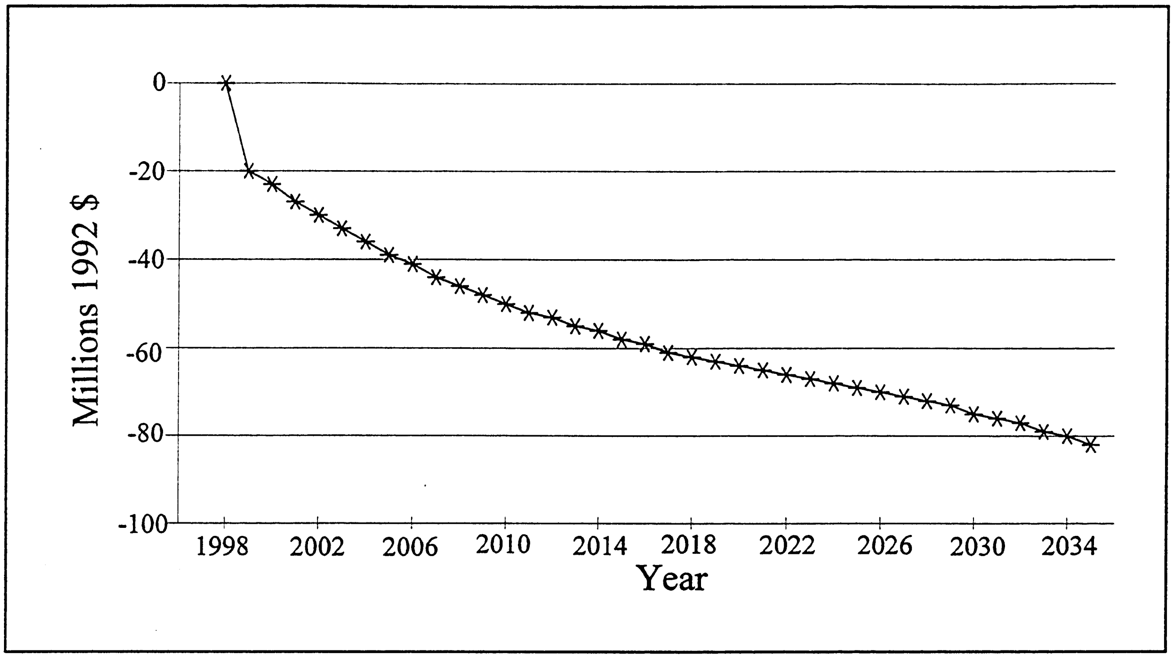

Figure D.2-5 Change in Real Disposable Personal Income, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline, Measured in Dollars

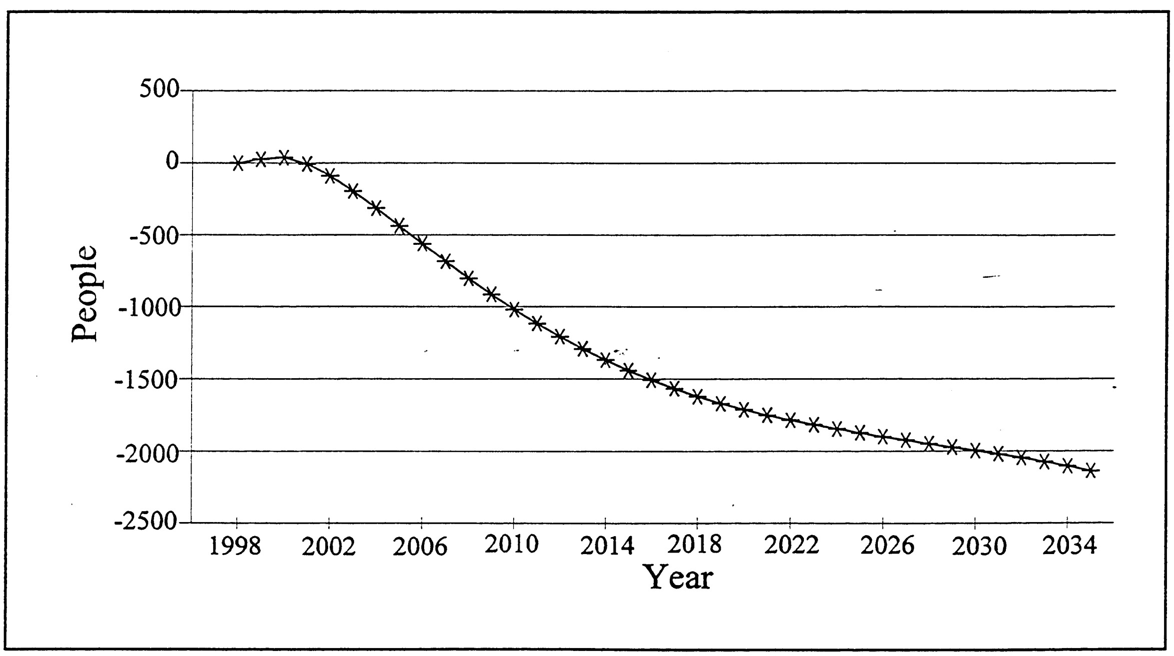

Figure D.2-6 Change in Population, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline, Measured in Number of People

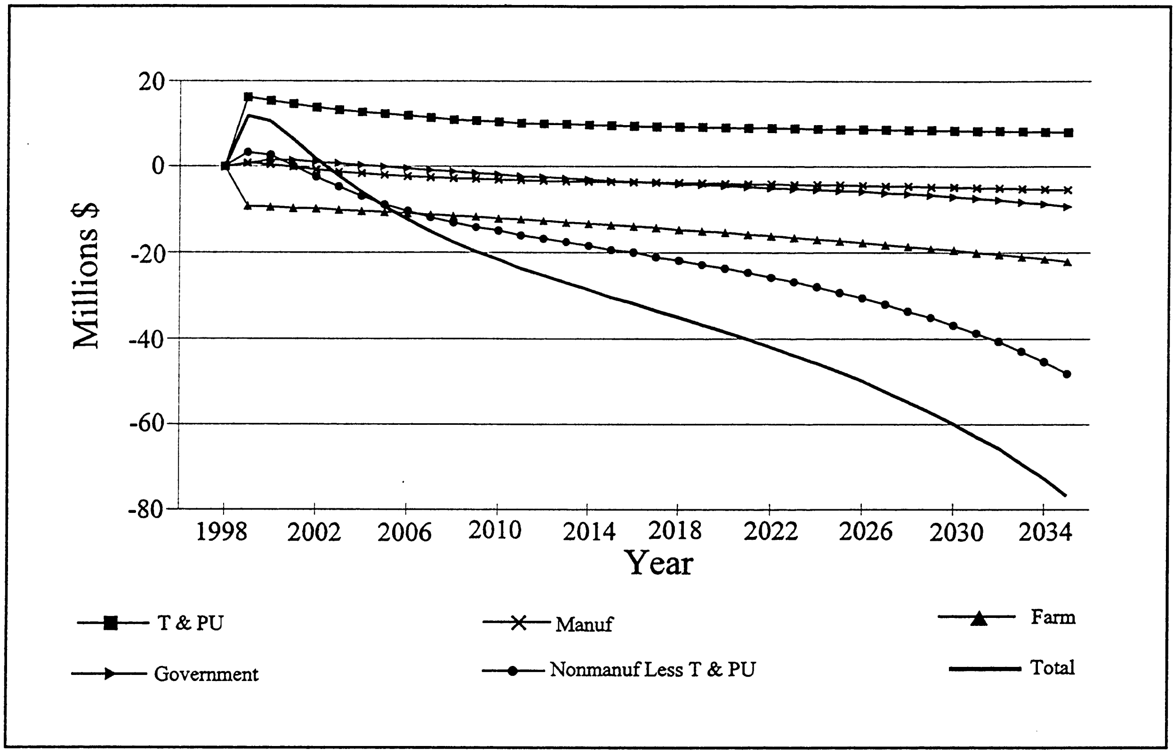

Figure D.2-7 Change in Labor & Proprietor's Income, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline, Measured in Dollars

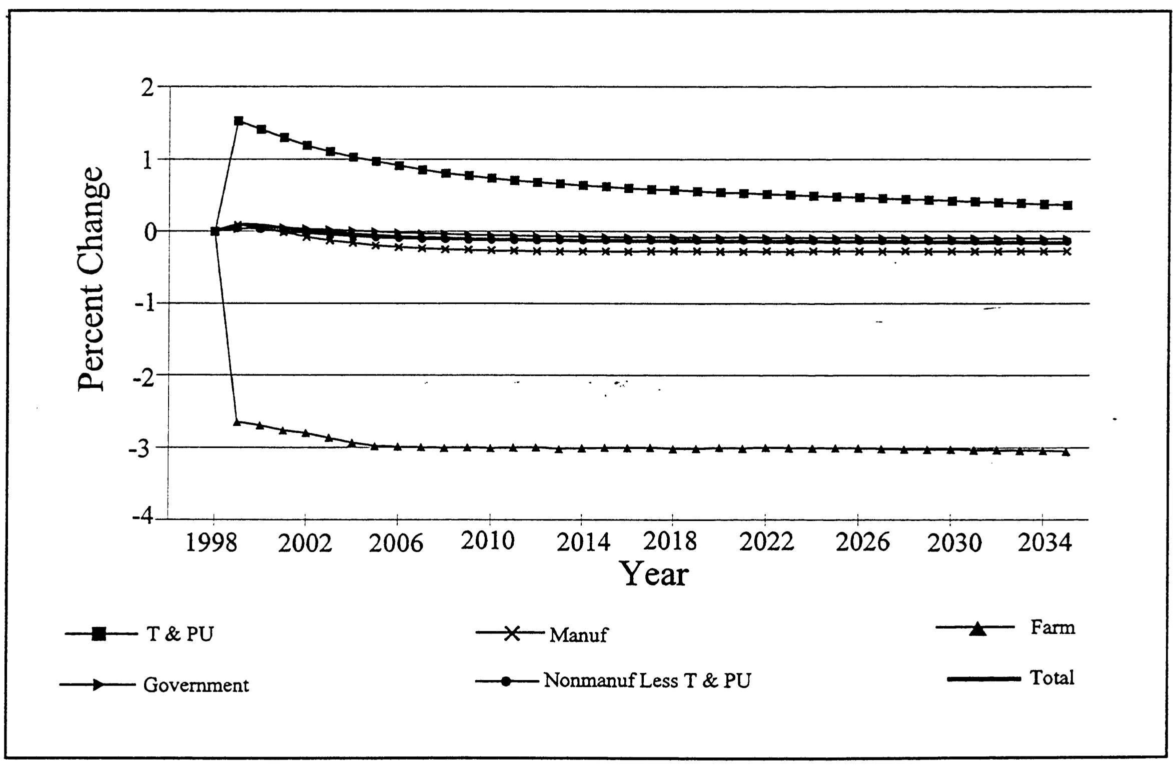

Figure D.2-8 Percent Change in Labor & Proprietor's Income, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline

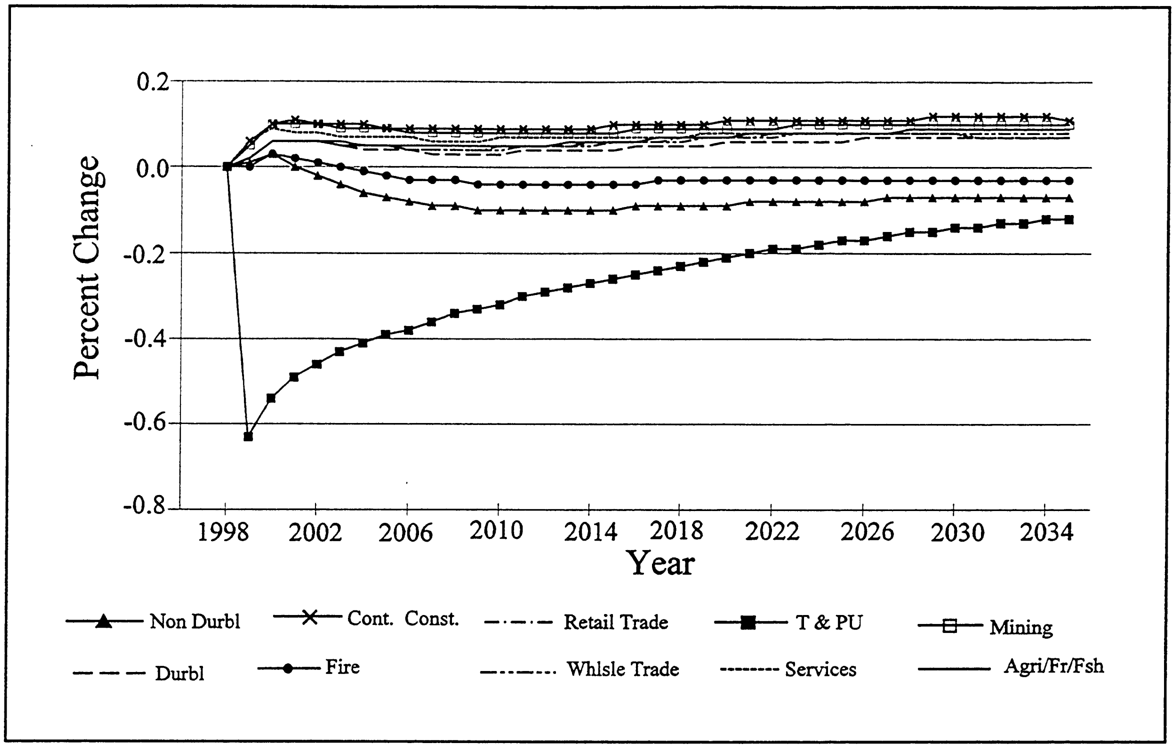

Figure D.2-9 Percent Change in Average Annual Wage Rate by Sector, 39,900 Kilogram (88,000 lb) Scenario Compared to the Baseline

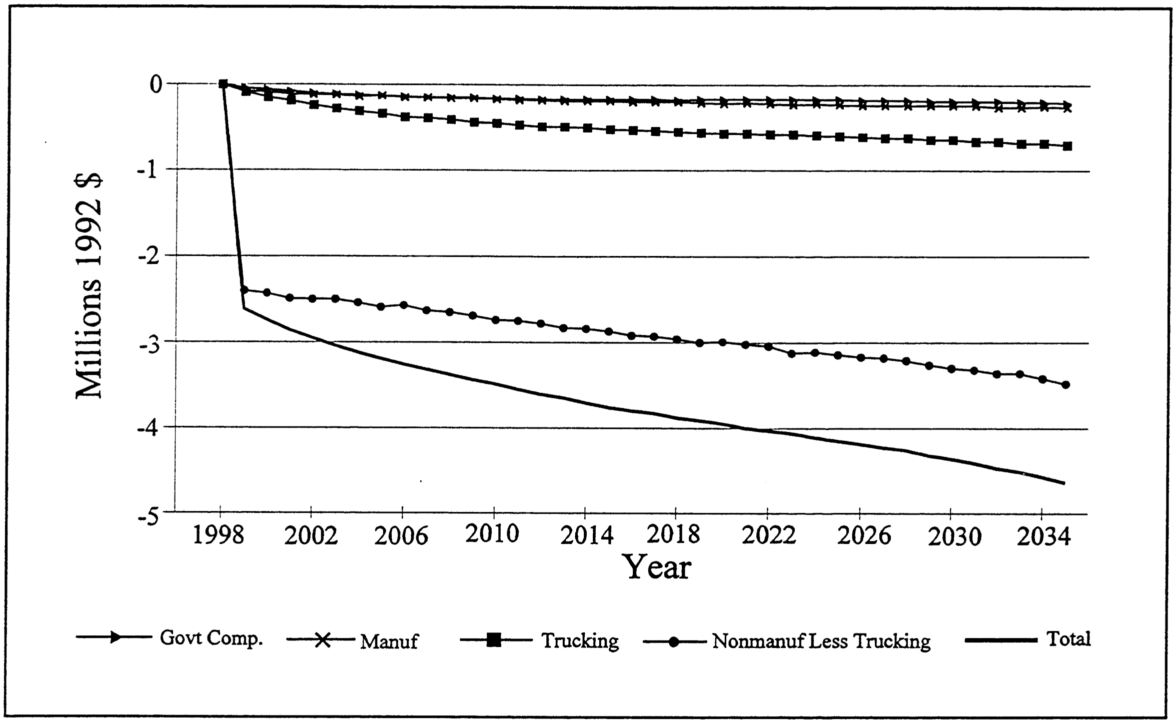

Figure D.3-1 Change in GSP (Value Added) by Sector, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline, Measured in Dollars

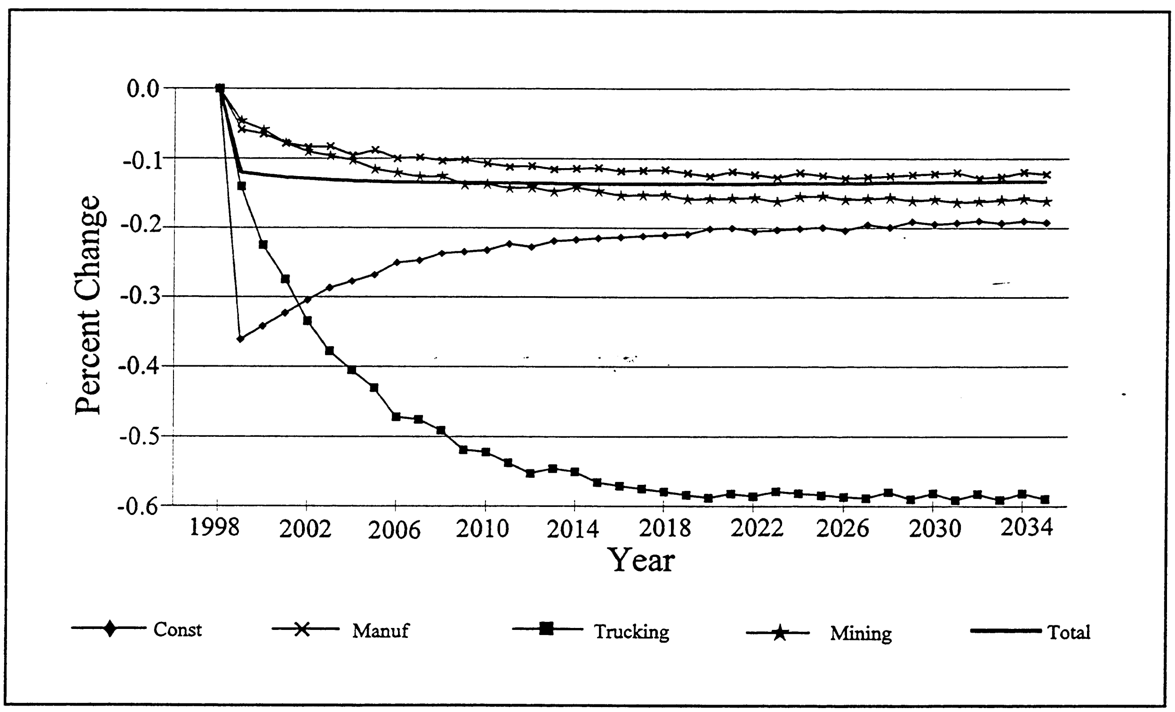

Figure D.3-2 Percent Change in GSP (Value Added) by Sector, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline

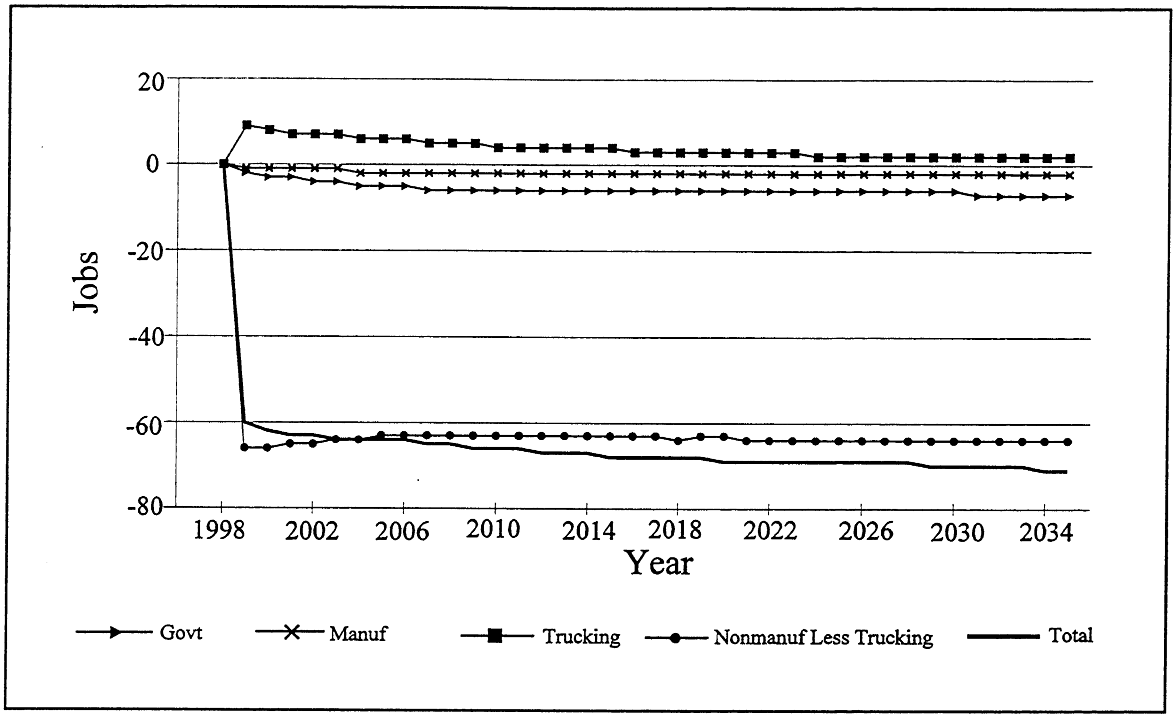

Figure D.3-3 Change in Non-farm Employment by Sector, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline, Measured in Jobs

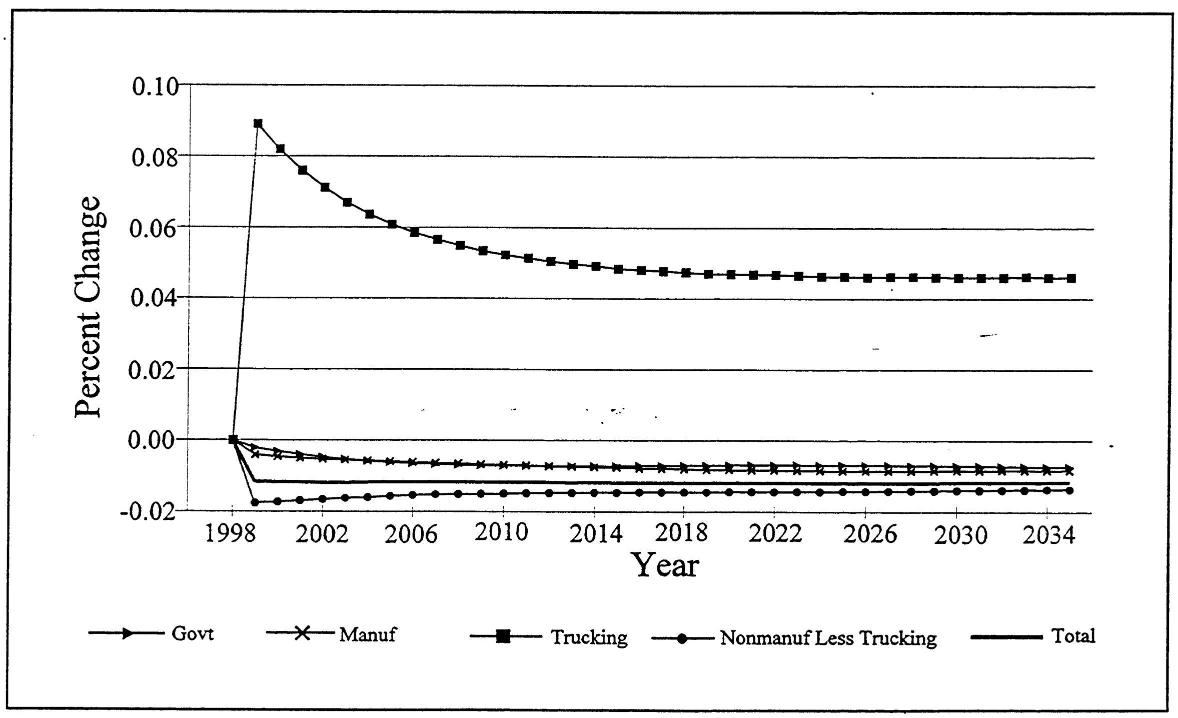

Figure D.3-4 Percent Change in Non-farm Employment by Sector, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline

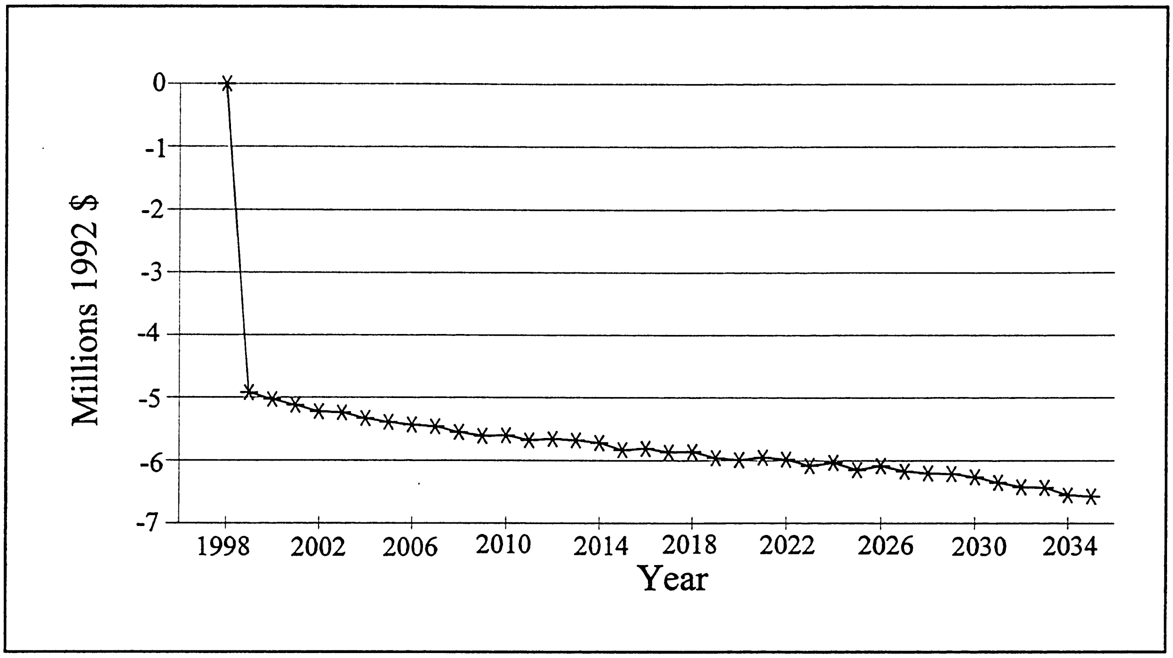

Figure D.3-5 Change in Real Disposable Personal Income, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline, Measured in Dollars

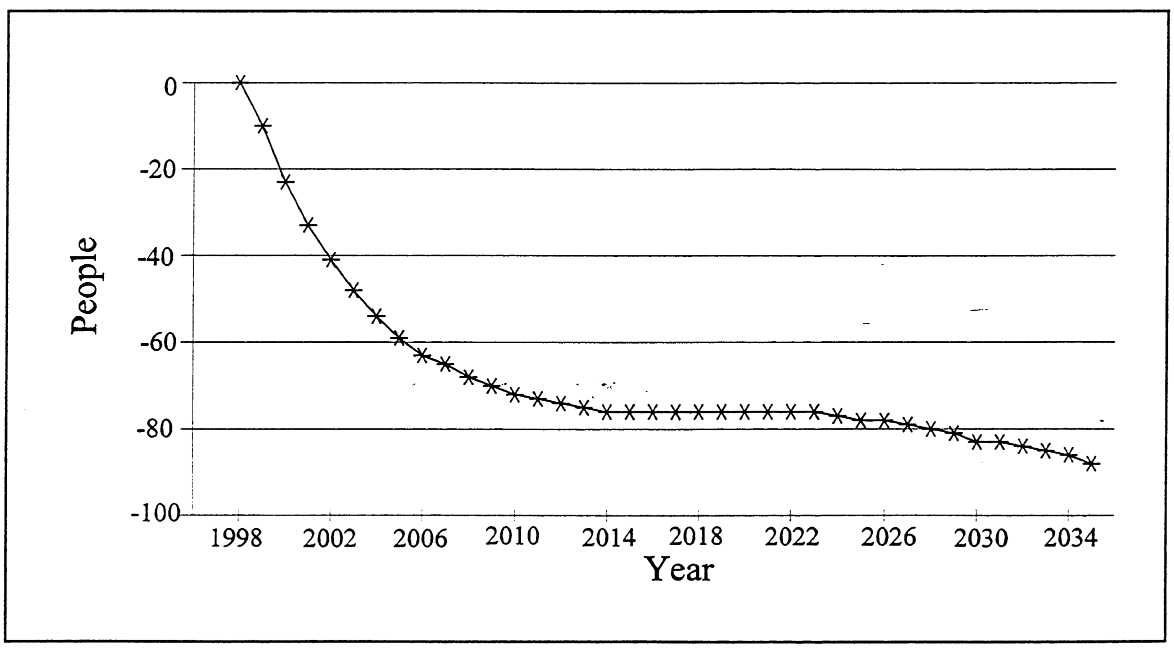

Figure D.3-6 Change in Population, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline, Measured in Number of People

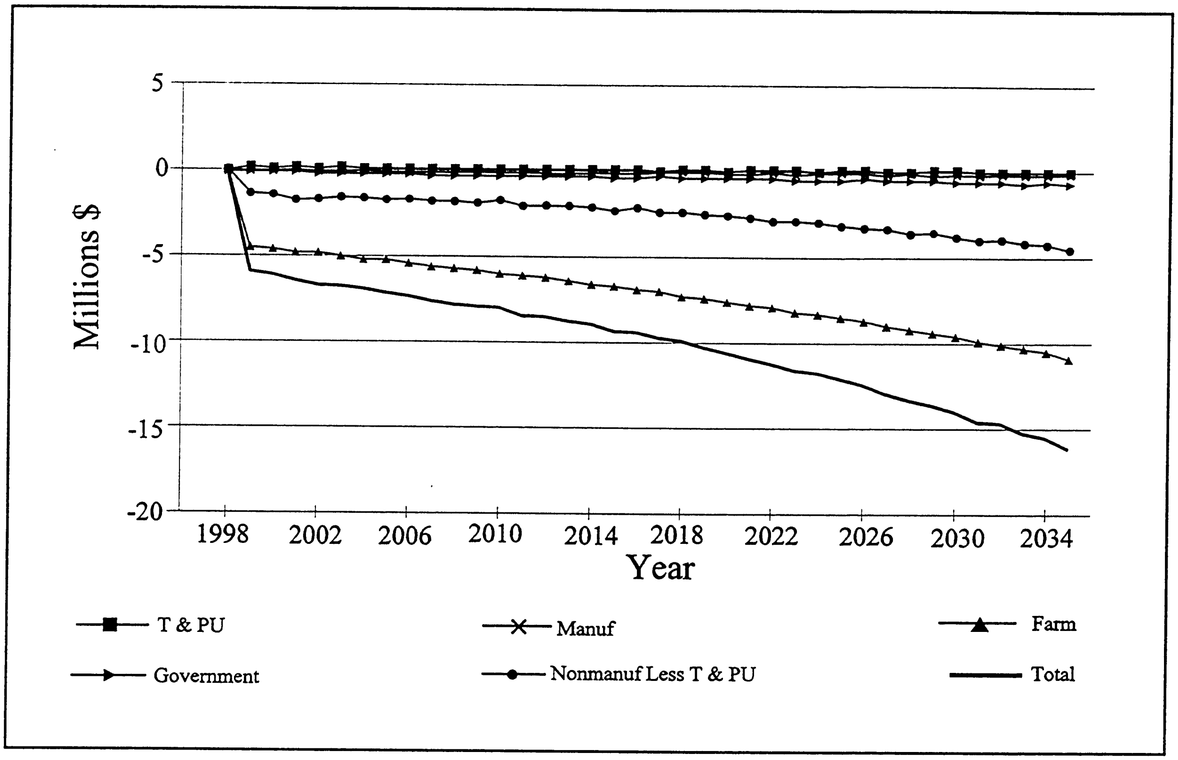

Figure D.3-7 Change in Labor & Proprietor's Income, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline, Measured in Dollars

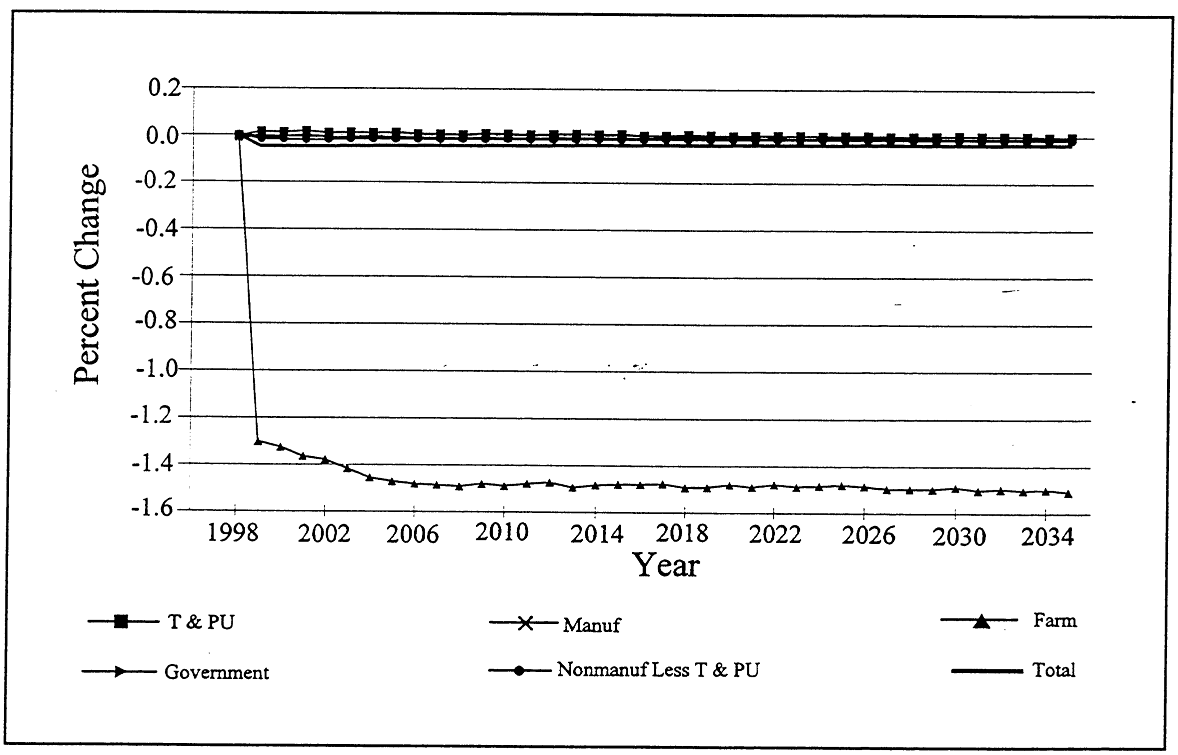

Figure D.3-8 Percent Change in Labor & Proprietor's Income, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline

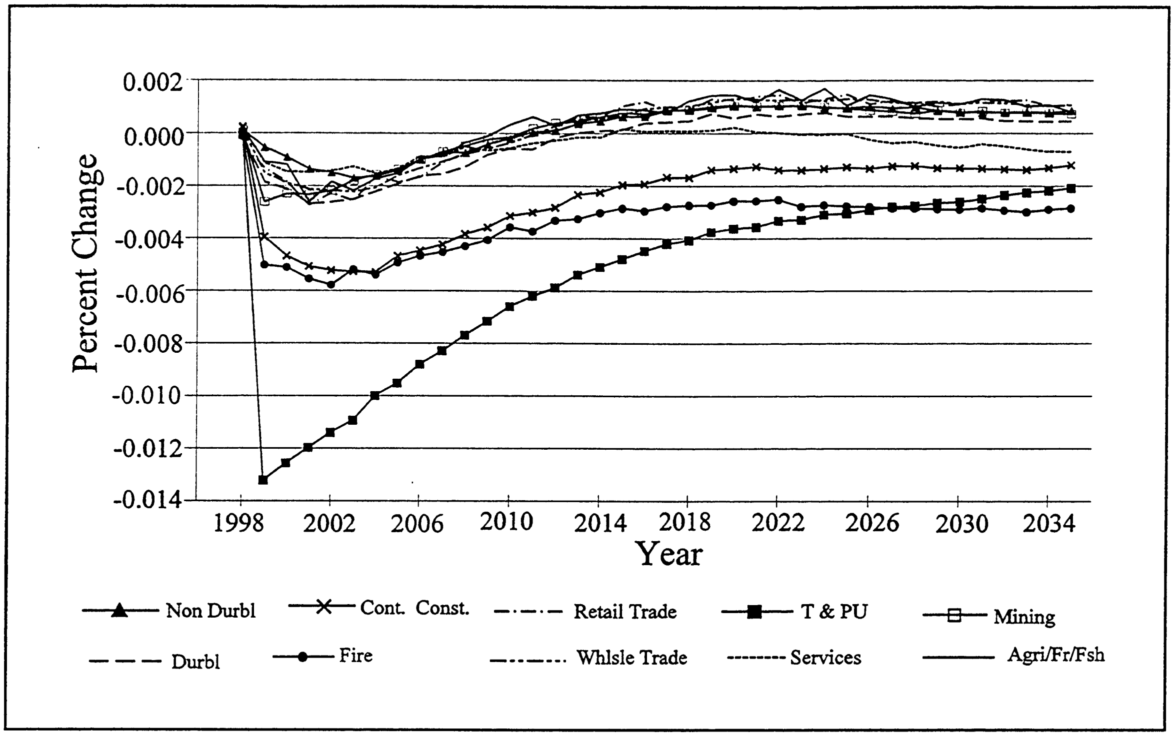

Figure D.3-9 Percent Change in Average Annual Wage Rate by Sector, 47,900 Kilogram (105,500 lb) Scenario Compared to the Baseline

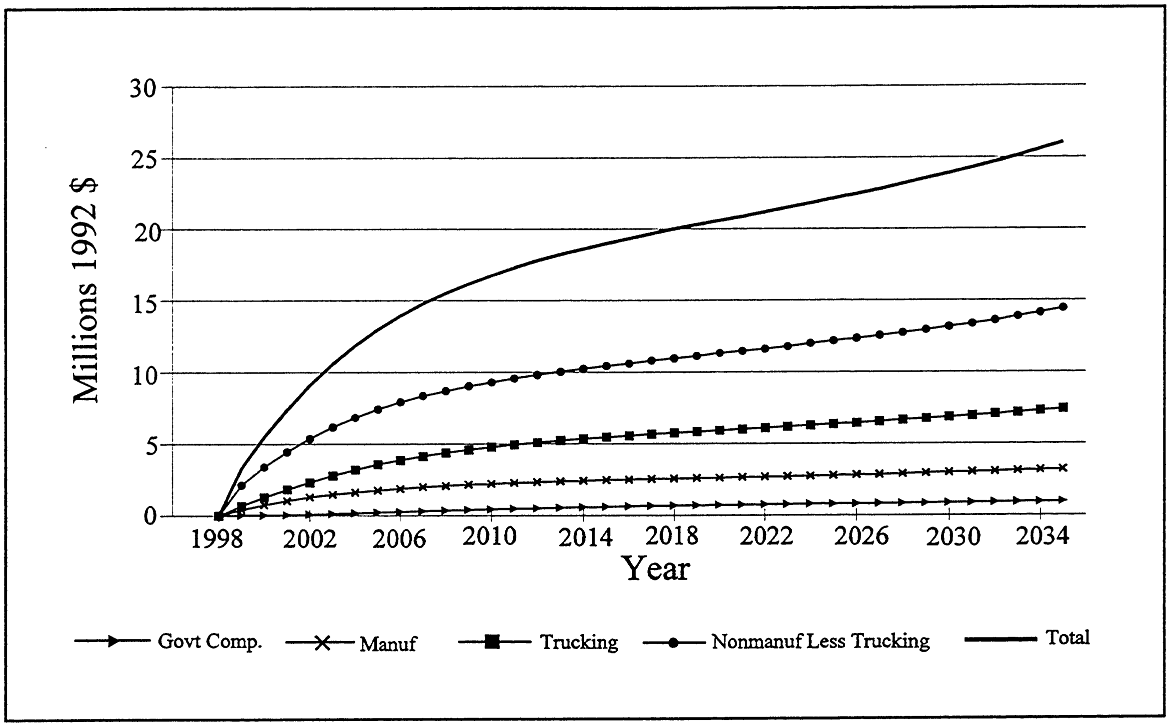

Figure D.4-1 Change in GSP (Value Added) by Sector, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline, Measured in Dollars

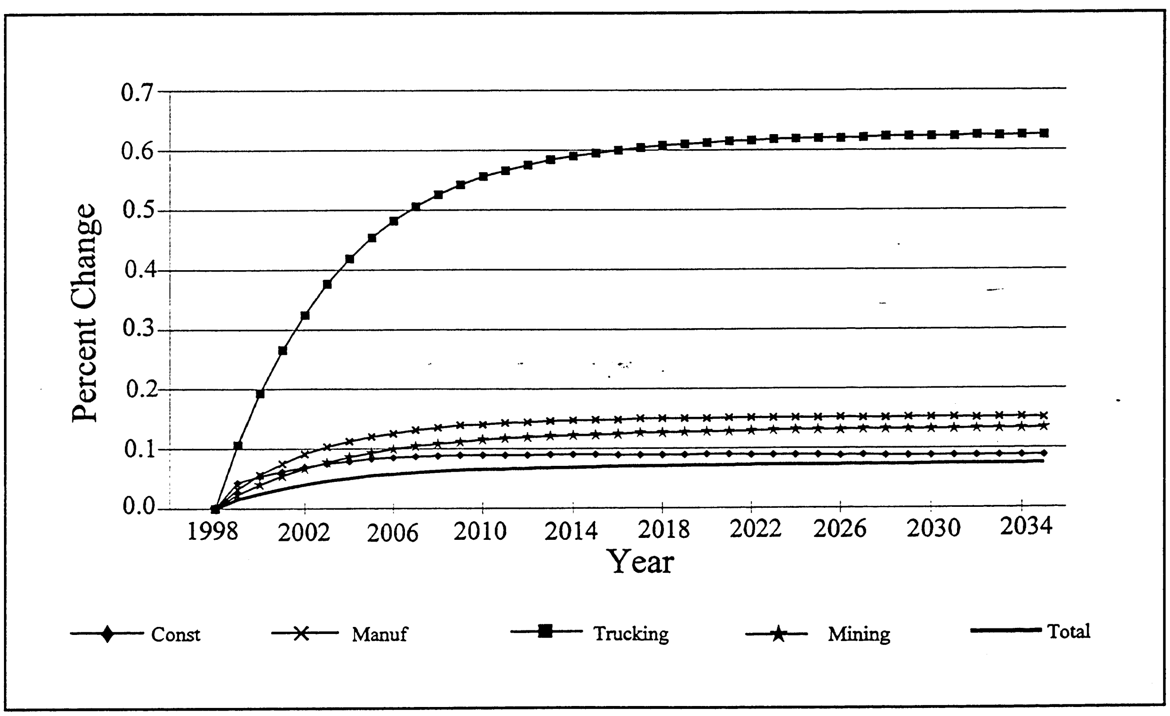

Figure D.4-2 Percent Change in GSP (Value Added) by Sector, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline

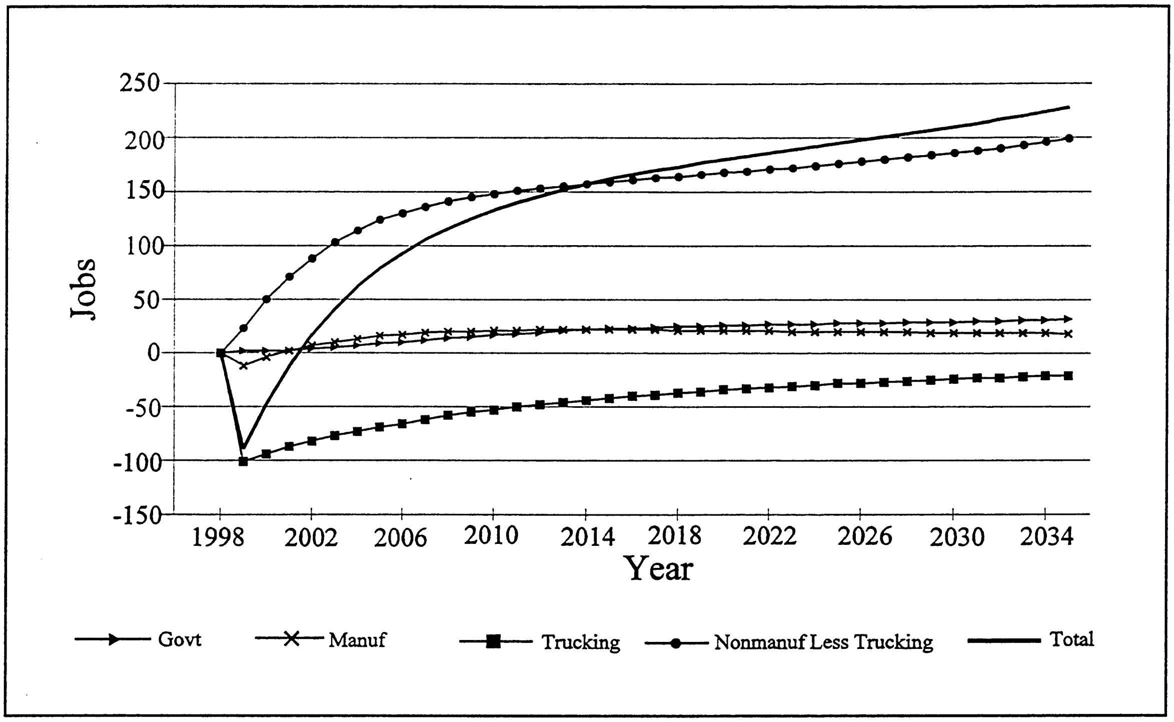

Figure D.4-3 Change in Non-farm Employment by Sector, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline, Measured in Jobs

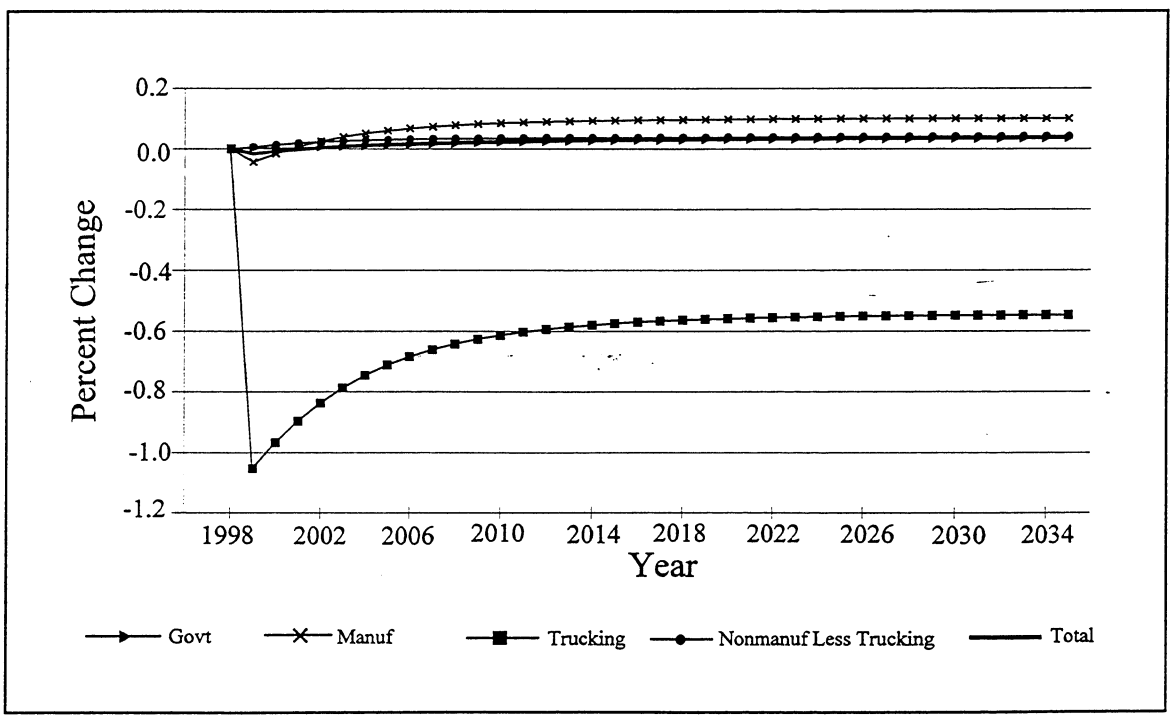

Figure D.4-4 Percent Change in Non-farm Employment by Sector, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline

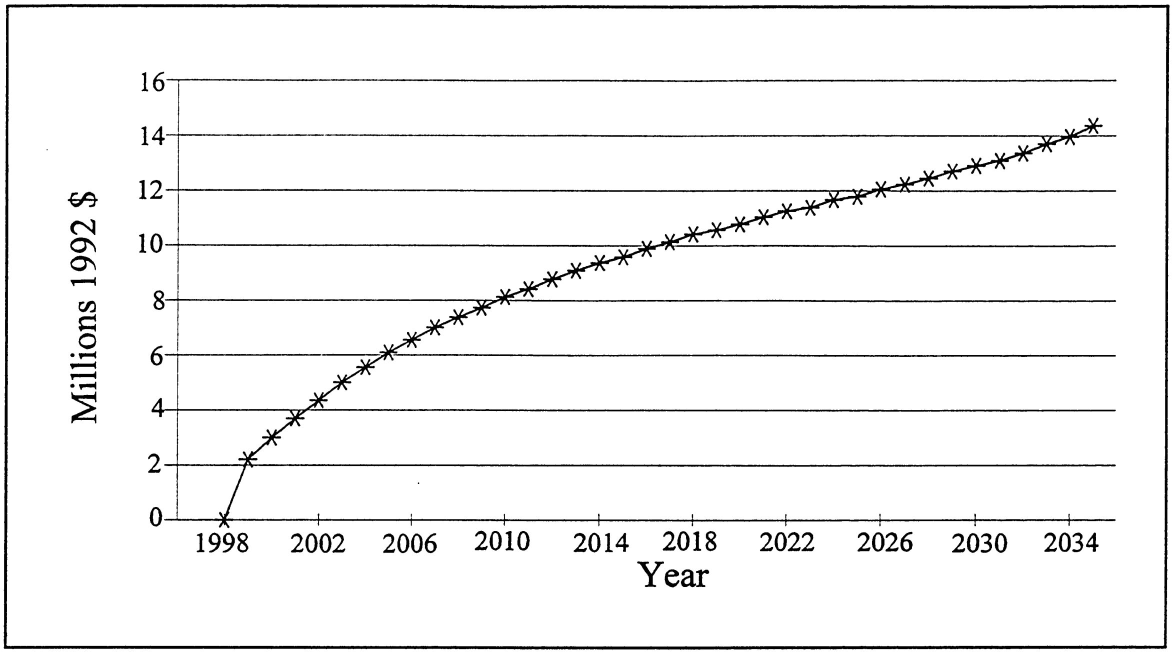

Figure D.4-5 Change in Real Disposable Personal Income, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline, Measured in Dollars

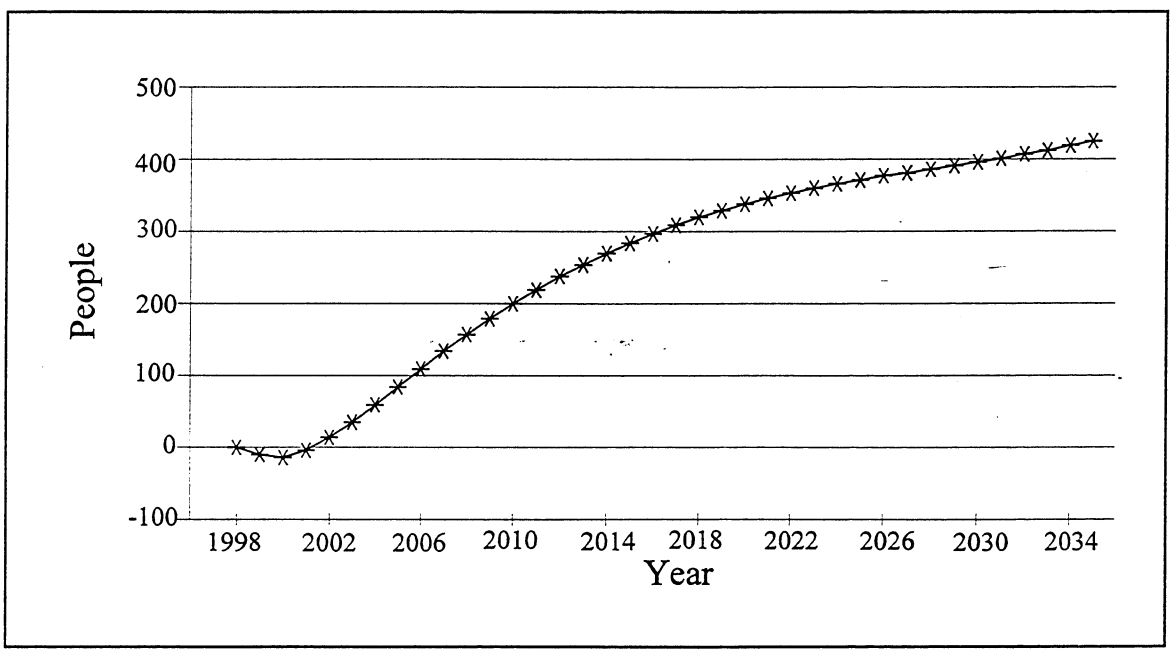

Figure D.4-6 Change in Population, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline, Measured in Number of People

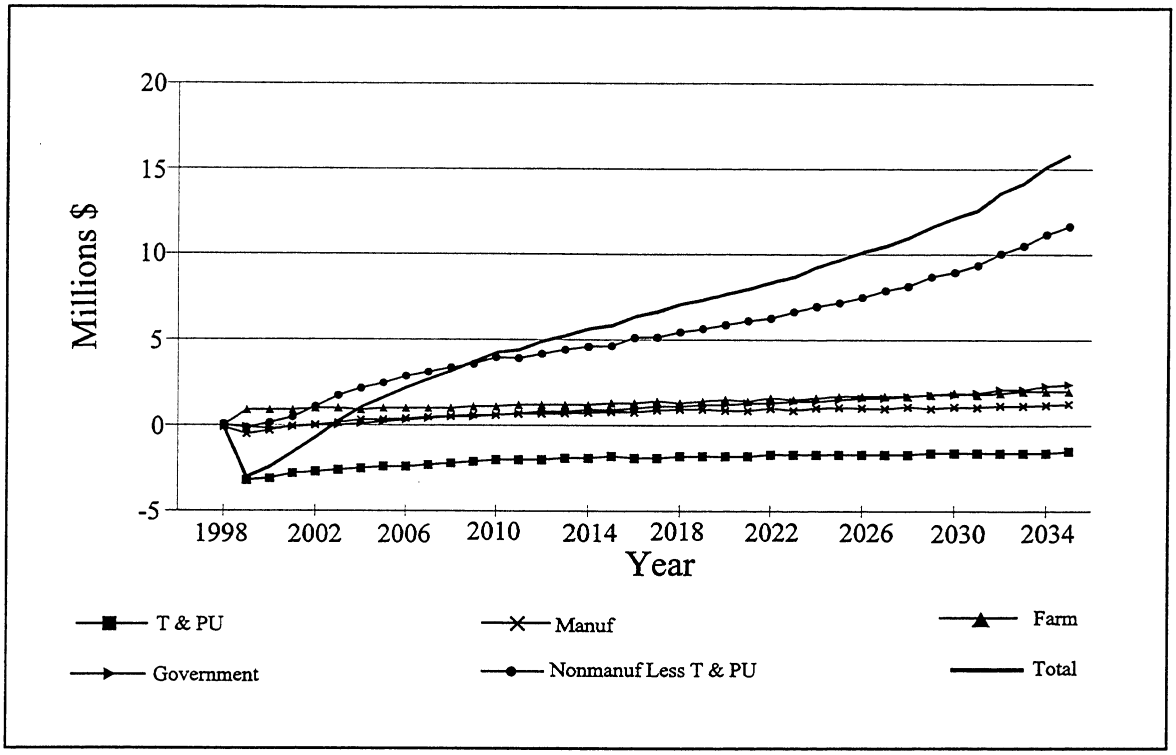

Figure D.4-7 Change in Labor & Proprietor's Income, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline, Measured in Dollars

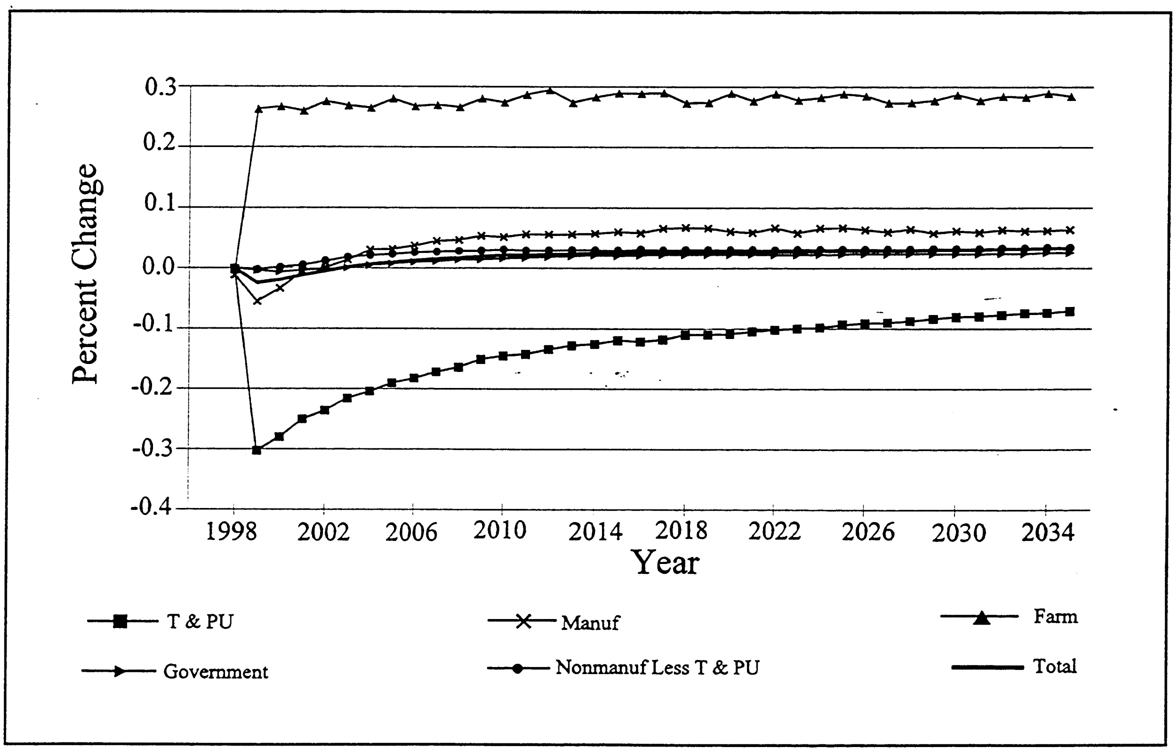

Figure D.4-8 Percent Change in Labor & Proprietor's Income, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline

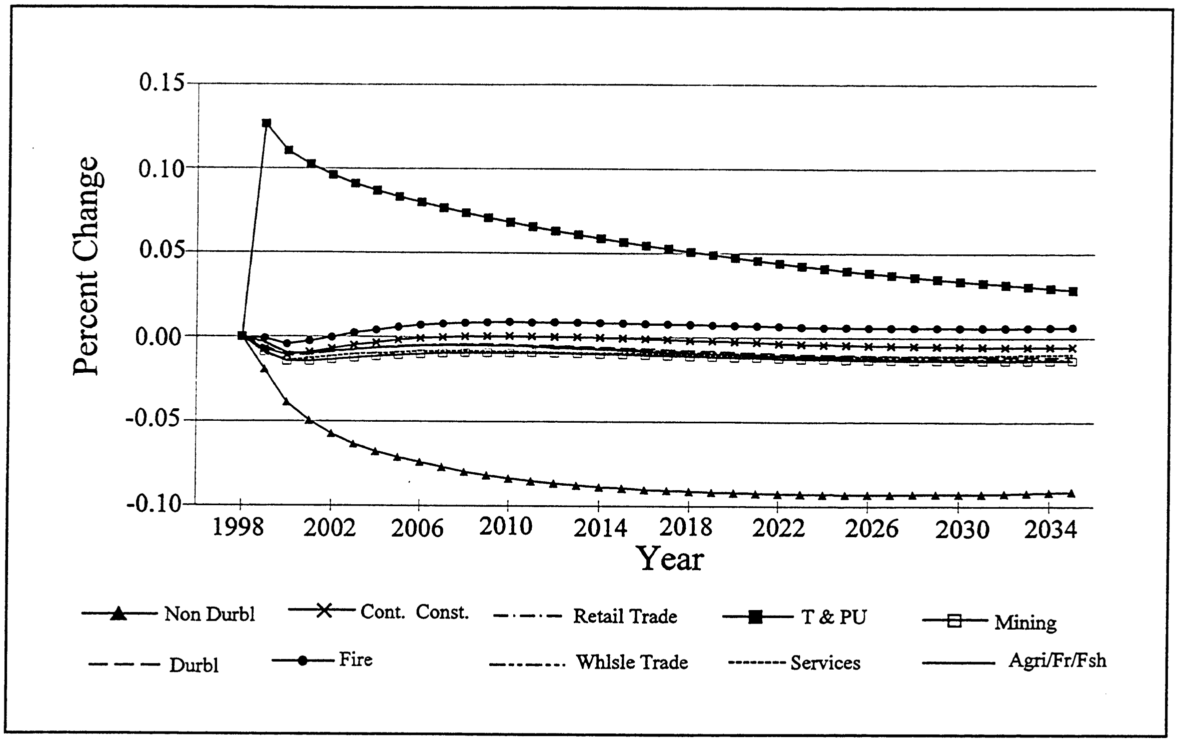

Figure D.4-9 Percent Change in Average Annual Wage Rate by Sector, 58,100 Kilogram (128,000 lb) Scenario Compared to the Baseline