CHAPTER 4. PAVEMENT DAMAGE ESTIMATES

This chapter presents the results of the estimated pavement damage due to the operations of the divisible-load permit vehicle fleet in NYS. It notes the key assumptions, the details of the methodology applied, and it illustrates this methodology by means of an example. Results are shown in Tables 4.1 through 4.6, with the associated Figures, at the end of the chapter.

4.1. Balance between Benefits and Costs of the Permit System

The main objective of this research project was the estimation of the economic impacts of the divisible-load permit system for New York State. These impacts turned out to be positive, as was to be expected intuitively, however the magnitude of the economic benefits that are estimated in Chapter 5 may be somewhat surprising. To put this analysis and the findings into proper perspective, it is equally essential that the negative impacts, including costs to the infrastructure, be estimated.

The primary economic benefits are almost exclusively accrued by the private sector, namely by the permit vehicle operators, while the costs (damage) to the infrastructure fall into the domain of the public sector. In this research, the infrastructure costs refer only to pavement damage. Impacts on bridges could not be considered, simply because the information on bridge crossings by permit vehicles was not available. A much more detailed and microscopic analysis of specific vehicle movements would have had to be conducted, based on a very expensive and time-consuming data collection effort, to obtain a reasonable estimate of bridge infrastructure damage.

An argument can also be made that in addition to pavement and bridge damages, safety impacts of extra-heavy vehicles, as well as their psychological impact on the traveling public should be considered as a cost of permitting vehicles to operate with loads larger than the federal limits. These psychological impacts are, of course, difficult to quantify and, hence, to analyze. With respect to safety impacts, it can be argued that the divisible-load permit system results in fewer trips being made, given a specific overall demand for freight tonnage to be moved. If one assumes legal operations, i. e. those not exceeding maximum loads as specified by the vehicle manufacturer, and regular vehicle safety maintenance (e.g. brakes, tires, steering), it is reasonable to argue that because fewer trucks are on the highways, the probability of an accident involving a truck will be smaller due to reduced conflict exposure.

The survey data developed in the course of this project was detailed enough to estimate seasonal costs to the road infrastructure for the three main classes of highways (interstates, state and local roads), thus permitting the differentiation of damages depending on the actual travel of permit vehicles along each highway class.

The literature and practice of pavement damage estimation varies a great deal. A number of schools of thought and practice are represented across the U.S. and across nations. It is apparent that the use of different pavement damage functions (e.g. by simply using different exponents) could generate very different results. Furthermore, it is important to note the specific assumptions that were made in the estimation of pavement damage for this project.

One key assumption pertains to the pavement damage costs of Equivalent Single Axle Loadings (ESAL) per mile, by road class. For this study the costs were taken as $0.02, $0.06, and $0.40 for interstate, state, and local highways, respectively. These values were selected by the research team based on conversations with state highway officials and on the literature. It should be noted that these values, expressed in 1987 dollars, are on the low side, compared to those reported in the 1982 FHWA Highway Cost Allocation Study of road damage (FHWA, 1982).

It should also be noted that the authors decided to use the present methodology to maintain compatibility with the predecessor to this study (Op. cit., 1987) in order to meaningfully compare summer results. One strong point of this methodology is the use of reported, rather than generic, data to perform the calculations. However, a careful examination of answers to the surveys lead the authors to caution that the results presented herein give only an order of magnitude estimation of costs and benefits. They are meant for illustrative purposes only. Additional sources of imprecision and uncertainty include recording, reporting and interpretation of the survey results.

The authors feel comfortable that the assumptions used in this study are reasonable. The methodology developed herein often relies on simple procedures which are used in practice by some, albeit not by all, highway agencies.

The following sections describe in detail the procedure used to estimate pavement damage based on the operations of the divisible-load permit fleet in New York State.

4.2 Procedure Used to Estimate Pavement Damage

4.2.1. Comments about the Procedure

The input data necessary to perform the computations consist of vehicle tare weight (vehicle without load), the distance between the first and each subsequent axle, and for each loaded trip, axle loadings and mileage on each type of road (interstates, state, and local roads).

The two key pieces of information needed to perform the calculations are mileage and Gross Vehicle Weight. Most operators, whose trucks made loaded trips, provided this information. However, only some of the respondents provided axle loading information. It appears, from the comments we received, that operators often do not know the weight carried on individual axles. When only the GVW was given, it was generally possible to estimate axle loadings from similar trucks (same axle configuration, same body style, and, whenever possible, same make and year) in one of the three surveys. Similarly, it was often possible to obtain the tare weight or the distance between the first and each subsequent axle. Operators did not seem to have problems providing this information, since it was not very time consuming and it did not change for each trip. However, many operators probably felt that it would require too much time to weigh each individual axle, each time the gross weight changed. From the comments received, it appears that a large fraction of the operators surveyed generally did not know individual axle loadings and had only an approximate idea of the GVW. This seems to hold true particularly in the construction industry.

Because some operators provided incomplete information, not all trucks (or trips) could be included in the calculations. Only trucks (or trips) for which all the necessary information was available or could be reasonably estimated from the data at hand were used for estimating pavement damage. An alternate procedure which prorated damages based on the ratio of loaded miles traveled by partial information respondents divided by loaded miles traveled by full information respondents was also considered. It was found to yield similar results so the simpler procedure, presented below, was retained.

4.2.2. Pavement Damage Estimation under the Permit System

The **input data** needed for each loaded trip were the following:

- Axle loadings (lbs.), and
- Mileage on interstate, state, and local roads.

The **computational procedure** used is described below:

The following steps were undertaken for each loaded trip for which all the input data were provided or could be approximated:

Step 1a: Calculate the sum of the Equivalent Single Axle Load (ESAL) by:

$$\text{E.S.A.L.} = \sum_{i=1}^{\text{Number of axles}} \left(\frac{\text{Load on axle i (lbs)}}{18{,}000 \text{ lbs}} \right)^4 \qquad (4.1)$$

Step 2a: Calculate the damage cost for each road type by multiplying the sum of the ESAL by the mileage driven on this road type for the trip considered, and by a cost per mile ($0.02/mi for interstates, $0.06/mi for state roads, and $0.40/mi for local roads).

Then, aggregate the results as follows:

Step 3a: Add up the cost of each trip for each road type to obtain a sample damage estimate for each road type. Divide the sample estimate by the number of trucks used to calculate it.

Step 4a: Multiply the damage per truck obtained in the previous step by 12822 times 65 times the average seasonal fraction of trucks on the road. In the above, 12822 is the size of the permitted trucks fleet and 65 is the assumed number of work days per season.

4.2.3. Pavement Damage Estimation under the Federal System

The input data used were

- Vehicle tare weight (lbs.)
- Distance between the first and each subsequent axle (in.),

and for each loaded trip,

- Axle loadings (lbs.), and
- Mileage on interstate, state, and local roads.

The computations were executed as shown in the following steps:

Step 1b: Calculate the Allowed Federal Axle Loading by:

$$\text{Weight (lbs)} = 500\left(\frac{L\,N}{N-1} + 12\,N + 36\right) \tag{4.2}$$

where: L is the distance (feet) between the two axles considered, and N is the number of axles considered.
In addition, the maximum load on any single axle is limited to 20,000 lbs. Equation 4.2, often called the "Bridge Formula," is used between an axle and the neighboring ones and the most stringent requirements are retained.

Then the following procedure was applied, for each trip:

Step 2b: For each axle, calculate the ratio of the actual axle load to the allowed federal axle load. Select the highest ratio or 1, whichever is greater. Denote this number as F.

Step 3b: Calculate the maximum allowed federal gross weight as the ratio of the actual GVW to F. This assumes that the truck would be loaded "similarly" under the federal system, but with a smaller total weight.

Step 4b: Calculate the maximum GVW the truck would carry under the federal system as the minimum of its actual GVW and its allowed federal GVW.

Step 5b: Calculate the truck maximum payload under the federal system for the trip considered.

Step 6b: Take the ratio of the actual payload to its permitted maximum payload to obtain the equivalent number of trips this truck would make under the federal system.

Step 7b: Calculate the new sum of the ESAL as sum of the ESAL obtained under the permit system multiplied by the equivalent number of trips under the federal system and divided by F raised to the 4th power.

Step 8b: Calculate the damage costs for each road type by multiplying the sum of the ESAL by the mileage on this road type for the trip considered, and by a cost per mile ($0.02/mi for interstates, $0.06/mi for state roads, and $0.40/mi for local roads).

Then, aggregate the results, following steps 3a and 4a described above.

4.2.4. Pavement Damage Estimation for 125%, 135%, or 145% of Federal Statutes

In this case the procedure used is similar to the one presented in the pavement damage analysis under the federal system. The only difference is at the end of Step 1, where the allowable axle loads considered under the federal system are multiplied by 1.25, 1.35, or 1.45 for 125%, 135%, or 145% of the federal Statutes, respectively. In the illustrative example that follows, the steps corresponding to these calculations are identified by a number, followed by a "c".

4.2.5. Example of Pavement Damage Cost Estimation

We illustrate the procedures described above on "truck 67" from the Fall 1991 survey. It is a 1975 three-axle Ford ready-mix concrete truck. We know from the survey that this truck made two similar loaded trips on the survey date, both of 9 miles length, with 5 miles on state roads and 4 miles on local roads. Its tare weight was 28,920. lbs., and the distances between the first, and second and third axles were 13'5" and 17'8", respectively. For trip 1, the axle loadings were 19,750 lbs., 20,430 lbs., and 20,425 lbs. on the first, second, and third axle, respectively, for a total GVW of 60,605 lbs. Hence, the net weight carried was 60,605-28,920 = 31,685 lbs. Only trip number 1 is considered in the calculations presented below.

4.2.5.1. Pavement Damage Estimation under the Permit System

Step 1a: ESAL = (19,750/18,000)4 + (20,430/18,000)4 + (20,425/18,000)4 = 4.77

Step 2a: Damage to state roads = 4.77 * $0.06/mi x 5 mi = $1.43
Damage to local roads = 4.77 * $0.40/mi x 4 mi = $7.63
No damage to interstate Highways.

The results are then aggregated, as explained in section 4.2.2.

4.2.5.2. Pavement Damage Estimation under the Federal System

Step 1b: Using the Bridge Formula, we calculate that each axle can carry 16,000 lbs (rounded).

Step 2b: F = Max (1, 19,750/16,000, 20,430/16,000, 20,425/16,000) = 1.277.

Step 3b: The federal allowed gross weight is 60,605/1.277 = 47,460 lbs.

Step 4b: Min (60605, 47460) = 47,460 lbs.

Step 5b: Maximum payload = 47,464 - 28,920 = 18,540 lbs.

Step 6b: Equivalent number of trips = 31,685/18,540 = 1.71 trips

Step 7b: New ESAL = old ESAL / 1.2774 x 1.71 = 3.06

Step 8b: Damage to state roads = 3.06 x $0.06/mi * 5 mi = $0.92
Damage to local roads = 3.06 * $0.40/mi x 4 mi = $4.90

The results are then aggregated, as explained in section 4.2.2.

4.2.5.3. Pavement Damage under 125% of the Federal System

Step 1c: We assume that each axle can now carry 1.25 times its federal load, i.e. 20,000 lbs.

Step 2c: F = Max (1, 19,750/20,000, 20,430/20,000, 20,425/20,000) = 1.0215.

Step 3c: The federal allowed gross weight is 60,605/1.0215 = 59,329 lbs.

Step 4c: Min (60,605 lbs., 59,329 lbs.) = 59,329 lbs.

Step 5c: Maximum payload = (59, 329 - 28,920) = 30,409 lbs.

Step 6c: Equivalent number of trips = 31,685/30,409 = 1.042 trips.

Step 7c: New ESAL = old ESAL / 1.0215^4 * 1.042 = 4.56

Step 8c: Damage to state Roads: 4.56 * $0.06/mi * 5 mi = $1.37.
Damage to local Roads: 4.56 * $0.40/mi * 4 mi = $7.30.

Pavement damage under 135% or 145% of the federal system can be calculated in a similar fashion, as explained in section 4.2.4.

4.2.6. Further Comments about the Methodology

For the calculation of pavement damage, only loaded trips are considered. There are essentially two reasons why empty trips are not considered:

i. Axle loadings of empty permit trucks are almost never provided in the survey responses. The questionnaire did not ask for these explicitly and they are probably unknown to the truck operators. The operators informed us several times in their survey comments that they often do not know the axle loadings of their loaded permit trucks. They seem to be concerned primarily with the GVW.

ii. Based on *Equation 4.1.*, used to calculate ESAL , it seems reasonable to expect the damage due to empty permit vehicles to be negligible, compared to the damage caused by loaded permit vehicles.

As mentioned above, some information necessary for the pavement damage calculation was missing from the questionnaire or was obviously erroneous. To estimate these parameters, the data were entered in a Quattro Pro database. Then distance between axles, tare, and axle loading were estimated from permit vehicles with the same axle configuration, vehicle type, and body type, but also, whenever possible, with the same make and year. We were thus able to "recover" most of the missing information. In no case, however, did we estimate mileage or GVW. While we realize that axle loading information is critical to the calculation procedures, it is important to remember that some operators did not know the loading of each individual axle. In order to have as much truck usage information available in each business category as possible, it was critical to make some assumptions about the axle loading of some of the trucks in the sample. In this context, choosing the axle loading provided for "similar" trucks appears to be reasonable. It is clear, however, that a few, very unevenly loaded trucks could create very significant road damage. Operators of these types of vehicles are unlikely to have answered our surveys. Therefore, it is possible that the estimates presented here give only a lower bound of pavement damage.

4.3. Results of Pavement Damage Estimation

An illustration of the methodology used for calculating the change in pavement damage resulting from an increase in the permitted weight limits is presented in Table 4.1. Calculations of the daily damage per truck were performed as detailed in the previous sections.

Results for the three surveys are presented in Tables 4.2 to 4.4, by road type, for the different weight scenarios considered: 125%, 135%, and 145% of the federal weight limits. Annual results for each weight scenario are shown in Table 4.5. Our computations show that increasing the weight limits to 125%, 135%, or 145% of the federal weight limits results in additional pavement damage of $19 million, $28 million, or $35 million per year respectively (all in 1987 dollars). These results are based on 65 working days per season and a permitted vehicles fleet of 12,822 power units.

Approximately 75% of the additional pavement damage under the weight scenarios is born by local roads, and 20% accrues to state roads. By comparison, the added damage to federal roads is quite small (5% of the total, less than $2 million per year). These numbers partly reflect the assumed costs per E.S.A.L.*mile for each road class ($0.02, $0.04, and $0.40 for interstate, state, and local roads respectively) but they are also strongly dependent on the number of loaded miles traveled on each road class. Table 4.6 provides a breakdown survey and by road class of these data. It shows that the number of loaded miles traveled on state roads is largest. The difference with local roads is larger in the fall, followed by winter and summer in this order.

Thus, seasonal differences in pavement damage estimates are related directly to the difference in permit vehicle usage by season, as discussed in Chapter 5, where the seasonal variations in economic benefits were assessed. A credible argument could be made that road damage varies depending on seasonal fluctuations in weather and, hence, in pavement conditions. Theoretically, one could take this into account and modify the parameters of the pavement damage function according to season. However, the only realistic and proper way would have to be based on (unavailable) information on the precise weather and pavement conditions during each of the trips undertaken by the vehicles in the permit fleet. This is obviously impossible to accomplish.

TABLE 4.1: ILLUSTRATION OF INCREMENTAL PAVEMENT DAMAGE ANALYSIS FOR 145% OF THE FEDERAL LIMITS

TABLE 4.1.1: SUMMER 1990 SURVEY

Road Class	Daily Damage per Truck Federal System	145% Fed. Limits	Increase in Daily Damage per Truck	% Increase in Damage	Truck Pop. Daily Increase in Damage
Local Road	$27.66	$47.30	$19.64	71%	$153,613
State Road	$5.25	$10.18	$4.93	94%	$38,560
Interstate	$1.99	$3.75	$1.76	88%	$13,766
All	$34.90	$61.23	$26.33	75%	$205,938

TABLE 4.1.2: WINTER 1991 SURVEY

Road Class	Daily Damage per Truck Federal System	145% Fed. Limits	Increase in Daily Damage per Truck	% Increase in Damage	Truck Pop. Daily Increase in Damage
Local Road	$20.98	$35.48	$14.50	69%	$52,057
State Road	$4.75	$9.24	$4.49	95%	$16,120
Interstate	$1.41	$2.66	$1.25	89%	$4,488
All	$27.14	$47.38	$20.24	75%	$72,665

TABLE 4.1.3: FALL 1991 SURVEY

Road Class	Daily Damage per Truck Federal System	145% Fed. Limits	Increase in Daily Damage per Truck	% Increase in Damage	Truck Pop. Daily Increase in Damage
Local Road	$19.12	$35.43	$16.31	85%	$100,381
State Road	$5.24	$9.59	$4.35	83%	$26,772
Interstate	$0.61	$1.17	$0.56	92%	$3,447
All	$24.97	$46.19	$21.22	85%	$130,600

TABLE 4.1.4: YEARLY SUMMARY

Road Class	Daily Damage per Truck Federal System	145% Fed. Limits	Increase in Daily Damage per Truck	Truck Pop. Daily Increase in Damage	Truck Pop. Yearly Increase in Damage
Local Road	$21.72	$38.41	$16.69	$101,608	$26 M
State Road	$5.12	$9.65	$4.53	$27,056	$7 M
Interstate	$1.16	$2.19	$1.03	$6,287	$2 M
All	$28.00	$50.25	$22.25	$134,951	$35 M

Calculations for the first line of Table 4.1.4:

$21.72 = ($27.66 + $20.98 + 2*$19.12)/4; $38.41 = ($47.30 + $35.48 + 2*$35.43)/4

$101,608 = ($153,613 + $52,057 + 2*$100,381)/4; $26 M = $101,608*65*4 (rounded)

Notes:

1) Results above are based on assumed costs of $0.02, $0.06, and $0.40 per E.S.A.L.*mile for interstate, state, and local roads respectively, and 65 working days per season. Extrapolations of sample results to the truck population assume that the average percentage of the truck population on the road is 61%, 28%, and 48% for Summer, Winter, and Fall respectively.
Fall values are used for Spring even though the extent of pavement damage may differ significantl due to weather effects (not considered here).

2) All dollar amounts are in 1987 $.

3) In the last column of Table 4.1.4, results are rounded to the nearest million; they are only an order of magnitude estimate of the true increases in pavement damage.

TABLE 4.2: SUMMER PAVEMENT DAMAGE INCREASE FOR WEIGHT SCENARIOS

TABLE 4.2.1: DAILY INCREASE IN PAVEMENT DAMAGE PER TRUCK FOR SUMMER

Road Class	Increase in Average Daily Damage per Truck for Summer		
	125% Federal System	135% Federal System	145% Federal System
Local Road	$10.29	$15.42	$19.64
State Road	$2.76	$3.97	$4.93
Interstate	$0.94	$1.37	$1.76
All	$13.99	$20.76	$26.33

FIGURE 4.2.1: PAVEMENT DAMAGE INCREASE PER TRUCK PER DAY FOR SUMMER

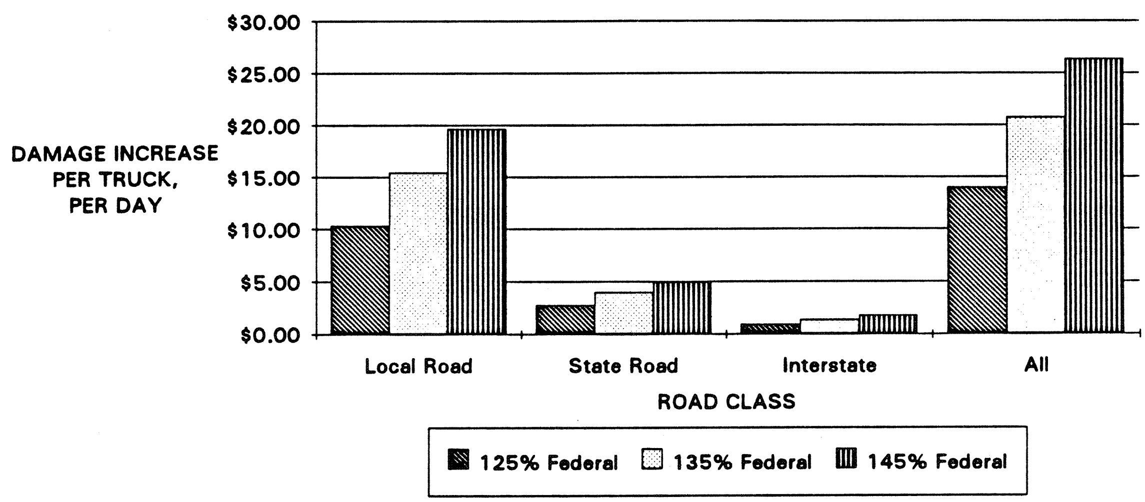

TABLE 4.2.2: PERMITTED TRUCK POPULATION INCREASE IN SUMMER PAVEMENT DAMAGE

Road Class	Increase in Average Seasonal Damage (million of 1987 $)		
	125% Federal System	135% Federal System	145% Federal System
Local Road	$5.2 M	$7.8 M	$10.0 M
State Road	$1.4 M	$2.0 M	$2.5 M
Interstate	$0.5 M	$0.7 M	$0.9 M
All	$7.1 M	$10.6 M	$13.4 M
All (rounded)	*$7 M*	*$11 M*	*$13 M*

Notes:

1) Results above are based on assumed costs of $0.02, $0.06, and $0.40 per E.S.A.L.*mile for interstate, state, and local roads respectively.

2) Extrapolations of the sample results to the truck population assume that the average percentage of the truck population on the road is 61% for the Summer. It also assumes 65 working days per season.

3) All dollar amounts are in 1987 $.

4) On the last line of Table 4.2.2, results are rounded to the nearest million; they are only an order of magnitude estimate of the true increases in pavement damage.

TABLE 4.3: WINTER PAVEMENT DAMAGE INCREASE FOR WEIGHT SCENARIOS

TABLE 4.3.1: DAILY INCREASE IN PAVEMENT DAMAGE PER TRUCK FOR WINTER

Road Class	Increase in Average Daily Damage per Truck for Winter 125% Federal System	135% Federal System	145% Federal System
Local Road	$8.21	$11.70	$14.50
State Road	$2.48	$3.54	$4.49
Interstate	$0.69	$0.97	$1.25
All	$11.37	$16.21	$20.24

FIGURE 4.3.1: PAVEMENT DAMAGE INCREASE PER TRUCK PER DAY FOR WINTER

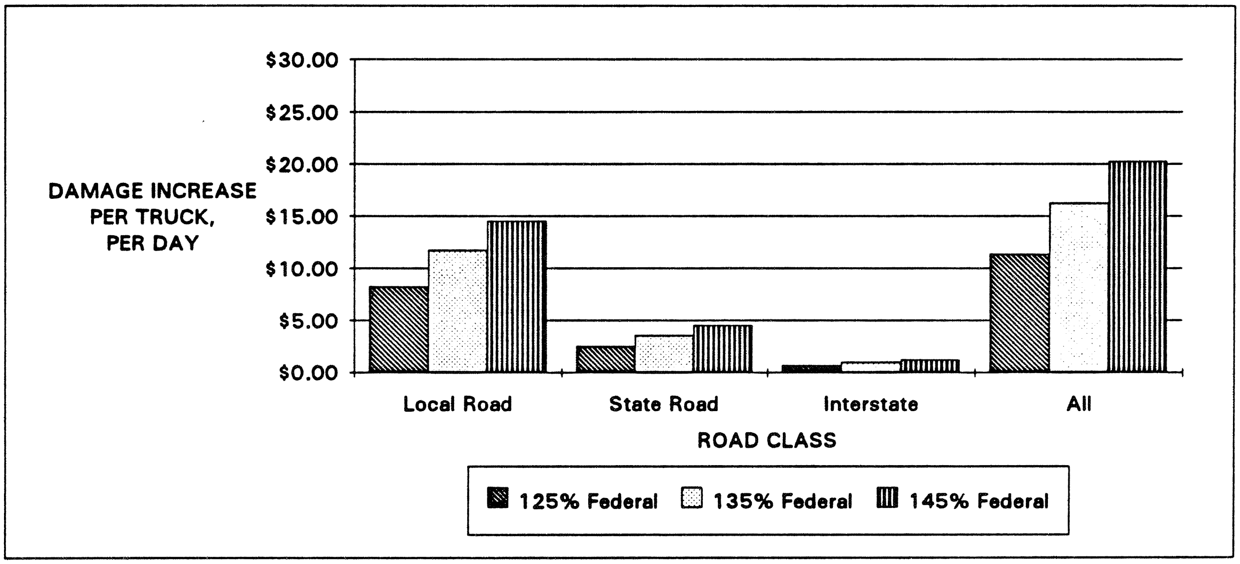

TABLE 4.3.2: PERMITTED TRUCK POPULATION INCREASE IN WINTER PAVEMENT DAMAGE

Road Class	Increase in Average Seasonal Damage (million of 1987 $) 125% Federal System	135% Federal System	145% Federal System
Local Road	$1.9 M	$2.7 M	$3.4 M
State Road	$0.6 M	$0.8 M	$1.0 M
Interstate	$0.2 M	$0.2 M	$0.3 M
All	$2.7 M	$3.8 M	$4.7 M
All (rounded)	*$3 M*	*$4 M*	*$5 M*

Notes:

1) Results above are based on assumed costs of $0.02, $0.06, and $0.40 per E.S.A.L.*mile for interstate, state, and local roads respectively.

2) Extrapolations of the sample results to the truck population assume that the average percentage of the truck population on the road is 28% for the Winter. It also assumes 65 working days per season.

3) All dollar amounts are in 1987 $.

4) On the last line of Table 4.3.2, results are rounded to the nearest million; they are only an order of magnitude estimate of the true increases in pavement damage.

TABLE 4.4: FALL PAVEMENT DAMAGE INCREASE FOR WEIGHT SCENARIOS

TABLE 4.4.1: DAILY INCREASE IN PAVEMENT DAMAGE PER TRUCK FOR FALL

Road Class	Increase in Average Daily Damage per Truck for Fall 125% Federal System	135% Federal System	145% Federal System
Local Road	$8.71	$12.74	$16.31
State Road	$2.67	$3.64	$4.35
Interstate	$0.29	$0.42	$0.56
All	$11.67	$16.80	$21.22

FIGURE 4.4.1: PAVEMENT DAMAGE INCREASE PER TRUCK PER DAY FOR FALL

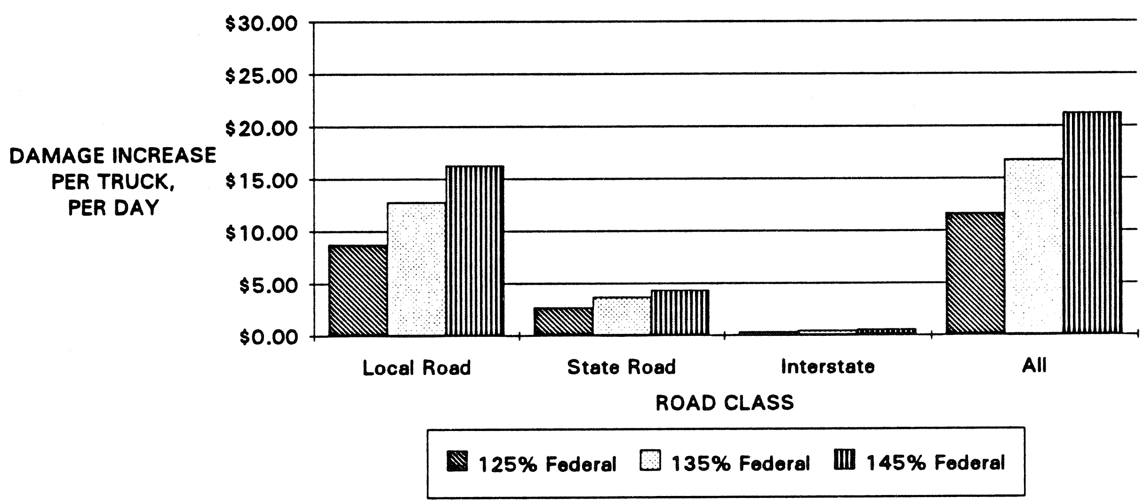

TABLE 4.4.2: PERMITTED TRUCK POPULATION INCREASE IN FALL PAVEMENT DAMAGE

Road Class	Increase in Average Seasonal Damage (million of 1987 $) 125% Federal System	135% Federal System	145% Federal System
Local Road	$3.5 M	$5.1 M	$6.5 M
State Road	$1.1 M	$1.5 M	$1.7 M
Interstate	$0.1 M	$0.2 M	$0.2 M
All	$4.7 M	$6.7 M	$8.5 M
All (rounded)	*$5 M*	*$7 M*	*$9 M*

Notes:

1) Results above are based on assumed costs of $0.02, $0.06, and $0.40 per E.S.A.L.*mile for interstate, state, and local roads respectively.

2) Extrapolations of the sample results to the truck population assume that the average percentage of the truck population on the road is 48% for the Fall. It also assumes 65 working days per season.

3) All dollar amounts are in 1987 $.

4) On the last line of Table 4.4.2, results are rounded to the nearest million; they are only an order of magnitude estimate of the true increases in pavement damage.

TABLE 4.5: ANNUAL PAVEMENT DAMAGE INCREASE FOR WEIGHT SCENARIOS

TABLE 4.5.1: AVERAGE DAILY INCREASE IN PAVEMENT DAMAGE PER TRUCK

Road Class	Increase in Daily Damage per Truck (Yearly Average) 125% Federal System	135% Federal System	145% Federal System
Local Road	$8.98	$13.15	$16.69
State Road	$2.65	$3.70	$4.53
Interstate	$0.55	$0.80	$1.03
All	$12.18	$17.64	$22.25

FIGURE 4.5.1: AVERAGE PAVEMENT DAMAGE INCREASE PER TRUCK PER DAY

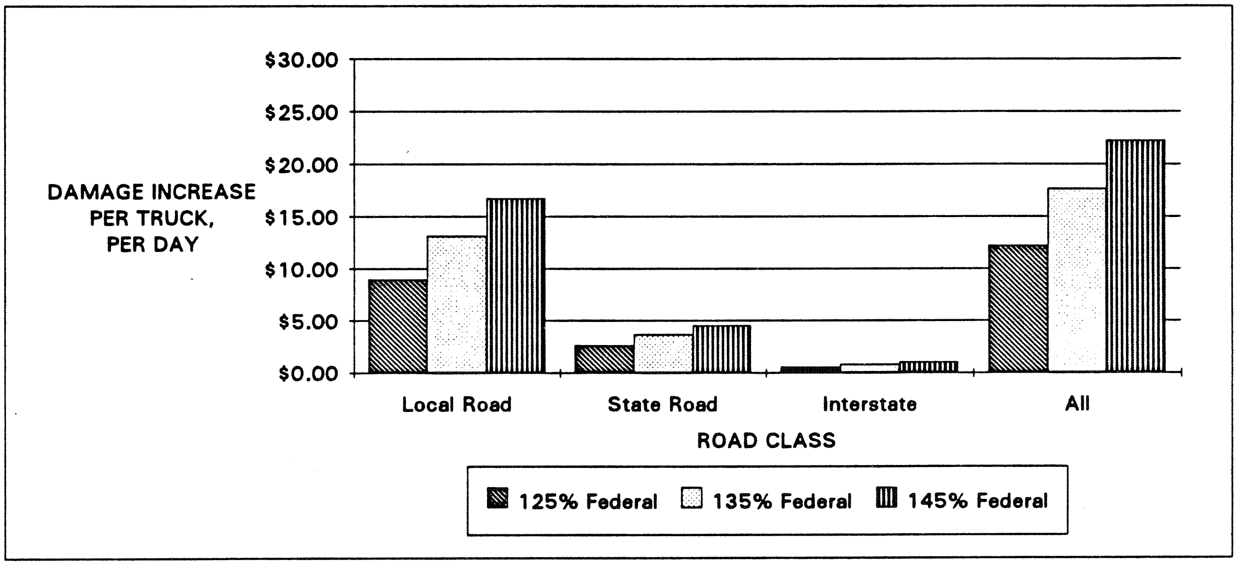

TABLE 4.5.2: PERMITTED TRUCK POPULATION INCREASE IN ANNUAL PAVEMENT DAMAGE

Road Class	Increase in Average Annual Damage (million of 1987 $) 125% Federal System	135% Federal System	145% Federal System
Local Road	$14.1 M	$20.8 M	$26.4 M
State Road	$4.1 M	$5.8 M	$7.0 M
Interstate	$0.9 M	$1.3 M	$1.6 M
All	$19.1 M	$27.8 M	$35.1 M
All (rounded)	*$19 M*	*$28 M*	*$35 M*

Notes:

1) Results above are based on assumed costs of $0.02, $0.06, and $0.40 per E.S.A.L.*mile for interstate, state, and local roads respectively.

2) The daily increase in pavement damage per truck is the average of the corresponding seasonal results in Tables 4.2 to 4.4. Fall results are used for the Spring even though the extent of pavement damage may differ significantly due to weather effects (not considered here).

3) All dollar amounts are in 1987 $.

4) On the last line of Table 4.5.2, results are rounded to the nearest million; they are only an order of magnitude estimate of the true increases in pavement damage.

TABLE 4.6: SAMPLE TRAVEL STATISTICS FOR PAVEMENT DAMAGE ANALYSIS

TABLE 4.6.1: MILES TRAVELLED BY ROAD CLASS

Road Class	SUMMER 1990		WINTER 1991		FALL 1991	
	Miles	%	Miles	%	Miles	%
Interstate	4083	35.8%	1665	34.8%	1237	21.3%
State Road	4136	36.3%	1912	40.0%	3126	53.9%
Local Road	3172	27.8%	1208	25.2%	1437	24.8%
All	11391	100.0%	4785	100.0%	5800	100.0%

FIG. 4.6.1: SEASONAL COMPARISON OF SURVEY RESPONDENTS LOADED MILES

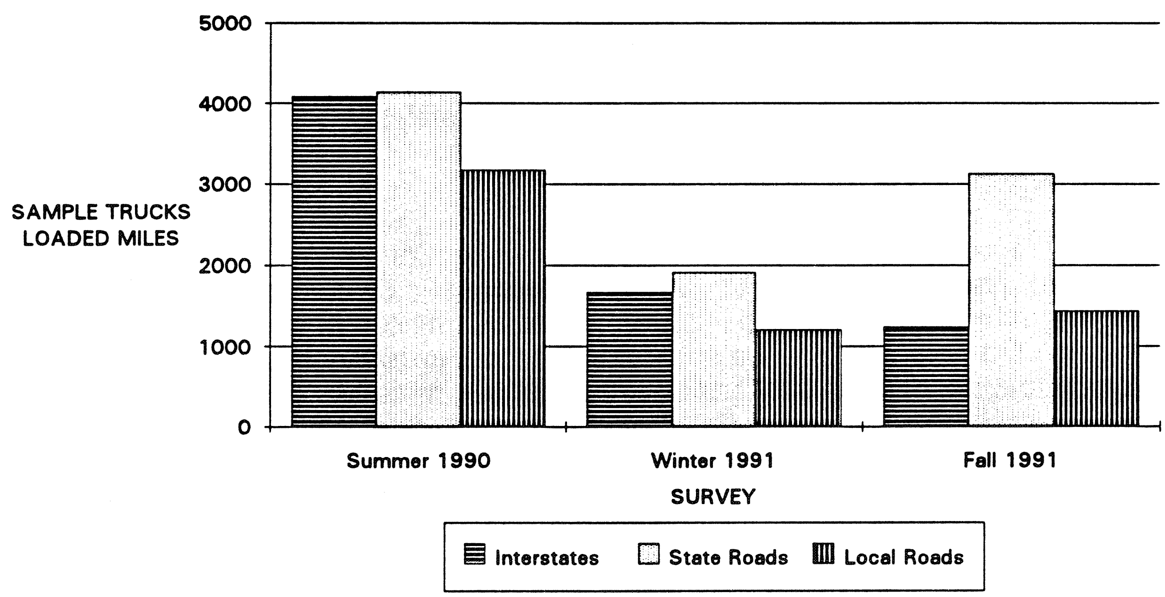

TABLE 4.6.2: NUMBER OF TRIPS BY ROAD CLASS

Road Class	SUMMER 1990		WINTER 1991		FALL 1991	
	Number of Trips	%	Number of Trips	%	Number of Trips	%
Interstate	185	17.2%	91	23.1%	80	11.4%
State Road	364	33.9%	127	32.2%	281	40.1%
Local Road	524	48.8%	176	44.7%	340	48.5%
All	1073	100.0%	394	100.0%	701	100.0%

Note:
Mileage and trip statistics given above are based on 135, 64, and 82 trucks for the Summer, Winter, and Fall surveys respectively. More respondents made loaded trips on the survey day, but some provided insufficient information to complete the pavement damage computations. A summary of responses to the surveys is provided in Table 3.1.

CHAPTER 5. PRIMARY ECONOMIC IMPACT ANALYSIS

This chapter presents the results of the primary economic impact analysis of the divisible-load permit system, which can be viewed as the savings truck operators realize under the permit system, compared to the costs they would incur if they transported the same loads, with the same vehicles, under the federal weight limits (which would frequently result in more vehicle trips). As was the case in the previous chapter, we first note the assumptions and some of the limitations of this analysis. The methodology used is then presented in detail and illustrated by means of an example. An attempt is made to analyze the primary economic impacts of the divisible-load permit system for different weight limit scenarios. Tables 5.1 through 5.9 and the associated Figures, which are included at the end of the chapter, provide an extensive overview of the results of this analysis.

5.1 Stratification by Business Category

In the analysis of the primary economic impact of the divisible-load permit system, an attempt was made to stratify the responses by business category of the operator. It was only possible to perform this stratification based upon operators who responded to the survey, since the Permit Application File (PAF) data base did not provide information about the business category of the permit holder.

One unfortunate result of this stratification after the surveys were conducted is the fact that several categories do not contain enough trucks to permit reaching statistically valid conclusions, because there were not enough vehicles pertaining to these categories on the road on the specified survey days. Only the categories "Mining & Quarrying", "Construction, including Ready Mix", "For-Hire Transportation", "Utilities & Sanitation" usually had enough respondents to allow extrapolation of the results to the corresponding part of the permit vehicle fleet. (The limit for a statistically valid estimate was arbitrarily set by the researchers at ten valid answers for trucks operating on the specified survey day.) Stating the same thing more positively, we can say that the bulk of the primary economic benefits are accrued among these four categories.

This apparent defect may in fact not have any significant impact on the results of this analysis, if the percentage of respondents in each business category is close to that of the fleet of permit vehicles. Under this assumption, our analysis shows that the bulk of the primary economic benefits is shared by the operators in the four categories mentioned above.

As emphasized earlier, every effort was made to preserve the randomness of the sample in each survey. And as pointed out in section 3.1, the responses obtained present the same characteristics as the survey population for a number of criteria. However, according to the comments received and our knowledge of the trucking business, it is possible that garbage and tank trucks are underrepresented in the results of these surveys. Therefore, we recommend that the results calculated for the categories "Utilities and Sanitation" and "Wholesale and Retail Trade" be interpreted with caution, since the benefits that the members of these business categories realize from the divisible-load permit system may be underestimated. But again, the results of any survey with much less that a 100% response rate should be viewed and interpreted with caution.

5.2 Procedure Used for Estimating Primary Economic Impacts (Savings)

5.2.1 Assumptions

The procedure followed to obtain estimates of the primary economic analysis is similar to the one adopted in an earlier study by Meyburg, Schuler et al. (1987) in order to allow comparisons between that study and this one.

For this reason, all costs in this study are expressed in 1987 dollars. The main cost assumptions are:

- Labor costs were assumed to be $12 per hour; they are incurred when the driver is "associated" with the truck.
- Standing costs were set at $16 per hour. They include allowance for registration, insurance, depreciation, and other costs that do not depend on usage. Depreciation costs for a new permit truck have been set at $6 per hour, and it was assumed that trucks in the permit vehicle fleet are fully depreciated after 10 years. For all three surveys, depreciation comes into play for trucks built in 1980 or after. Moreover, the rate of depreciation is assumed to decrease linearly between the first and the tenth year.
- Finally, the per-hour operating cost, based on a GVW of 50,000 lbs., was set at $21 per hour. In addition, we assumed that the addition of 1,000 lbs. of payload imposes a fuel consumption penalty of 0.02 gallons per mile. As in the 1987 study, we used a cost of $1.00 per gallon for diesel fuel (1987 dollars), so that an increase in payload of 1,000 lbs. converts to an added operating cost of 2 cents per mile. Conversely, reduction of the payload by 1,000 lbs. reduces the cost of operation by 2 cents per mile.

These assumptions lead to the following equations:

Vehicle parked (e.g. overnight):

$$\text{Cost / hour (\$)} = 16.0 + 0.6\ (\text{year} - 1980) \qquad (5.1)$$

Vehicle waiting with driver:

$$\text{Cost / hour (\$)} = 28.0 + 0.6\ (\text{year} - 1980) \qquad (5.2)$$

Vehicle during trip:

$$\text{Cost / mile (\$)} = \frac{49.0 + 0.6\ (\text{year} - 1980)}{\text{Average speed (mph)}} + 0.00002\ (\text{GVW} - 50{,}000) \qquad (5.3)$$

In Equations 5.1 through 5.3, the term "(year-1980)" was replaced by "0" for trucks built before 1980.

5.2.2 Estimating Procedure

The calculations performed can be described in the following steps:
For each loaded trip:

Step 1: Calculate the trip duration and the average trip speed.

Step 2: If the truck goes back empty, calculate the waiting time. Assume that the return trip has the same duration as the initial trip.

Step 3: Calculate the cost of the trip per mile under the permit system, using *Equation 5.3*, and multiply the result by the number of miles driven during the trip. If there is an empty return trip, replace the GVW (in lbs.) with its tare weight in *Equation 5.3*. Also calculate the cost of the waiting period between the initial and the return trips, based on *Equation 5.2*. Then add up the cost of the trip, the waiting period, and the return trip.

Step 4: Under the federal system, consider the maximum GVW that will be carried, based on the same load distribution, with the axle loads scaled down to meet the federal load limits. Proceed as in step 3 above, and multiply the results by the prorated increase in the equivalent number of trips required to move the same loads under reduced limits, as computed in the pavement damage analysis. (See Chapter 4)

For a given truck, aggregate the various periods during which the truck is in use (whether on the road or waiting with its driver) under both the federal and the permit system scenarios, i.e. the 145%, 135%, 125% limits and the actual usage. For the federal system, calculate the number of days the truck would be needed on the basis of a 12-hour work day. Standing costs can now be calculated. The next step is to compute the cost difference between the federal statutes and the other four scenarios. Finally, costs per truck can be aggregated by primary business category.

It was assumed that the weight distribution across the different axles stayed the same under the different weight limit scenarios. The weights were simply scaled down proportionately so that the heaviest axle load is in compliance with the weight limit.

5.2.3 Illustrative Example of Economic Benefit Estimation

We consider again "truck #67" from the Fall 1991 survey. Our example truck is a 3-axle 1975 Ford ready-mix concrete truck. Its tare weight is 28,920 lbs. On the survey day, it made two similar loaded trips, both of 9 miles, with 5 miles on state roads and 4 miles on local roads. Each loaded trip was followed by a waiting period (63 and 79 minutes, respectively) and then by a return trip during which the truck was empty. In addition, we know that the truck hauled 60,605 lbs. and 60,795 lbs. during the first and the second trip, respectively.

It is easy to check that this truck would be allowed to carry exactly the same load under 145% of the federal system. As was found in the pavement damage analysis (Chapter 4), the total gross weight the truck could carry under the federal system, with the same axle loadings, would be 47,464 lbs. and 47,404 lbs. for the first and second trips, respectively. Therefore, we have:

Step 1: Duration of each trip: approximately 19 minutes. Average speed: 28.5 mph.

Step 2: The waiting periods between a loaded trip and the corresponding return trips were 63 and 79 minutes.

Step 3: Trip costs under **145% of the federal system:**

Trip No. 1:

Loaded trip	= ($49/28.5+$0.00002x(60,605-50,000))x9 = $17.43
Waiting period	= $28*63/60 = $29.40
Return trip	= ($49/28.5+$0.00002x(28,920-50,000))x9 = $11.72
Total trip cost	= $58.55

Trip No. 2:

Loaded trip	= ($49/28.5+$0.00002x(60,795-50,000))x9 = $17.46
Waiting period	= $28x79/60 = $38.87
Return trip	= ($49/28.5+$0.00002x(28,920-50,000))x9 = $11.72
Total trip cost	= $66.05
Cost of both trips	= $124.60

Step 4: Trip costs under the **federal system:**

Trip No. 1:

Loaded trip	= ($49/28.5+$0.00002x(47,464-50,000))x9x1.709
	= $25.74
Waiting period	= $28x63/60x1.709 = $50.24
Return trip	= ($49/28,5+$0.00002x(28,920-50,000))x9x1.709
	= $20.03
Total trip cost	= $96.02

Trip No. 2:

Loaded trip	= ($49/28.5+$0.00002x(47404-50,000))x9x1.725
	= $25.96

Waiting period	=.$28x79/60x1.725 = $63.60
Return trip	= ($49/28.5+$0.00002x(28920-50000))x9x1.725
	= $20.22
Total trip cost	= $109.78
Cost of both trips	= $205.80

Now, we can calculate standing costs, total costs, and the cost difference between the two systems.

- Under 145% of federal limits, the truck is in use for 101+117=218 minutes. Therefore, the standing costs are (1440-218)/60x$16 = $325.87. The total costs are $325.87+$124.60 = $450.47.
- Under the federal system, the truck is in use for 173+200=373 minutes. The standing costs are (1,440-373)/60x$16 = $284.53. This leads to a total cost of $284.53+$205.80 = $490.33. The operating cost difference between the two systems is $39.86 for the two trips undertaken by the permit vehicle used in this example.

The reasoning and the computations used for the 125% and 135% scenarios are identical to those illustrated above for the 145% limit.

5.3 Results and Conclusions of Primary Economic Impact Analysis under Different Weight Limit Scenarios

It should be noted at the outset that the estimated dollar savings to the vehicle operators computed as the primary economic impact have to be viewed as order-of-magnitude figures, not as precise measures of these savings. There are several reasons for this cautiousness. First, the number of permit vehicles by business category is small. Hence estimates of savings may be imprecise, as pointed out in section 4.1. Second, a number of assumptions were made, both in terms of specific numerical inputs to the procedure (e.g. hourly labor, vehicle standing and vehicle operating costs), and in terms of the procedure used to determine the operating cost savings, as described in section 4.2.1. Furthermore, regional differences within NYS were not taken into account.

Tables 5.1 through 5.4 present a illustrative examples of seasonal cost savings per truck and for the permit population under the assumption of 145% of federal weight limits. This illustration is compatible with that provided in the analysis of secondary economic impacts (Chapter 6).

Tables 5.5 through 5.8 provide a summary of estimated cost savings to operators ("economic benefits") under the three weight limit scenarios (125%, 135%, and 145% of federal limits) in comparison to the costs that would be incurred if the federal statutes on weight limits were in effect for the Divisible-Load Permit Vehicle fleet. The tables show the cost savings per vehicle per day, as well as the population extrapolation of cost savings for all permit trucks in the major industries.

As can be expected, annual cost savings are lowest under the 125% scenario ($551 million) and highest under the 145% scenario ($708 million), with savings of $653 million under the 135% scenario.

Our procedure assumes that cost savings for the spring equal those for the fall, even though spring pavement damage could be much larger due to weather effects. Budget limitations prevented us from considering this important aspect. These numbers are based on the savings within the individual business categories that used permitted vehicles. About fifty percent of the savings are observed in the "Construction (incl. Ready-Mix)" industry alone.[1] The next largest beneficiaries of the permit system are "For-Hire Transportation", "Mining & Quarrying" and "Utilities & Sanitation" with approximately 12 %, 13 %, and 12 %, respectively.

Detailed explanations of the economic benefit calculations by season and by truck are contained in the tables at the end of this chapter.

5.4 Seasonal Comparisons and External Impacts

A look at the operating cost savings by season shows the intuitively obvious result, namely that the primary economic benefits to operators of permitted vehicles are highest in summer, followed by fall/spring and winter. *(Table 5.5)*. This result can be explained simply by the fact that business activities, particularly in the dominating "Construction (incl. Ready-Mix)" category is strongest in summer and weakest in winter. Hence, fewer vehicle trips are made using the divisible-load permit vehicles that were the object of this investigation.

For the 145% scenario, it is interesting to note that the percentage savings for the most dominant business category ("Construction") is highest in the fall/spring (61%, i.e. $92 million/$151 million), with winter showing the lowest percentage, as expected, namely 34% ($34 million/$101 million). In summer, construction accrues 49% of all annual savings (i.e. $150 million/$305 million), another intuitively plausible finding (Tables 5.5 through 5.7).

Unfortunately, certain reservations about these findings are in order. While this second phase of the investigation into the consequences, benefits, and costs of permitting truck weights in New York State to exceed federal limits has allowed the consideration of seasonal variations in the nature and extent of permit vehicle use, the validation of earlier findings, and of longer-term trends, it has also introduced added degrees of economic variation. Because of the economic recession that has gripped New York State with increasing severity since 1990 (long before the aggregate nationwide economic indices hit the recessionary benchmark), it is not entirely clear how much of the variation in permit fleet utilization (both in composition and intensity, as shown in Tables 3.11 and 3.12) between summer 1990, winter 1991 and fall 1991 reflects seasonal variations, versus a longer-cycle reduction in fleet use because of the tightening grip of the recession.

Certainly much of the variation in usage shown in Tables 3.11 and 3.12 reflects seasonal economic activity, since the decline in usage between summer 1990 and winter 1991, and then modest rise through fall 1991 in the

---

[1] According to the U.S. Government Classification by SIC codes, "ready-mix concrete" falls under "manufacturing". However, because of the high degree of aggregation of our industries (eight categories) and the fact that most of the ready-mix concrete is used for construction purposes, ready-mix concrete trucking was included in the construction category.

"Construction" and "Ready-Mix Concrete" categories roughly parallels the expected general pattern of construction-related activity (Table 3.11).

At question, however, is whether the normal construction seasonal pattern should yield higher activity in the fall than is shown for 1991 because the level of use reported in the survey is depressed by the recession. Evidence to support this conjecture is provided in Table 3.12, where the fall 1991 percentage of "no work" respondents falls from the winter 1991 high, but still remains higher than the summer 1990 level. If accurately answered, the respondents should have reflected variations in use due to seasonal factors in the separate category, which in fact does reflect the anticipated seasonal pattern. Nevertheless, the possibility always exists that respondents may have mis-classified the reason for not using their vehicles on the survey date between the "no-work" and "seasonal" categories, since both categories reflect the same outcome: the vehicle is not being operated.

Since approximately 60 percent of the permitted vehicles are used in construction-related activities (construction, ready-mix concrete, and mining and quarrying) that are known to be seasonal in nature, it is not surprising, however, that the strong seasonal usage pattern of the entire fleet emerges as a result of this survey. However, other vehicle uses that might also be expected to reflect highly seasonal patterns (oil deliveries, forestry and lumbering, agriculture) in fact show fairly level usage over the year. As noted earlier, it is possible that some tank truck operators were reluctant to fill out and return the questionnaires because they may have considered this task too cumbersome. One remaining caveat is the fact that no spring survey was conducted, when that may be the peak period of activity for agricultural and forestry and lumbering activities.

5.5 Summary of Primary Benefits and Costs

One of the goals of this study was to quantify the primary economic impacts of decreased weight limits to help decide on future policies concerning weight limits of commercial vehicles. Estimates of cost savings for the trucking industry and pavement damage costs incurred by society with respect existing federal limits are displayed in Tables 5.5 through 5.8 and 4.2 through 4.5, respectively. From an economic point-of-view, the relevant measure for selecting the "optimum" weight regime is the marginal primary net benefits (defined here as primary benefits to the trucking industry minus pavement damage costs.) Thus, weight limits could be increased until the marginal primary net benefits become zero, so long as primary net benefits increase with increased weight limits. Table 5.9 presents approximate values of the marginal primary net benefits based on incremental net primary benefits between the various weight regimes considered (100%, 125%, 135%, and 145% of the current federal limits). In theory, if weight limits were adhered to, a permit system approximating 145% of federal limits would be close to optimal.

TABLE 5.1: PRIMARY ECONOMIC ANALYSIS ILLUSTRATION, SUMMER SURVEY

TABLE 5.1.1: SUMMER DAILY COST SAVINGS PER TRUCK FOR 145% OF FEDERAL LIMITS.

Primary Business Category	No. of Trucks that Provided Full Cost Data	Average Daily Cost per Truck Federal System	145% Fed. Limits	Reduction in Average Daily Cost per Truck	% Decrease in Cost
Agriculture & Forestry	5	$1,142.45	$704.37	$438.08	38%
Mining & Quarrying	19	$1,896.43	$1,095.78	$800.65	42%
Construction (& Ready-Mix)	77	$1,375.13	$808.55	$566.58	41%
Manufacturing	4	$1,191.48	$721.48	$470.00	39%
For-Hire Transportation	13	$1,435.05	$1,017.29	$417.76	29%
Utilities & Sanitation	7	$1,688.75	$848.27	$840.48	50%
Wholesale & Retail Trade	8	$2,117.74	$1,302.51	$815.23	38%
Other	2	$447.16	$445.18	$1.98	0%
All Categories	*135*	*$1,486.73*	*$888.58*	*$598.15*	*40%*

TABLE 5.1.2: SUMMER TRUCK POPULATION COST SAVINGS FOR 145% OF FEDERAL LIMITS.

Primary Business Category	Reduction in Average Daily Cost per Truck	No. of Sample Trucks on Public Roads	Cost Reduction for Summer Sample (a)	Population (Million) (b)
Agriculture & Forestry	$438.08	7	$199,326	$9.6 M
Mining & Quarrying	$800.65	23	$1,196,972	$57.9 M
Construction (& Ready-Mix)	$566.58	84	$3,093,527	$149.7 M
Manufacturing	$470.00	5	$152,750	$7.4 M
For-Hire Transportation	$417.76	15	$407,316	$19.7 M
Utilities & Sanitation	$840.48	16	$874,099	$42.3 M
Wholesale & Retail Trade	$815.23	8	$423,920	$20.5 M
Other	$1.98	4	$515	$0.0 M
All Categories	*$598.15*	*162*	*$6,298,520*	*$304.8 M*

Sample calculations for the first line of Table 5.1.2:

(a): $199,326 = $438.08(daily savings/truck) * 7(business cat. trucks/day) * 65(work days/season)

(b): $9.6 M (rounded) = $199,326 * 12822 (truck population)/265 (sample trucks)

265 is the number of respondents with permitted trucks for the summer survey (see Table 3.1)

Notes:

1) All dollar amounts are in 1987 $. The benchmark for cost savings is the Federal System.

2) Results in the last column of Table 5.1.2 are rounded to the nearest hundred thousand dollars for the secondary economic analysis. They provide only an order of magnitude estimate.

3) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.

4) The last line of Table 5.1.2 does not match exactly: different aggregations give different results.

TABLE 5.2: PRIMARY ECONOMIC ANALYSIS ILLUSTRATION, WINTER SURVEY

TABLE 5.2.1: WINTER DAILY COST SAVINGS PER TRUCK FOR 145% OF FEDERAL LIMITS.

Primary Business Category	No. of Trucks that Provided Full Cost Data	Average Daily Cost per Truck Federal System	Average Daily Cost per Truck 145% Fed. Limits	Reduction in Average Daily Cost per Truck	% Decrease in Cost
Agriculture & Forestry	8	$792.79	$634.28	$158.51	20%
Mining & Quarrying	2	$2,044.87	$1,045.51	$999.36	49%
Construction (& Ready-Mix)	25	$1,101.73	$690.39	$411.34	37%
Manufacturing	2	$953.57	$701.46	$252.11	26%
For-Hire Transportation	7	$1,836.50	$1,213.06	$623.44	34%
Utilities & Sanitation	10	$1,115.50	$695.47	$420.03	38%
Wholesale & Retail Trade	8	$1,459.01	$911.60	$547.41	38%
Other	2	$1,141.35	$583.37	$557.98	49%
All Categories	*64*	*$1,216.37*	*$777.09*	*$439.28*	*36%*

TABLE 5.2.2: WINTER TRUCK POPULATION COST SAVINGS FOR 145% OF FEDERAL LIMITS.

Primary Business Category	Reduction in Average Daily Cost per Truck	No. of Sample Trucks on Public Roads	Cost Reduction for Winter Sample (a)	Cost Reduction for Winter Population (Million) (b)
Agriculture & Forestry	$158.51	9	$92,728	$4.1 M
Mining & Quarrying	$999.36	2	$129,917	$5.8 M
Construction (& Ready-Mix)	$411.34	29	$775,376	$34.4 M
Manufacturing	$252.11	4	$65,549	$2.9 M
For-Hire Transportation	$623.44	7	$283,665	$12.6 M
Utilities & Sanitation	$420.03	15	$409,529	$18.2 M
Wholesale & Retail Trade	$547.41	12	$426,980	$18.9 M
Other	$557.98	2	$72,537	$3.2 M
All Categories	*$439.28*	*80*	*$2,284,256*	*$101.3 M*

Sample calculations for the first line of Table 5.2.2:

(a): $92,728 = $158.51(daily savings/truck) * 9(business cat. trucks/day) * 65 (work days/season)

(b): $4.1 M (rounded) = $92,728 * 12822(truck population) / 289(sample trucks)

289 is the number of respondents with permitted trucks for the Winter survey (see Table 3.1).

Notes:

1) All dollar amounts are in 1987 $. The benchmark for cost savings is the Federal System.

2) Results in the last column of Table 5.2.2 are rounded to the nearest hundred thousand dollars for the secondary economic analysis. They provide only an order of magnitude estimate.

3) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.

4) The last line of Table 5.2.2 does not match exactly: different aggregations give different results.

TABLE 5.3: PRIMARY ECONOMIC ANALYSIS ILLUSTRATION, FALL SURVEY

TABLE 5.3.1: FALL DAILY COST SAVINGS PER TRUCK FOR 145% OF FEDERAL LIMITS.

Primary Business Category	No. of Trucks that Provided Full Cost Data	Average Daily Cost per Truck Federal System	145% Fed. Limits	Reduction in Average Daily Cost per Truck	% Decrease in Cost
Agriculture & Forestry	3	$896.53	$555.71	$340.82	38%
Mining & Quarrying	10	$1,009.38	$678.44	$330.94	33%
Construction (& Ready-Mix)	43	$1,102.05	$661.90	$440.15	40%
Manufacturing	1	$528.72	$528.72	$0.00	0%
For-Hire Transportation	11	$1,382.41	$878.06	$504.35	36%
Utilities & Sanitation	6	$825.22	$574.93	$250.29	30%
Wholesale & Retail Trade	5	$699.24	$668.19	$31.05	4%
Other	3	$713.04	$505.56	$207.48	29%
All Categories	*82*	*$1,054.80*	*$675.71*	*$379.09*	*36%*

TABLE 5.3.2: FALL TRUCK POPULATION COST SAVINGS FOR 145% OF FEDERAL LIMITS.

Primary Business Category	Reduction in Average Daily Cost per Truck	No. of Sample Trucks on Public Roads	Cost Reduction for Fall Sample (a)	Population (Million) (b)
Agriculture & Forestry	$340.82	4	$88,613	$5.5 M
Mining & Quarrying	$330.94	10	$215,111	$13.3 M
Construction (& Ready-Mix)	$440.15	52	$1,487,707	$92.2 M
Manufacturing	$0.00	3	$0	$0.0 M
For-Hire Transportation	$504.35	13	$426,176	$26.4 M
Utilities & Sanitation	$250.29	9	$146,420	$9.1 M
Wholesale & Retail Trade	$31.05	5	$10,091	$0.6 M
Other	$207.48	3	$40,459	$2.5 M
All Categories	*$379.09*	*99*	*$2,439,444*	*$151.1 M*

Sample calculations for the first line of Table 5.3.2:

(a): $88,613 = $340.82(daily savings/truck) * 4(business cat. trucks/day) * 65(work days/season)

(b): $5.5 M (rounded) = $88,613 * 12822 (truck population)/207 (sample trucks)

207 is the number of respondents with permitted trucks for the fall survey (see Table 3.1).

Notes:

1) All dollar amounts are in 1987 $. The benchmark for cost savings is the Federal System.

2) Results in the last column of Table 5.3.2 are rounded to the nearest hundred thousand dollars for the secondary economic analysis. They provide only an order of magnitude estimate.

3) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.

4) The last line of Table 5.3.2 does not match exactly: different aggregations give different results.

TABLE 5.4: PRIMARY ECONOMIC ANALYSIS ILLUSTRATION, ANNUAL RESULTS

TABLE 5.4.1: AVERAGE DAILY COST SAVINGS PER TRUCK FOR 145% OF FEDERAL LIMITS.

Primary Business Category	Seasonal Reduction in Cost per Truck per Day WINTER	SUMMER	FALL (and SPRING)	Average Daily Savings per Truck
Agriculture & Forestry	$158.51	$438.08	$340.82	**$319.56**
Mining & Quarrying	$999.36	$800.65	$330.94	**$615.47**
Construction (& Ready-Mix)	$411.34	$566.58	$440.15	**$464.56**
Manufacturing	$252.11	$470.00	$0.00	**$180.53**
For-Hire Transportation	$623.44	$417.76	$504.35	**$512.48**
Utilities & Sanitation	$420.03	$840.48	$250.29	**$440.27**
Wholesale & Retail Trade	$547.41	$815.23	$31.05	**$356.19**
Other	$557.98	$1.98	$207.48	**$243.73**
All Categories	***$439.28***	***$598.15***	***$379.09***	***$448.90***

TABLE 5.4.2: TRUCK POPULATION COST SAVINGS FOR 145% OF FEDERAL LIMITS.

Primary Business Category	Seasonal Industry-Wide Reduction in Cost WINTER	SUMMER	FALL (and SPRING)	Total Yearly Savings
Agriculture & Forestry	$4.1 M	$9.6 M	$5.5 M	**$24.7 M**
Mining & Quarrying	$5.8 M	$57.9 M	$13.3 M	**$90.3 M**
Construction (& Ready-Mix)	$34.4 M	$149.7 M	$92.2 M	**$368.5 M**
Manufacturing	$2.9 M	$7.4 M	$0.0 M	**$10.3 M**
For-Hire Transportation	$12.6 M	$19.7 M	$26.4 M	**$85.1 M**
Utilities & Sanitation	$18.2 M	$42.3 M	$9.1 M	**$78.7 M**
Wholesale & Retail Trade	$18.9 M	$20.5 M	$0.6 M	**$40.6 M**
Other	$3.2 M	$0.0 M	$2.5 M	**$8.2 M**
All Categories	***$101.3 M***	***$304.8 M***	***$151.1 M***	***$708.3 M***

Sample calculations for the top-right cell of both tables:

$319.56 = ($158.51 + $438.08 + 2*$340.82)/4, from Tables 5.1.1, 5.2.1, and 5.3.1.

$24.7 M = $4.1 M + $9.6 M + 2*$5.5 M, from Tables 5.1.2, 5.2.2, and 5.3.2.

Notes:

1) Ready-Mix Concrete trucks were included in "Construction".
2) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.
3) Operating cost savings for Spring and Fall were assumed equal since there was no Spring survey.
4) Numbers in the table above are rounded to the nearest hundred thousand dollars for the secondary economic analysis. They provide only an order of magnitude estimate of the true costs.
5) The last line of Table 5.4.2 does not match exactly: different aggregations give different results.
6) All dollar amounts are 1987 $. The benchmark for cost savings is the Federal System.

TABLE 5.5: SUMMER COST SAVINGS FOR WEIGHT SCENARIOS

TABLE 5.5.1: SUMMER DAILY COST SAVINGS PER TRUCK

Primary Business Category	Reduction in Average Daily Cost per Truck (1987 $) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$569.94	$726.27	$800.65
Construction (& Ready-Mix)	$440.55	$503.87	$566.58
For-Hire Transportation	$386.11	$405.90	$417.76
Utilities & Sanitation	$728.51	$827.92	$840.48
Other Categories	$444.33	$516.38	$557.69
All Categories	*$468.98*	*$544.30*	*$598.15*

FIG. 5.5.1: SUMMER DAILY COST SAVINGS PER TRUCK BY BUSINESS CATEGORY

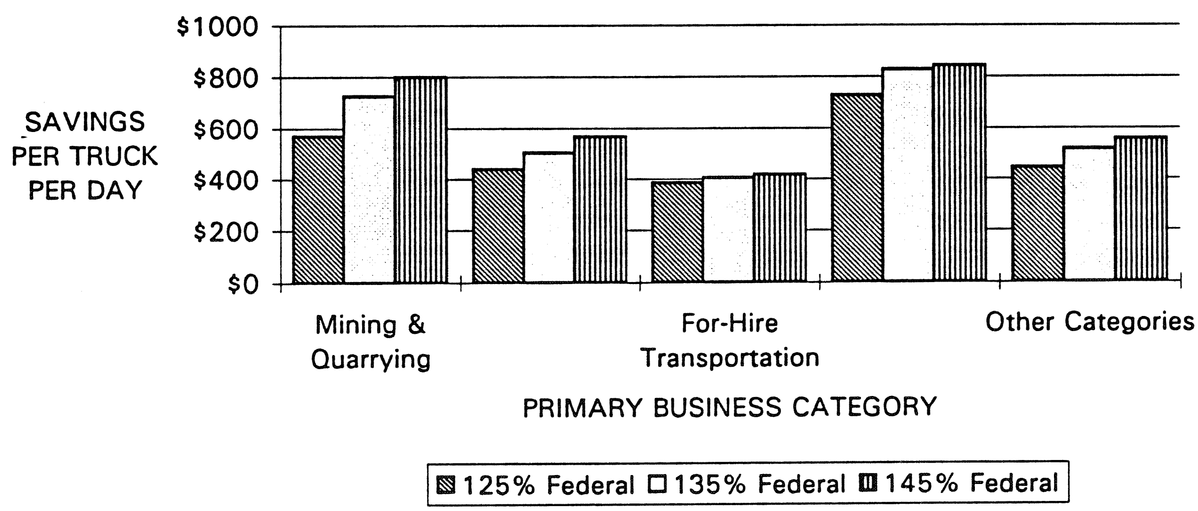

TABLE 5.5.2: TRUCK POPULATION SUMMER COST SAVINGS

Primary Business Category	Reduction in Seasonal Cost (rounded to the nearest $100,000) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$41.2 M	$52.5 M	$57.9 M
Construction (& Ready-Mix)	$116.4 M	$133.1 M	$149.7 M
For-Hire Transportation	$18.2 M	$19.1 M	$19.7 M
Utilities & Sanitation	$36.7 M	$41.7 M	$42.3 M
Other Categories	$33.5 M	$39.0 M	$42.1 M
All Categories	*$238.9 M*	*$277.3 M*	*$304.8 M*

Sample calculation for the top-left cell of Table 5.5.2:

$41.2 M = $569.94 * 7(bus.cat.trucks) * 65(work days/season) /265(sample)*12822(population)

Notes:

1) All dollars amounts are in 1987$. The benchmark for cost savings is the Federal System.

2) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.

3) Results above assume total compliance with legal load limits.

4) The last line of Table 5.5.2 does not match exactly: different aggregations give different results.

TABLE 5.6: WINTER COST SAVINGS FOR WEIGHT SCENARIOS

TABLE 5.6.1: WINTER DAILY COST SAVINGS PER TRUCK

Primary Business Category	Reduction in Average Daily Cost per Truck (1987 $) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$914.45	$962.68	$999.36
Construction (& Ready-Mix)	$312.70	$345.62	$411.34
For-Hire Transportation	$355.31	$524.62	$623.44
Utilities & Sanitation	$297.18	$409.08	$420.03
Other Categories	$250.83	$330.45	$363.37
All Categories	*$314.40*	*$389.66*	*$439.28*

FIG. 5.6.1: WINTER DAILY COST SAVINGS PER TRUCK BY BUSINESS CATEGORY

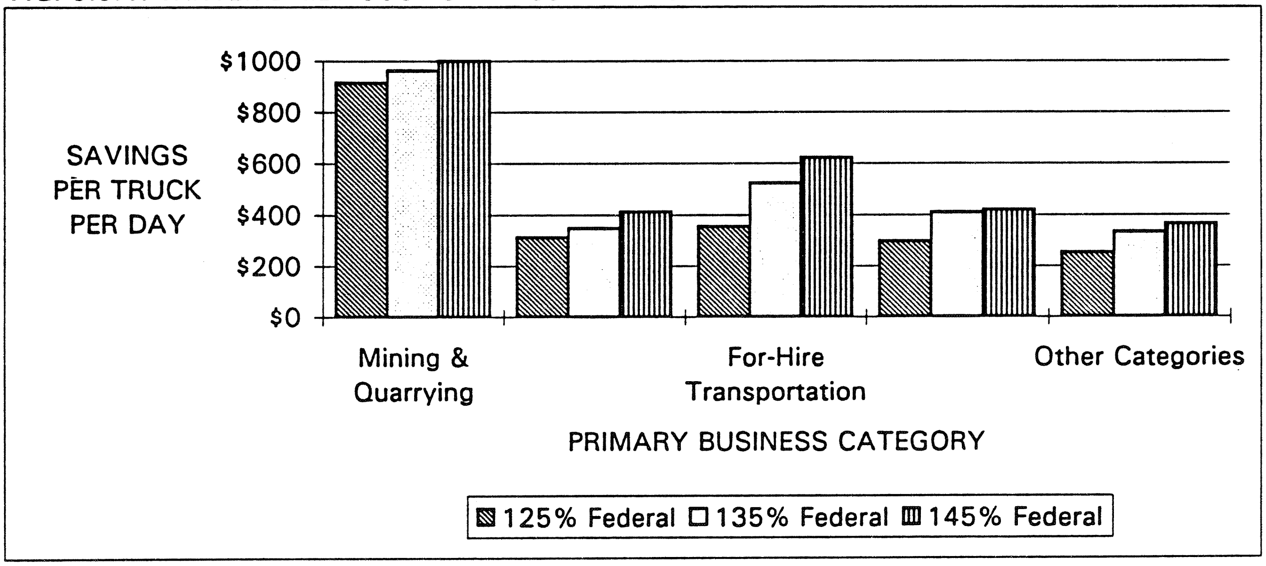

TABLE 5.6.2: TRUCK POPULATION WINTER COST SAVINGS

Primary Business Category	Reduction in Seasonal Cost (rounded to the nearest $100,000) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$5.3 M	$5.6 M	$5.8 M
Construction (& Ready-Mix)	$26.2 M	$28.9 M	$34.4 M
For-Hire Transportation	$7.2 M	$10.6 M	$12.6 M
Utilities & Sanitation	$12.9 M	$17.7 M	$18.2 M
Other Categories	$19.5 M	$25.7 M	$28.3 M
All Categories	*$72.5 M*	*$89.9 M*	*$101.3 M*

Sample calculation for the top-left cell of Table 5.6.2:

$5.3 M = $914.45 * 2(bus.cat.trucks) * 65(work days/season) /289(sample)*12822(population)

Notes:

1) All dollars amounts are in 1987$. The benchmark for cost savings is the Federal System.

2) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.

3) Results above assume total compliance with legal load limits.

4) The last line of Table 5.6.2 does not match exactly: different aggregations give different results.

TABLE 5.7: FALL COST SAVINGS FOR WEIGHT SCENARIOS

TABLE 5.7.1: FALL DAILY COST SAVINGS PER TRUCK

Primary Business Category	Reduction in Average Daily Cost per Truck (1987 $) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$254.30	$319.34	$330.94
Construction (& Ready-Mix)	$350.87	$419.75	$440.15
For-Hire Transportation	$350.45	$448.42	$504.35
Utilities & Sanitation	$239.27	$247.79	$250.29
Other Categories	$139.48	$146.17	$150.01
All Categories	*$299.94*	*$358.73*	*$379.09*

FIG. 5.7.1 : FALL DAILY COST SAVINGS PER TRUCK BY BUSINESS CATEGORY

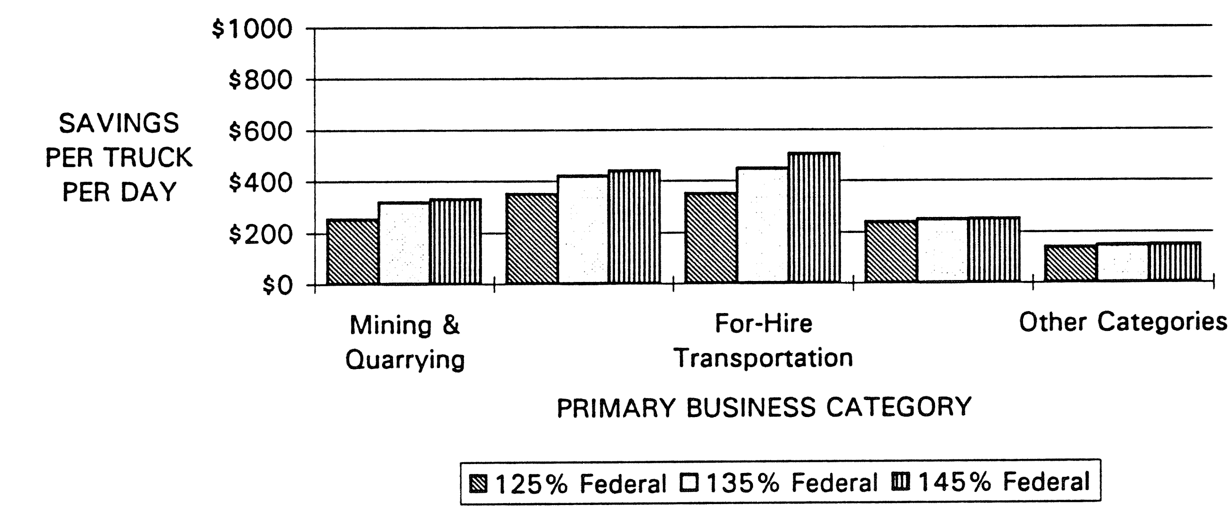

TABLE 5.7.2: TRUCK POPULATION FALL COST SAVINGS

Primary Business Category	Reduction in Seasonal Cost (rounded to the nearest $100,000) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$10.2 M	$12.9 M	$13.3 M
Construction (& Ready-Mix)	$73.5 M	$87.9 M	$92.2 M
For-Hire Transportation	$18.3 M	$23.5 M	$26.4 M
Utilities & Sanitation	$8.7 M	$9.0 M	$9.1 M
Other Categories	$8.4 M	$8.8 M	$9.1 M
All Categories	*$119.6 M*	*$143.0 M*	*$151.1 M*

Sample calculation for the top-left cell of Table 5.7.2:

$10.2 M = $254.30* 10(bus.cat.trucks)* 65(work days/season) /207(sample)*12822(population)

Notes:

1) All dollars amounts are in 1987$. The benchmark for cost savings is the Federal System.

2) Shading of the results for a primary business category indicates that the number of sampled trucks may be too small to give statistically reliable estimates of costs.

3) Results above assume total compliance with legal load limits.

4) The last line of Table 5.7.2 does not match exactly: different aggregations give different results.

TABLE 5.8: ANNUAL COST SAVINGS FOR WEIGHT SCENARIOS

TABLE 5.8.1: ANNUAL DAILY COST SAVINGS PER TRUCK

Primary Business Category	Reduction in Average Daily Cost per Truck (1987 $) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$498.25	$581.91	$615.47
Construction (& Ready-Mix)	$363.75	$422.25	$464.56
For-Hire Transportation	$360.58	$456.84	$512.48
Utilities & Sanitation	$376.06	$433.15	$440.27
Other Categories	$243.53	$284.79	$305.27
All Categories	*$345.82*	*$412.86*	*$448.90*

FIG. 5.8.1: ANNUAL DAILY COST SAVING PER TRUCK BY BUSINESS CATEGORY

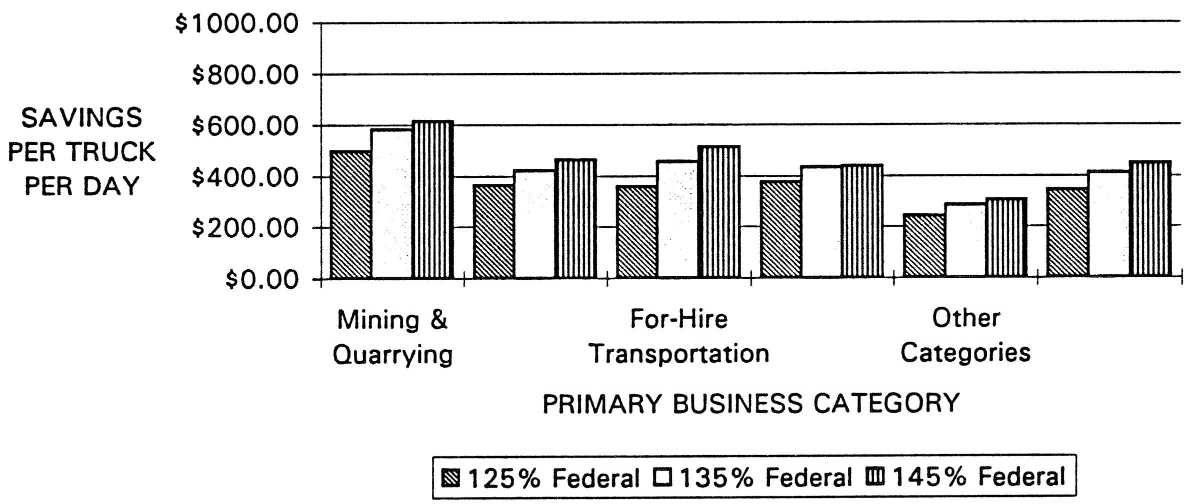

TABLE 5.8.2: TRUCK POPULATION ANNUAL COST SAVINGS

Primary Business Category	Reduction in Annual Cost (rounded to the nearest $100,000) 125% Federal System	135% Federal System	145% Federal System
Mining & Quarrying	$66.9 M	$83.9 M	$90.3 M
Construction (& Ready-Mix)	$289.6 M	$337.8 M	$368.5 M
For-Hire Transportation	$62.0 M	$76.7 M	$85.1 M
Utilities & Sanitation	$67.0 M	$77.4 M	$78.7 M
Other Categories	$69.8 M	$82.3 M	$88.6 M
All Categories	*$550.6 M*	*$653.2 M*	*$708.3 M*

Sample Calculations for the top-left cell of both tables:

$498.25 = ($569.94 + $914.45 + 2*$245.30), from Tables 5.5.1, 5.6.1, and 5.7.1.

$66.9 M (rounded) = $41.2 M + $5.3 M + 2*$10.2 M, from Tables 5.5.2, 5.6.2, and 5.7.2.

Notes:

1) The benchmark for cost savings is the Federal System.
2) Results above assume total compliance with legal load limits.
3) The last line of Table 5.8.2 does not match exactly: different aggregations give different results.
4) All dollar amounts are in 1987 $.

TABLE 5.9: INCREMENTAL CHANGES IN NET BENEFITS FOR VARIOUS WEIGHT LIMITS

CATEGORY	(125%-100%) Federal Limits		(135%-125%) Federal Limits		(145%-135%) Federal Limits	
	Calculation	Result	Calculation	Result	Calculation	Result
Incremental Benefits (Cost Savings) to Truck Operators	$550.6M=	$550.6 M	$653.2M-$550.6M	$102.6 M	$708.3M-$653.2M	$55.1 M
(see last line of Table 5.8.2)		-		-		-
Incremental Costs (Road Damage) to Society	$19.1M=	$19.1 M	$27.7M-$19.1M=	$8.6 M	$35.1M-$27.7M=	$7.4 M
(see last line of Table 4.5.2)						
Incremental Net Benefits (Benefits - Costs)		$531.5 M		$94.0 M		$47.7 M

Notes:
1) Results are in million of 1987 dollars, rounded to the nearest $100,000.
2) To calculate annual values, Fall results are used for the Spring even though the extent of pavement damage may differ significantly due to weather effects (not considered here).
3) Costs and benefits give only an order of magnitude estimate of the true benefits and costs.
4) These results are calculated assuming total compliance with the legal weight limits.

CHAPTER 6. SECONDARY ECONOMIC IMPACT ANALYSIS

This chapter represents the results of our analysis of the long-run secondary economic impacts of the divisible-load permit system on New York State's economy. These secondary impacts are due to the propagation of decreased transportation costs associated with the permit system throughout the various sectors of the state's economy. The nature of secondary economic impacts are described qualitatively, and limitations in their numerical estimation due to available data are outlined. Then, the methodology followed is summarized briefly, although a detailed discussion of the calculations has been relegated to Appendix B. Finally, the numerical illustrations obtained are discussed; they are shown in Tables 6.1 to 6.7 which can be found at the end of the chapter.

6.1 Overview of Potential Consequences

As shown in Chapter Five, increasing the weights that trucks are permitted to carry in New York State can yield an appreciable direct reduction in costs, not only for trucking, but also for those industries that use the services of trucks carrying heavy loads. While the estimated reduced cost of doing business in New York State for these industries, primarily construction, mining and quarrying, utilities and sanitary services, agriculture and logging, wholesale and retail trade, in addition to for-hire transportation, is substantial (an estimated $708 million savings in $1987 as a result of permitted truck weights of 145% of the federal limit), the ultimate economic benefits to New York State are even greater. As an example, these estimates assume that the real flow of trucking services remains constant, even though the cost has declined. Therefore, the output level in these directly affected industries is also assumed to remain constant. In that case, the initial direct economic impact of increased weight limits, while beneficial to the affected industries, and certainly to the consumers of products from New York's business because of lower prices, may nevertheless lead to an initial decrease in the overall level of economic activity in New York. This is a consequence of the fact that the existing volume of cargo can be redistributed onto fewer trucks making fewer trips. This change will require fewer drivers, resulting in a payroll reduction.

Of course, in this example of increased weight limits there is an offsetting positive macroeconomic side to these decreases in industry costs; although they do imply an initial tendency to decrease costs, employment, and possibly revenues in the trucking industry in New York. That is why it is important to explore the secondary economic effects of these decreases in the overall cost of production within particular industries. The first offset is that falling trucking costs imply falling costs for construction, as an example (smaller costs per square foot of completed space). The positive impact that falling costs and therefore prices have on the quantity of products demanded, what economists call price elasticity effects, must be explored in order to gauge the offsetting rise in demand for the output of many of New York State's industries as their prices (cost of doing business) fall.

But the analysis of secondary economic impacts does not end there: as the demand for the output of New York State's industries rises, so too will those industries' demands for productive inputs, many of which are also produced in New York. Thus, there will be a multiplicative expansion in the state's economy as a result of the initial price-induced rise in consumer demand for products. In the long run those total economic repercussions average about twice the size of the original demand increases (although the multiplier can vary widely by industry). As an example, the U.S. Department of Commerce's estimated multipliers for New York State (1986) are reproduced in Table 6.1, and they form the basis for estimating the secondary, and consequently total private economic impacts on New York of raising permitted vehicle weights.

6.2 Data Limitations for Economic Analysis

Before the output multipliers can be applied, the direct cost impacts of the regulatory changes must be translated into estimates of altered levels of demand for those industries' products. The estimates of these price elasticity effects is the most tenuous part of the process of estimating secondary economic impacts, both because detailed, current estimates of demand sensitivity to changing prices for goods and services consumed within New York are not available, and because there are no current detailed estimates of total New York State output, or of the level of demand by its consumers for products according to the broad industrial categories analyzed separately in this analysis.

However, the purpose of this study is not to develop a detailed categorization, analysis and forecast of New York State's economy -- the last New York State-developed study of the required level of detail was published in 1972 by Seastrand (1972), based upon 1963 data -- available sources were used here to extrapolate estimates of total NYS output and demand levels, by industry, in order to illustrate how a proper secondary economic impact study would be performed if accurate accounts of economic activity were maintained. Also, separate studies of demand sensitivity to changing prices in New York have not been conducted and published since Saltzman's and Chi's paper (1977), which is based upon data from 1959 through 1973. Also, the product categories for which Saltzman and Chi estimated their price responses do not coincide with the industry categories for which the cost-impacts of changed truck weights are reported. Thus again, very old estimates had to be manipulated in order to illustrate how a proper analysis of secondary economic impacts should be performed; the estimates themselves are limited in their value by the inadequate level of current detailed economic data available for New York.

The level of industrial detail used in this analysis was determined by two factors: one, the level of detail available in the reported Regional Input-Output Multiplier System II (RIMS II) multipliers shown in Table 6.1; and two, a judgment regarding the detail with which individual truck operators would report their activities and the nature of their business on the survey conducted in this project. Taken together, these factors result in the reporting of economic activity by the following eight broad categories:

1. Agriculture, Forestry and Fisheries
2. Mining and Quarrying
3. Construction (plus Ready-Mix Concrete)
4. Manufacturing
5. Transportation (for hire)
6. Communications, Utilities and Sanitary Services
7. Wholesale and Retail Trade
8. Services -- including Finance and Real Estate

6.3 Methodology

The key to developing secondary economic impact estimates for New York is the availability of a detailed numerical description of the state's economy. One frequently used format is an input-output table that, in essence, consists of a series of recipes that describe how the various inputs (factors of production) are combined to produce a dollar's worth of output, by industry, in New York State. A stylistic illustration of an input-output table is provided in Table 6.2. Reading down the columns of the table, A_{cc} represents how many dollar's worth of construction activity goes into producing a dollar's worth of output in construction; A_{mc} shows how many dollars' worth of manufacturing equipment is required to produce a dollar's worth of construction output. Obviously a full table would have a separate entry for each sector of the economy and many of the entries would be zero. For the analysis performed here where eight separate activities are identified, there will be eight separate rows and columns.

A detailed discussion of how an input-output table is manipulated and used to estimate secondary economic impacts is provided in Appendix B, but an intuitive grasp of the procedure can be acquired by considering Table 6.2. An important economic relationship to observe is that the total value of gross state product (GSP) can be computed in one of two ways by adding up separate components from individual industries. First, the total purchases by consumers of NYS products can be added up ($Y_c + Y_m$); or second, the total incomes paid to NYS residents both through wages and salaries and interest and profits on investments can be summed ($V_c + V_m$).

But to determine the aggregate income or output effects, the individual industry by industry consequences of reduced trucking costs must be traced through the economy. Since each column in Table 6.2 can be thought of as a recipe -- what economists call a production function -- for generating a dollar's worth of output in each industry, A_{cc} represents the dollar ratio of construction industry activity required to produce yet another dollar's worth of construction output and A_{mc} shows how many dollars' worth of manufactured products are required to produce a dollar's worth of construction output. The value added figure, V_c, at the bottom of the column shows how much has to be paid to the employees of and investors in the construction industry. Now, if we weight each of these input-output coefficients in the construction column by the total dollar volume of construction activity, and add up those numbers together with the value-added, the result should be identical to the total value of output in the construction industry, X_c. This fact can be used to estimate the percentage impact on the price of construction services, as an example, that results from a change in trucking costs facing that industry, if it is assumed that physical quantities remain constant initially. While a detailed description of methodologies is provided in Appendix B, if it is assumed that as trucking costs change, all other ways of doing business (proportions of inputs) remain constant, initially, then the absolute dollar value of trucking cost changes facing each industry are easily converted into percentage changes in product prices.

The next step is to translate the changing product prices into changes in demand for New York State's products. This is accomplished with the assistance of the economic concept known as the price elasticity of demand, η, which represents the percentage change in output that is caused by a percentage decrease in price. Thus, for this analysis $\eta = 1$ is a key number: if the elasticity is larger than one, industry demand will rise more than prices have fallen, so total revenues will increase; if η is less than one, industry revenues will fall as a result of a given percentage price decrease. Having estimates of price elasticities of final demand, η, for each of the eight industrial groupings considered in this analysis, the estimated changes in trucking costs in each industry can be translated into an estimate of changed final demand for each industry's product.

The final step is to trace through the multiplicative impact that the changed final demand has on the output and employment of all other industries in NYS that contribute to the production of a final product. As an example, if as the result of falling trucking costs, the price of construction falls and therefore the final demand for construction output rises (which implies η is larger than one), the quantity demanded of all of the necessary inputs for the construction industry, including raw materials, manufactured equipment, labor, trucking services and some construction activity, will also rise. These ramifications can be inferred by reading across the rows of the input-output Table 6.2. A_{cc} tells us how much construction goes into construction activities, A_{cm} shows how much construction goes into additional manufacturing output, and if we add these amounts to the final demand for construction activity, Y_c, a revised estimate of the total value of construction output in NYS, X_c, is provided. Repeated algebraic manipulations of this table, as detailed in Appendix B, lead to a set of multipliers that relate the long-run changes in output of all NYS industries to a change in a particular industry's final demand. These are the multipliers summarized in Table 6.1. Earnings and employment multipliers are computed by a similar method.

Thus, using this procedure, it is possible to translate estimates of changes in trucking costs by affected industry into total, long-run macroeconomic impacts on the value of total output, earnings and employment in NYS.

6.4 Estimating Underlying NYS Economic Parameters

As emphasized in the preceding section, the NYS economic information that is required to estimate the changes in dollars spent for the final demand, Y, of New York State products include: the level of that final demand by the eight target industries, the dollar value of total output by those industries, X, and the price elasticities of demand, η, for each group of products or services. Those data are not regularly tabulated and reported for NYS, and so they are estimated for use in this analysis.

6.4.1 Final Demands and the Value of Output

The base year used for estimating the economic impacts of changed trucking regulations is 1987, although the surveys analyzing physical impacts were conducted in 1990 through 1991, because supporting economic data are not available beyond 1989. In fact, distressingly little detailed data are available for New York State for 1987, and the base economic data used in this analysis was projected from data on gross state product (GSP) that are available from the U.S. Bureau of Economic Analysis for New York State by business category. The 1987 data on GSP in New York are summarized in Table 6.3 according to the eight business classifications for which primary economic impacts were calculated in Chapter 5. NYS data on final demand, Y_i, or the value of output, X_i, are not available directly, however, and these values had to be estimated in order to complete the analysis of secondary economic impacts.

Since the GSP in each industrial category is approximately equal to the value added in that category, adding up the industry-specific GSP's in column 1 of Table 6.3 provides an estimate of total state GSP. But since GSP is also equal to the sum of the final demands for products in New York, the final demands for 1987 are estimated in column 5 by applying a 1987 allocation for the northeast region of the United States to NYS, as summarized in column (3). Thus total GSP from column (1) times the allocation factor in column (3) yields the NYS estimates of final demand by business category in column (5). Note from the fractional allocations in column three that 45 percent of the final demand for products from the northeast is for financial and other services, 26 percent is for manufactured products, 11 percent is for wholesale and retail trade and 9 percent is for construction.

As a final step, the value of output is estimated for each industry in 1987 by assuming 1987 input-output coefficients for the northeast region are valid for NYS. Working down the columns of an input-output table (in Table 6.2, for illustrative purposes), whatever fraction of the value of total output that is not used to pay producers of intermediate goods is assigned to the value-added, which is equivalent to GSP in that industry. But, if the input-output coefficients remain stable over time, then the total fraction of the value of output, X, flowing to the value-added (GSP) also remains constant. This ratio is tabulated in column (2) of Table 6.3 for the northeast, and the resulting estimates of value of output, X, derived by multiplying columns (1) and (2), are summarized in column (4).

6.4.2 Sensitivity of NYS Final Demand to Unit Costs (Prices)

The source of demand-response estimates for various sectors of the NYS economy is Saltzman and Chi (1977). They estimate linear demand relationships that include a one-year lagged value of final demand as an explanatory variable. This formulation replicates a response structure to changing prices that is not instantaneous, but rather continues at a declining rate over many years. The typical form of equation that they estimate for other consumer services, as an example, is:

$$Y_{i,t} = a + b\,Y_{i,t-1} + c\left(\frac{P_i}{P_c}\right)_{t-1} + d\,Z_t + \varepsilon_t \qquad (6.1)$$

where $Y_{i,t}$ is the final expenditure demand for other services in year t; $Y_{i,\,t-1}$ is the value in the previous year; P_i is the price of other services; P_c is a price index for consumption goods; Z_t represents all other non-price variables included in the equation; and ϵ_t is the error term. The values of a, b, c and d are parameters that are estimated by Saltzman and Chi using econometric techniques.

These demand estimates are used together with an input-output model, whose solution assumes the economy is in a long-run, steady-state equilibrium. The input-output model is consistent with the intention of this section of the report: to estimate the long-term economic impacts of changed truck-weight permits. Therefore, we are interested in estimating the long-run economic impacts of a price change implied by equation (6.1). In that case, $Y_{i,t} = Y_{i,\,t-1}$, and the equation can be restated as:

$$Y_i = \frac{a}{1-b} + \frac{c}{1-b}\left(\frac{P_i}{P_c}\right) + \frac{d}{1-b}Z + \frac{\varepsilon}{1-b} \qquad (6.1a)$$

Since we are interested in how Y_i changes as P_i varies, take total differentials of equation (6.1a) with respect to (P_i/P_c):

$$dY_i = \underbrace{\frac{c}{1-b}}_{\gamma_i} d\left(\frac{P_i}{P_c}\right) \qquad (6.2)$$

The estimated values of γ_i are shown in column (1) of Table 6.4. For most industries, these values represent weighted averages of estimates by Saltzman and Chi since the consumption categories analyzed by those authors do not coincide with the eight categories used in this analysis. The average elasticities used here are weighted by the percentage composition of final demand; however, because of these manipulations, the demand response estimates reported in Table 6.4 can be considered at best approximations.

Also, since Saltzman's and Chi's estimates of changes in demand expenditures are calibrated in terms of \$1958, the values of γ_i must be inflated by the ratio of 1987 prices to 1958 prices for commodity i because the variable triggering the expenditure change is a price ratio -- a pure number without units. In calibrating the model, Saltzman and Chi also used the ratio of two price indices for (P_i/P_c) -- the ratio of the actual price of commodity i to its 1958 price, divided by the ratio of all consumption prices to their 1958 level. Thus equation (6.2) is manipulated as follows:

$$\underbrace{\left(\frac{P_i^{87}}{P_i^{58}}\right) dY_i^{58}}_{dY_i^{87}} = \gamma_i \left(\frac{dP_i^{87} / P_i^{58}}{P_c^{87} / P_c^{58}}\right) \tag{6.2a}$$

Rearranging the right-hand side of equation (6.2a) leads to an estimate of the change in $1987 demand revenues as a result of changed trucking regulations as follows:

$$\frac{dY_i^{87}}{dReg} = \gamma_i \underbrace{\left(\frac{P_i^{87} / P_i^{58}}{P_c^{87} / P_c^{58}}\right)}_{\alpha_i} \underbrace{\left(\frac{dP_i^{87}}{dReg} \Big/ P_i^{87}\right)}_{\frac{C_i}{X_i}} \tag{6.3}$$

Equation (6.3) expresses the change in expenditures for final demand by business category as a function of the percentage change in the prices of industry i that are induced by the change in trucking permit regulation -- precisely the triggering value developed from the estimates of changed trucking costs. Here C_i represents the changed trucking costs in industry i; X_i is the total dollar value of output of industry i in NYS. Thus C_i/X_i represents the percentage change of cost, and ultimately of price under competitive pressures, in industry i, when physical output remains constant.

Finally, the implied price elasticity of demands can be computed by inserting equation (6.3) into equation (B.16) in Appendix B and manipulating terms, as summarized in equation (6.4):

$$\eta_i^{87} = 1 - \frac{\alpha_i^{87}}{Y_i^{87}} \tag{6.4}$$

The values of P_i^{87}/P_i^{58} (the industry-specific price deflators), the total expenditure effects, α_i, and the implied price elasticities, η_i, are summarized in columns (2), (3) and (4) of Table 6.4. The implicit price deflator for all consumption goods between 1958 and 1987 of 3.543 was used in equation (6.3) for computing demand effects. The computation of the price elasticity of demand in column (4) draws upon the estimates of final demand from Table 6.3.

As summarized in column (4) of Table 6.4, all demand elasticities for expenditures on final demand are greater than or equal to one. This means that decreased trucking costs (increased permitted weights) will have a positive overall impact on the economy. Notice that in agriculture and forestry products, in mining and in construction, where the elasticities are one, the decreased salaries and expenses for operating fewer trucks as a result of increased permitted weights would just be offset by the increased demand for the outputs of those industries. So, the net effect on final dollar expenditures in those industries would be zero. In all other industries, however, expenditures on final demand would rise as a result of decreased trucking costs, and so would the multiplicative effects. Conversely, any action that increases trucking costs per ton-mile will decrease the state's level of economic activity in the long run. However, it must be emphasized that these estimates of elasticities are old and very coarse, so the resulting estimates of secondary impacts are primarily illustrative.

6.5 Estimates of Long-Run Secondary Economic Impacts

6.5.1 Assume Savings Remain in Industries with Reduced Trucking Costs

These estimates of long-run economic benefits to New York State of permitting selected trucks to exceed federal weight limits are developed in accordance with the business categories used in Chapters 4 and 5, and are based on the initial (primary) cost savings that are estimated in Chapter 5 for permitted trucks operating at 145% of federal limits. These industry-specific estimates of net trucking cost savings are drawn from Table 5.4.2 and are restated in column (1) of Table 6.5. These estimated direct primary economic impacts are then divided by their respective industry's 1987 value of output (column (4) of Table 6.3) in order to obtain each industry's percentage reduction in the price of output due to decreased trucking costs. These estimates of the percentage impact on unit costs for New York's industries are shown in column (2) of Table 6.5. The percentage cost reductions will lead to equivalent price reductions as a result of competitive pressures, if the flow of real goods and services remains constant initially. The price changes are then multiplied by the total expenditure effects tabulated in column (3) of Table 6.4 to show the total effect on the final quantity demanded, by industry, in New York State, as shown in column (3) of Table 6.5.

The substantial dollar amount of direct savings in trucking costs in NYS due to the permit system, however, translates into a very small percentage reduction in the overall price of products produced by New York State industries as shown in column (2). The average percentage decrease in the unit cost of business is only 0.10 percent, with the largest sectorial reduction of .8 percent being in construction. Note that the 12.8 percent reduction reported for mining and quarrying may be due to erroneous classifications by survey respondents of construction-related trips to quarrying by sand and gravel carriers. Since the total value of output of mining in New York State is extremely small, a small number of misclassifications can lead to large percentage price change errors in that industry.

These estimated price changes are translated into revisions in demand for New York State's products, by industry, using the price elasticity estimates from column (4) of Table 6.4. Because the estimated price elasticity of demand for construction (and several other industries) is 1.0, the percentage price decrease yields no change in final demand. In fact, only wholesale and retail trade yields a significant number, $1.7 million, in final demand changes as a result of reduced trucking costs.

The next step is to apply impact multipliers to these estimated changes in final demand. In order to illustrate likely impacts, the impact multipliers reported in Table 6.1 were aggregated based upon each industry's 1963 fraction of final demand. These estimates of aggregated multipliers by eight industrial categories are listed in Table 6.6. The correct procedure would require the construction of the 39-by-39 matrix of input-output coefficients, aggregating them to an eight-by-eight matrix based upon current (1987) values of output (not 1963 data), and then performing the matrix manipulations described in Appendix B in order to compute the new multipliers. However, these input-output coefficients are not widely available through NYS, and this simplified approximation was used for illustrative purposes.

When the estimated changes in final demand from column (3) of Table 6.5 are applied to the impact multipliers that have been aggregated up to eight industrial categories from the 39 groupings reported in Table 6.1, very small secondary impacts are implied as shown in Table 6.5. Nevertheless, the secondary macroeconomic benefits completely offset the initial decline in revenue and earnings faced by New York State industries as a result of trucking costs savings. Here, as a result of the $3.0 million net increase in final demand, total New York output is estimated to increase by $5.6 million, earnings increase by $1.8 million, and employment rises by 98 jobs in all NYS businesses.

Evidence is provided in these results of the tremendous sensitivity of the reported estimates to changes in the price elasticities of demand, particularly for construction. As an example, were the true value of $\eta_C = 1.1$, equivalent to the largest value estimated for any New York industry, instead of 1.0, the estimated decrease in trucking costs in construction alone would result in a $29.9 million increase in final demand, a $59.3 million increase in output, a $18.7 million increase in earnings, and a gain in employment of 919. In this hypothetical illustration, the secondary employment gain would overwhelm any reduction in the employment of truck drivers that may have resulted from the inauguration of the permit systems.

6.5.2 Assume Trucking Cost Savings Dispersed Throughout the State's Economy

As a further refinement in methodology, instead of assuming that all of the initial cost savings in trucking remain in those businesses where the trucks are used, a longer run analysis of the dispersion of those cost savings throughout other NYS businesses can be performed, as described in the second methodology in Appendix B. Illustrative estimates of those dispersions in cost savings and their economy-wide impact are shown in Table 6.7. In particular, the impact of construction cost savings, as those price effects work their way through the entire economy are highlighted. As an example, comparing column 2 in Table 6.5 with column 1 in Table 6.7, the ultimate percentage change in costs (and therefore in prices) is seen to be much greater in most instances when the full economy-wide ramifications are considered. Here the ultimate percentage cost reduction in construction rises from .8 percent to 1.5 percent, in manufacturing from .01 percent to 1.3 percent, and for utilities from .18 percent to 2.8 percent. The cost, and ultimately price, reductions are so much larger in this second case because, as an example, the way in which construction cost savings influence manufacturing costs are accounted for. And in the case of utilities, the interplay between construction costs, manufacturing costs and utility costs are all considered.

Not surprisingly, therefore, the secondary macro-economic benefits arising from the use of vehicles with weight permits 45 percent in excess of Federal limits are estimated to be much larger if economy-wide cost interactions are considered. As an example, the total value of state output is estimated to increase by $278.2 million (compared with $5.6 million using the simplified methodology), NYS earnings are estimated to increase by $79.3 million (compared with $1.8 million) and net employment increases by 4,099 jobs (compared with 98). If, in fact, the price elasticity for construction output is 1.1 instead of 1.0, the estimated gains are even larger, as shown in Table 6.7.

6.6 Cautionary Notes

The good news is that these illustrations show the importance of reduced trucking costs, as derived from the weight permit system, on the economic health of NYS. The bad news is that the status of recording and reporting sectorial economic data in NYS, and consequently the ability to update the input-output tables, is so poor that the estimates presented in this report cannot be relied upon. This conclusion is reinforced by the absence of recent estimates of the sensitivity of final demand to changing prices, by business category. The estimates in Tables 6.5 and 6.7 are presented merely to illustrate the order of magnitude of likely benefits to NYS resulting from this permit system.

Furthermore, while these estimates of secondary economic impacts shown in Tables 6.5 and 6.7 are illustrative of eventual impacts, they should not be used in a cost-benefit comparison with the estimated cost impact of the permit system on highway construction and maintenance costs. Those pavement costs have not been subjected to this type of secondary economic impact analysis, primarily because of the inadequate underlying economic data that are available for NYS. So it is fair only to compare the net primary economic benefits estimated for trucking costs, as summarized in column (1) of Table 6.5 with the direct economic costs estimated for pavements in Chapter 4, as described at the end of Chapter 5.

TABLE 6.1: TOTAL MULTIPLIERS BY INDUSTRY AGGREGATION FOR OUTPUT, EARNINGS, AND EMPLOYMENT.

	OUTPUT (1) (Dollars)	EARNINGS (2) (Dollars)	EMPLOYMENT (3) (Number of jobs)
AGRICULTURE, FORESTRY, AND FISHERIES			
Agricultural products and agricultural, forestry, and fishery services	1.7164	0.4264	49.6
Forestry and fishery products	1.6293	0.4421	52.5
MINING			
Coal mining	1.6067	0.4568	24.3
Crude petroleum and natural gas	1.4479	0.2067	7.9
Miscellaneous mining	1.7411	0.4503	19.9
CONSTRUCTION			
New construction	1.9951	0.6226	30.3
Maintenance and repair construction	2.0101	0.7245	35.0
MANUFACTURING			
Food and kindred products and tobacco	1.8085	0.3390	17.6
Textile mill products	1.7284	0.4007	22.0
Apparel	2.0381	0.5477	32.0
Paper and allied products	1.8273	0.4150	18.6
Printing and publishing	2.1795	0.6031	28.3
Chemicals and petroleum refining	1.5622	0.2176	8.8
Rubber and leather products	1.8816	0.4669	25.8
Lumber and wood products and furniture	1.7832	0.4820	27.7
Stone, clay, and glass products	1.8966	0.5139	22.5
Primary metal industries	1.8358	0.3741	15.2
Fabricated metal products	1.8000	0.4848	22.4
Machinery, except electrical	1.9588	0.5569	22.9
Electric and electronic equipment	2.0245	0.6174	27.2
Motor vehicle and equipment	1.8771	0.4662	18.1
Transportation equipment, except motor vehicles	1.9873	0.5962	23.3
Instruments and related products	1.8516	0.4888	20.2
Miscellaneous manufacturing industries	1.9111	0.4850	26.5
TRANSPORTATION, COMMUNICATION, AND UTILITIES (includes government enterprises)			
Transportation	2.0401	0.6945	30.9
Communication	1.6587	0.4384	17.1
Electric, gas, water, and sanitary services	1.5389	0.2353	9.3
WHOLESALE AND RETAIL TRADE			
Wholesale trade	1.8834	0.6295	29.0
Retail trade	1.9501	0.7315	51.6
FINANCE, INSURANCE, AND REAL ESTATE			
Finance	1.9858	0.6688	26.6
Insurance	2.2441	0.7340	33.0
Real estate	1.3666	0.1382	7.7
SERVICES			
Hotels and lodging places and amusements	2.1062	0.6073	39.9
Personal services	1.9562	0.7054	65.7
Business services	1.9566	0.7668	41.9
Eating and drinking places	1.9959	0.5544	50.1
Health services	2.0883	0.8342	40.7
Miscellaneous services	2.1195	0.7500	40.1
Households	1.0918	0.3082	18.0

Notes:

1) Each entry in column 1 represents the total dollar change in output that occurs in all row industries for each additional dollar delivered to final demand by the industry corresponding to the entry.

2) Each entry in column 2 represents the total dollar change in earnings of households employed by all row industries for each additional dollar of output delivered to final demand by the industry corresponding to the entry.

3) Each entry in column 3 represents the total change in number of jobs in all row industries for each additional 1million dollar of output delivered to final demand by the industry corresponding to the entry.

SOURCE: Regional Input-Output Modeling System, Regional Economic Activity Division, Bureau of Economic Analysis.

TABLE 6.2: STYLISTIC REPRESENTATION OF INPUT-OUTPUT COEFFICIENTS FOR A SIMPLE ECONOMY

		OUTPUT INDUSTRIES		
		Construction	*Manufacturing*	INAL DEMAN
INPUT INDUSTRIES	*Construction*	Acc	Acm	Yc
	Manufacturing	Amc	Amm	Ym
	VALUE ADDED	Vc	Vm	

TABLE 6.3: HISTORIC AND PROJECTED ECONOMIC ACTIVITY IN NEW YORK STATE

BUSINESS CATEGORY	*Column 1* 1987 GSPi (Subcategories of Gross State Product)	*Column 2* 1987 N.E. Region Proportional Multiple of Value of Output	*Column 3* 1987 N.E. Region Fractional Allocation of Final Demand	*Column 4* Estimated 1987 NYS Value of Output, Xi (millions)	*Column 5* Estimated 1987 NYS Final Demand, Yi (millions)
Agriculture and Forestry	$2,466	2.9140	0.0134	$7,186	$5,159
Mining and Quarrying	$420	1.6780	0.0032	$705	$1,232
Construction	$18,071	2.5520	0.0875	$46,117	$33,686
Manufacturing	$57,873	3.0640	0.2632	$177,323	$101,327
Transportation	$11,956	2.2130	0.0273	$26,459	$10,510
Utilities	$22,896	1.9350	0.0452	$44,304	$17,401
Wholesale and Retail Trade	$61,837	1.4390	0.1101	$88,983	$42,387
Finance, Services & Government	$209,463	1.4550	0.4500	$304,769	$173,242
Total	$384,982	- -	1.0000	$695,846	$384,944

Note: All dollar amounts are in millions of $1987.

TABLE 6.4: PROJECTED 1987 DEMAND RESPONSES FOR NEW YORK STATE

BUSINESS CATEGORY	*Column 1* Partial Demand Response, . see (1)	*Column 2* Sectorial Price Deflator, Pi(87)/Pi(58), (2)	*Column 3* Total Expenditure Response, .	*Column 4* Price Elasticity of Demand, .
Agriculture and Forestry	$0	- -	$0	1.0000
Mining and Quarrying	$0	- -	$0	1.0000
Construction	$0	- -	$0 [-$3,369]	1.0000 [1.1000]
Manufacturing	-$8,073	2.58	-$5,878	1.0580
Transportation	-$39	3.06	-$34	1.0030
Utilities	-$182	4.90	-$252	1.0140
Wholesale and Retail Trade	-$3,916	3.29	-$3,636	1.0860
Finance, Services & Government	-$13,913	4.03	-$15,824	1.0910

Notes:
1) Derived from estimates by Saltzman and Chi (1977).
2) Implicit GNP deflator for all consumption goods, Pc(87)/Pc(58)=3.543.
3) All dollar amounts are in million of $1987.
4) [.] represents a sensitivity analysis where the price elasticity of demand for construction is changed from 1.0 to 1.1.

TABLE 6.5: ESTIMATED SECONDARY ECONOMIC IMPACTS ON NEW YORK STATE'S ECONOMY OF CHANGING PERMITTED TRUCK WEIGHTS FROM 100% TO 145% OF FEDERAL LIMITS

	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*
BUSINESS CATEGORY	Net Change in Trucking Cost for 145% Fed. Limits	Fractional Change in Industry Price Ci/Xi	Change in Final Demand ΔYi	ESTIMATED TOTAL SECONDARY IMPACTS Output	Earnings	Employment (No. of Jobs)
Agriculture and Forestry	-$24.7 M	-0.0034	$0.0 M	$0.0 M	$0.0 M	0
Mining and Quarrying	-$90.3 M	-0.1281	$0.0 M	$0.0 M	$0.0 M	0
Construction	-$368.5 M	-0.0080	$0.0 [$26.9] M	$0.0 [$53.7] M	$0.0 [$16.9] M	0 [821]
Manufacturing	-$10.3 M	-0.0001	$0.3 M	$0.7 M	$0.2 M	8
Transportation	-$85.1 M	-0.0032	$0.1 M	$0.2 M	$0.1 M	3
Utilities	-$78.7 M	-0.0018	$0.4 M	$0.7 M	$0.2 M	6
Wholesale and Retail Trade	-$40.6 M	-0.0005	$1.7 M	$3.2 M	$1.1 M	67
Finance, Services & Government	-$8.2 M	0.0000	$0.4 M	$0.8 M	$0.3 M	14
Total	-$708.3 M	-0.0010	$3.0 [$29.9] M	$5.6 [$59.3]	$1.8 [$18.7] M	98 [919]

Notes:

1) Percentage price change may be atypical because of possible misclassification of sand and gravel truck trips for construction purposes into quarrying by survey respondents.

2) [.] represents a sensitivity analysis showing impact of changing the price elasticity of demand for construction from 1.0 to 1.1.

3) All dollar amounts are in millions of 1987 $, rounded to the nearest hundred thousand dollars.

4) Column 1 is the last column of Table 5.4.

5) The Xi's needed to calculate Column 2 come from Column 4 of Table 6.3.

6) Column 3 is obtained by multiplying Column 2 of Table 6.5 by Column 3 of Table 6.4. The other columns are calculated from Column 3 and the corresponding multipliers in Table 6.6.

7) Estimated total secondary impacts give only an order of magnitude of the real changes in output, earnings, and employment.

TABLE 6.6: ESTIMATED TOTAL IMPACT MULTIPLIERS, BY EIGHT BUSINESS CLASSIFICATIONS, FOR NEW YORK STATE

BUSINESS CATEGORY	Multiplier per Dollar of Increased Final Demand in Each Industry		
	Output	Earnings	Employment
Agriculture and Forestry	1.7013	0.4921	50.1
Mining and Quarrying	1.5542	0.3300	15.2
Construction	1.9958	0.6276	30.5
Manufacturing	1.9367	0.5007	24.5
Transportation	2.0401	0.6945	30.9
Utilities	1.5984	0.3362	13.2
Wholesale and Retail Trade	1.9168	0.6805	40.3
Finance, Services & Government	1.8608	0.5883	31.8

TABLE 6.7: ALTERNATIVE ESTIMATES OF SECONDARY ECONOMIC IMPACTS OF CHANGING PERMITTED TRUCK WEIGHTS FROM 100% TO 145% OF FEDERAL LIMITS

	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*
			Estimated Total Secondary Impacts		
BUSINESS CATEGORY	**Frac. Change in Industry Prices $[I-A']^{-1} Ci/Xi$**	**Change in Final Demand ΔYi**	**Output**	**Earnings**	**Employment (No. of Jobs)**
Agriculture and Forestry	-0.0099	$0.0 M	$0.0 M	$0.0 M	0
Mining and Quarrying	-0.1467 (1)	$0.0 M	$0.0 M	$0.0 M	0
Construction	-0.0145	$0.0 [$49.0] M	$0.0 [$97.7] M	$0.0 [$30.7] M	0 [1493]
Manufacturing	-0.0128	$75.3 M	$145.8 M	$37.7 M	1845
Transportation	-0.0085	$0.3 M	$0.6 M	$0.2 M	9
Utilities	-0.0277	$7.0 M	$11.2 M	$2.3 M	92
Wholesale and Retail Trade	-0.0033	$12.1 M	$23.3 M	$8.3 M	489
Finance, Services & Government	-0.0033	$52.3 M	$97.4 M	$30.8 M	1664
Total	- -	$147.0 [$196.0] M	$278.2 [$375.9] M	$79.3 [$110.0] M	4099 [5592]

Notes:

1) Percentage price change may be atypical because of possible misclassification of sand and gravel truck trips for construction purposes into quarrying by survey respondents.

2) [.] represents a sensitivity analysis showing impact of changing the price elasticity of demand for construction from 1.0 to 1.1.

3) All dollar amounts are in million of $1987, rounded to the nearest hundred thousand dollars.

4) Estimated total secondary impacts give only an order of magnitude of the real changes in output, earnings, and employment.

CHAPTER 7. TRANSFER ANALYSIS

A quantitative analysis of permit transfers turned out to be impossible, and upon further investigation somewhat redundant. The investigators learned from the economic impacts analysis, from the comments volunteered by the respondents, and from the staff at NYSDOT administering the Divisible-Load Permit System that permits have achieved a sizable economic value to operators.

Since permits are not a commercial commodity, but rather tied to special "grandfather" privileges of the present holders of such permits, there is great reluctance to disclose under what monetary conditions permits change hands among operators. Furthermore, transfers of permits within companies to newer vehicles simply support the notion that operators like to hold on to the permits and to operate their new vehicles under the permit system. When permits change hands between operators, this can only happen legally by transferring the permitted vehicle together with the sale of the business to the purchasing operator. Naturally, it is virtually impossible to establish, as outsiders, what part of the sale price, even if we could get hold of that information, is attributable to the vehicle and business, and what part to the permit.

This was confirmed by contacting by phone the few respondents who had answered that they sold their truck or transferred a divisible-load permit in the fall of 1991 survey. Most of the respondents did not want to disclose the amount of the transaction nor were they willing or able to give us a specific number for the value of the divisible-load permit. One operator told the investigators that the permits were "far too valuable" to be sold, and several others did not know that permits could be sold. From this informal phone investigation, it appears that there is no real market where transactions can take place to exchange divisible-load permits. But it seems clear to the investigators that permits are a scarce resource that are sought, not only by expanding operators but also by existing operators who have recognized their economic value.

Much of the pressure exerted on the State Legislature and DOT to open up the system again was based on the perception that permits provide a sizable economic advantage to their holders. And the exclusive nature of the permit system was viewed as severely distorting competition among operators within the same industry or business category.

CHAPTER 8. RESULTS AND CONCLUSIONS

1. Perform truck usage surveys for summer, winter and spring

- The permit vehicle usage surveys conducted in the course of this research were successful in generating a data base that is used to provide more detailed annual estimates of both economic benefits (savings) and infrastructure (pavement) damage, attributable to the operation of the New York State Divisible-Load Permit System. In addition, an assessment of seasonal variations in usage can now be made.

2. Perform pavement damage assessment

- Estimates of annual increased pavement damage (in millions of 1987 dollars per year) are:

125% of federal limits:	$19 million
135% of federal limits:	$28 million
145% of federal limits:	$35 million

- While it is clear that pavement conditions are affected significantly by freeze-thaw cycles, no attempt was made to quantify the effects of weather on pavement damage. The necessary detailed information about truck usage and relevant pavement conditions is simply not available. Nevertheless, the research team believes that the unit cost figures used for each road class ($0.02, $0.06, and $0.40 for Interstate, state, and local highways, respectively) are reasonable to account for part of the road damage caused by divisible-load permit vehicle traffic.

3. Perform primary economic impact analysis for different weight limit scenarios, based on the results of three permit vehicle usage surveys (summer, winter, spring/fall)

- Annual estimates of primary economic benefits (in millions of 1987 dollars per year) are:

125% of federal limits:	$551 million
135% of federal limits:	$653 million
145% of federal limits:	$708 million

- The "Construction, incl. Ready-Mix Concrete" industry is the largest direct beneficiary of the system, followed by "For-Hire Transportation", "Mining and Quarrying", and "Utilities and Sanitation". (Please note that we were not able to discuss the proper impacts of vehicles with frequently changing loads during a "tour", i.e. tank and refuse vehicles.)

- Divisible-load vehicle permits are a valuable asset to operators. They carry a value far in excess of permit fees.

4. Evaluate seasonal truck usage variations and their impacts

- Strong seasonal variations in permit vehicle usage by known primary business category can be observed. They are tied to seasonal variations in economic activity in some business categories, such as construction, agriculture, heating fuel deliveries.

- The effects of the economic recession on seasonal variations and overall impacts during the survey period (between summer 1990 and fall 1991) have to be taken into account when determining **absolute** dollar figures for cost savings and, hence, pavement damage.

- However, when it comes to assess the adequacy of the divisible-load permit weight limits, the relevant criterion is the incremental change in benefits and costs. Ideally, load limits should be set at the point where positive marginal net benefits (benefits minus costs) become zero. Although figures generated in this study should be considered only as order-of-magnitude estimates, incremental net benefits were calculated for the various weight limit scenarios considered. It appears that permit weight limits at 145% of federal limits are close to the optimum.

5. Perform secondary economic impact analysis

- The analysis of secondary economic impacts indicates that the cost decreases in trucking have a beneficial impact on nearly everyone in NYS, as the benefits work their way through the economy. Even though available data are not adequate to report precise estimates of the level of change in values of output, earnings, and employment in various sectors of the economy, the illustration presented in this report suggests that benefits from the divisible-load permit system are significant and pervasive throughout the State's economy in the long run.

6. Perform permit transfer analysis

- A quantitative analysis of permit transfers turned out to be impossible, and upon further investigation somewhat redundant. The investigators learned from the economic impacts analysis, from the comments volunteered by the respondents, and from the staff at NYSDOT administering the Divisible-Load Permit System that permits have achieved a sizable economic value to operators.

7. Develop policy recommendations

- Policy recommendations are presented in Chapter 9.

CHAPTER 9. POLICY IMPLICATIONS

9.1 Results of Weight Scenarios for the Divisible-Load Permit System

All results of this study strongly support the continuation of NYS's divisible-load permit system. The estimated primary direct benefits outweigh estimated pavement damage increases due to heavy vehicles by a factor ranging between 20 ($708 million/$35 million) for 145 percent of the federal limits, and 29 ($551 million/$19 million) for 125 percent of the federal limits. At the time of the surveys, the permit system, on average, allowed a maximum load close to 135 percent of the federal limits, resulting in an incremental benefits to costs ratio of close to 23 ($653 million/$28 million).

Given the limitations of the surveys (which do not, for example, take into account bridge damage, nor do they consider weather effects on pavement damage), it appears that a permit limit of 145 percent of federal limits may be close to optimum, since at this level incremental benefits of even heavier loads are close to estimated incremental pavement damage. Other considerations, such as public perception of extra-heavy vehicles should, of course, be taken into account when setting the load limits and may lead to a different average increase over federal limits.

9.2 Potential Modifications and Extensions

9.2.1 Seasonal Permits

As expected, this study showed that benefits (and costs) from the permit system vary significantly by season, due to the variations in economic activity of the industries using these permits. It appears that some business categories, agriculture or fuel delivery, for example, have use for the permits only in certain times of the year. As a matter of fairness but also to increase the flexibility of the permit system, seasonal or even temporary divisible-load permits were introduced by recent changes in permit legislation.

9.2.2 Permit Fee-Level

This study estimated the additional damage caused by divisible-load permit vehicles, above the road damage that would have been caused under the federal weight limits. Where other taxes do not charge divisible-load permit vehicles for this added damage, there is a basis for increasing the permit fee in order to recover these added pavement costs, as was done recently by NYS. Whether the increased fees do in fact cover the added pavement damage remains to be determined. Since the estimated statewide primary economic benefits exceed by far these estimated pavement damage costs, most vehicle operators should find it in their interest to continue to operate while paying higher fees.

Several cautionary notes: (1) With higher fees some marginal operators will decide to drop their permits. In particular, seasonal operators may find that the benefits no longer exceed the higher permit fees. However, it is also likely that many seasonal operators inflict less additional annual pavement damage than does the average permitted vehicle. Therefore, the recent permit legislation gives particular consideration to seasonal permits with pro-rated fees. (2) Since much of the pavement damage is inflicted on local roads, institutional efficiency may warrant the consideration of transferring a portion of added permit fees that are based on pavement damage estimates to local jurisdictions in NYS.

9.2.3 Facilitating Permit Exchanges

Since substantial anecdotal information was received that operators do sell existing permits to each other, while the total number of permits available in NYS was fixed and distributed to current or previous operators, NYSDOT could facilitate this market by providing an information exchange, at a minimum, or by acting as a broker. The benefit to NYS would be to help get the permits into the hands of operators who will benefit most from their use. Also, by acting as an intermediary, NYSDOT could acquire valuable information about evolving use of the permits, both in terms of business category and geographic location. Finally, by observing the prices at which permits are exchanged, NYSDOT would acquire valuable information about the value of the permits to the users and the extent of "pent-up" demand. Of course, the recent changes in permit legislation creates a modest increase in available permits, thus reducing the pressure for permit acquisitions from other operators.

9.2.4 Increasing the Number of Permits

The fact that net user benefits far exceed additional pavement damage costs strongly suggests that the issuance of these additional permits is beneficial to NYS and its economy. However, the fees for additional permits should cover estimated added pavement damage costs to NYS. By facilitating an exchange of existing permits, NYSDOT could obtain valuable information to guide it in altering future permit fees and in issuing additional permits. As an example, if there are numerous trades of existing permits at prices in excess of the estimated incremental pavement damage caused by permitted vehicles, then NYSDOT might expect to find many buyers of additional permits, even if the fee is set at the level of estimated pavement damage. Of course, the recent legislative changes governing the sale of permits only in conjunction with the sale of business is likely to reduce the number of changes in permit ownership.

CHAPTER 10. SUGGESTIONS FOR FUTURE RESEARCH

The surveys and the subsequent analyses performed in this study represent an attempt to quantify benefits and costs of the permit of the divisible-load system, both in time (across 3 seasons), and in space (for the whole state), for a range of truck operators. Since the complex topic investigated in this research is likely to continue to be of great importance to both the trucking industry and the public sector responsible for infrastructure and safety, it is likely that this research will be followed by other efforts to gain more detailed definitive answers about costs and benefits of allowing specific axle loads or GVW on highways and bridges in New York State and elsewhere. Future research in this area should be supported by a larger budget in order to allow much more careful and in-depth observation and recording of truck movements and load characteristics than was possible in the work reported here. The preliminary estimates of the magnitude of the benefits and costs developed in this analysis warrant the expenditure for detailed analyses.

A major challenge for future work will be to obtain better coverage of the truck operators across all business categories, with a special focus on the categories that might have been under-represented in this and in previous studies. These categories include but are not limited to refuse haulers, fuel delivery trucks, and utilities and sanitation vehicles, in general. As mentioned several times in this report, these categories offer special challenges linked to the nature of the business and the impracticality for the drivers to collect the information requested in this study.

One possible approach would be to obtain the cooperation of a "small" (to limit study costs) number of selected operators thought to be representative of specific business categories. A confidential, intensive study would then be conducted using a combination of mail surveys, phone interviews, and possibly follow-up on-site visits geared especially at the business category of interest. Such an approach could possibly require compensating truck operators for their time. This cluster sampling approach would result in an observational study. It would enable the collection of excellent information about truck operations.

This approach could be complemented by accessing information collected on a routine basis by other state agencies. In particular, in order to obtain information about axle loading and overloading, information from weight stations could be analyzed. It could be used to generate distributions of weight loads for various classes of trucks, possibly pertaining to various industries, which would be of great help to check for industry representativeness in future truck usage surveys.

The assumption made in this project concerning operator compliance with the different load limit scenarios is optimistic at best. A study of load limit compliance of permitted and non-permitted vehicles would provide valuable information for refining the pavement damage estimates of future studies.

To address safety concerns, cooperation with local and state police could help to keep track of the number of permitted vehicles involved in road accidents. We want to caution however that such a study should go beyond the simple compilation of the number of accidents. To be more useful, accidents should be related to usage data, including loads carried, miles driven, etc.

To better assess damages to the infrastructure, a future study should be devoted to the development of a methodology for evaluating damage to bridges resulting from heavy vehicle traffic.

While it is generally understood that disproportionate infrastructure damage by heavy vehicles occurs during freeze/thaw cycles, the quantitatively reliable allocation of these damages is a complex undertaking. Nevertheless, more information and understanding of this impact needs to be built into future research assessing the infrastructure impact of heavy vehicles.

Also, collecting the information needed for statistically reliable estimates of non-compliance through systematic police spot-checks would probably require significant time and financial resource allocations. In addition, given its unpopularity, these spot-checks probably could not be repeated for several days of the week or during different seasons, as needed for statistical validity.

Of course, it would be preferable to measure actual vehicle loadings without the knowledge of the truck operator, using weigh-in-motion technology. However, there are still problems with the use of this technology and the logistical issues of sorting permit vehicles from "regular" vehicles in the traffic stream to identify true weight limit violations. In summary, it remains very difficult to collect valid data on actual weight limit compliance.

For primary economic analysis, a key factor in developing estimates of benefits are the per-unit operating and capital costs used in Equations 4.1 to 4.3. For comparison purposes with the 1987 study, the same average cost factors, which are U.S. averages were used. However, in future analyses, an effort should be made to develop factor costs for various regions of the state. Similarly, the secondary economic analysis presented herein relies on regional multipliers.

Much time and effort for this project were spent collecting data. While some of this data can be collected using surveys, we believe that permit application forms should be the basis for collecting data that would enable NYSDOT to follow "on the fly" the evolution of permit usage. The information to collect include: SIC code of the operator (2-digit level at least), operator size characteristics and basic truck information (e.g. year, make, axle spacing, body type). For safety issues, collaboration with the State Police and the Department of Motor Vehicles would help keep track of accidents in which trucks operating with divisible permits are involved.

A generic problem was emphasized for NYS: sufficient economic data should be collected by the state on a routine basis in order estimate secondary economic effects. We believe that the benefits from this economic data collection and assembly for NYS far exceed its costs because many state agencies could use the data to perform in-depth impact analyses of their potential programs. The primary initial concern of most efficiency-improving state programs is that it will cost jobs. As the illustrative secondary economic impact analysis performed in this study shows, in the long run, efficiency improvements create far more jobs than they cost initially.

Finally, NYSDOT could use the permit application forms to collect, on a routine basis, some data that could help answer some policy questions. This includes, for example, industry affiliation which should be recorded at a minimum with 2 digits SIC codes.