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IMPACT ASSESSMENT OF THE REGULATION OF HEAVY TRUCK OPERATIONS

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EXECUTIVE SUMMARY

Study objectives. The main objective of this project was to evaluate the impact of the New York State divisible-load permit system for heavy trucks in terms of benefits and costs to society. The costs result primarily from increased pavement damage; the benefits accrue to the trucking industry (primary economic benefits) and also to New York State's economy (secondary economic benefits). The present study is a follow-up of an earlier investigation (1987, Meyburg, Richardson, Schuler, et al.) that was commissioned by the New York State Permanent Advisory Committee on Truck Weights to investigate benefits of the divisible-load permit system. Research objectives for this project have been expanded and modified, based on findings from the surveys. Seasonal benefits and costs for several levels of departure from the federal weight regime were evaluated in order to assess the "optimum" weight limit under a simplified weight system, based on ratios of the federal limits.

Background. Since 1985. New York State has allowed a fleet of approximately 12,800 power units to operate above the federal limits on gross vehicle weight and axle loads. A permit system comprising eleven permit categories was instituted, corresponding to different truck configurations (number of axles), weight limits (either a ratio of federal limits or fixed limits), and geographic area of operation (statewide or downstate). The New York State Permanent Advisory Committee on Truck Weights commissioned the 1987 study referenced above, followed by this study, to evaluate the economic benefits and costs of this divisible-load permit system.

However, questions about truck weight regulations are not unique to New York State. Many state legislatures and transportation departments are concerned about the costs of increasing weight limits. Economic benefits of alternative weight policies are, in general, poorly understood. Despite the issues at stake, there have been few published studies addressing these concerns. To our knowledge, the predecessor to this study (Meyburg, Richardson, Schuler, et al., 1987) was the first one to be based on actual field data.

Methodology. In order to collect the information necessary to assess pavement damage and primary economic benefits, a 7.1% sample representing 916 vehicles was drawn from the New York State Department of Transportation permit application file. Operators of the trucks sampled were then surveyed three times over a one-year period in order to try to capture seasonal variations; one survey was conducted in the summer of 1990, another one in the winter of 1991, and the last one in the fall of 1991. No survey was conducted in the spring and it was assumed that vehicle usage information collected for the fall was representative of spring usage as well. Each survey questionnaire asked the operator of a specific truck to provide information for a randomly selected day of the week about mileage driven on three different road classes; driving and waiting times; changes

in axle loadings; and general information about the truck itself and the trucking company operating it. The response rates for the summer, winter, and fall surveys were 33.1%, 36.7%, and 28.9%, respectively. These response rates underscore the difficulty of collecting primary information about truck usage. After extensive checks of the nature of the respondents against several criteria, including known characteristics of the entire divisible-load permit fleet, the research team considers that these response rates are sufficient to estimate the order of magnitude of both the costs and benefits described above. The methodology used is detailed in Chapter 3.

Pavement Damage. Estimates of pavement damage were calculated from the data collected, using the ASSHTO formula (which gives equivalent single-axle loading based on a fourth power law). Damage to other parts of the infrastructure, such as bridges, could not be estimated because it was not possible to keep track of the bridge crossings by the vehicles surveyed. The impact of weather on pavement deterioration was not considered.

Extrapolating the pavement damage from the sample results to the whole fleet of permitted vehicles yields the following estimates of annual increases (above 100% of federal limits) in pavement damage (in millions of 1987 dollars per year):

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

it is important to note that these results assume full compliance with the corresponding weight limits. Pavement damage estimates are discussed in Chapter 4.

Primary Benefits. Primary economic benefits, (i.e. the savings to the transportation industry due to reduced transportation costs under limits higher than the federal limits), are evaluated for 125%, 135%, and 145% of the federal limits. The methodology employed assumes that the load transported by each truck on the survey day under the divisible-load permit system would, under the federal regime, be transported by the same truck, along the same route, but with more trips, if necessary, so that federal weight limits would be respected. In addition, the load distribution on each axle that was reported in the surveys was maintained, but scaled down from the data reported in the survey, in order to estimate the number of trips that would be required at lower weight limits. It should be noted that a number of small operators surveyed indicated that they did not have scales to weigh their trucks. Therefore, their loads may be misrepresented. Average statewide labor and operating costs were used for the calculations.

Extrapolations of sample results to the whole fleet of permit vehicles give annual estimates of primary economic benefits (in 1987 dollars) of:

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

The operating cost savings were greatest for the "Construction (including Ready-Mix Concrete) Industry", "For-Hire Transportation", "Mining & Quarrying", and "Utilities & Sanitation". Much of the variation in seasonal costs and benefits reflect seasonal economic activities. Superimposed on this seasonal variation are the effects of the national and regional economic recessions. Nevertheless, strong seasonal patterns of usage for some industries do emerge. Therefore, consideration of alternative regulatory treatment for some industries may be warranted.

As expected intuitively, the primary economic benefits of the permit system substantially exceed its costs, although not all costs could be quantified in this study. As an example, differential impacts on traffic safety in NYS are not included, although the use of permitted vehicles is shown to reduce the volume of truck traffic and, therefore, the exposure to accidents involving trucks. However, the question remains whether or not there is an increased frequency of accidents involving permitted vehicles. Unfortunately, NYS accident data do not contain information about the load (weight) status of vehicles involved in accidents.

Within the limited perspective of direct economic costs and benefits, the proper way to optimize the level of user-benefits, net of pavement costs, is to set the permit limit where marginal benefits equal incremental pavement damage costs (net marginal benefits approach zero). As shown at the end of Chapter 5, these results suggest that a weight limit at 145% of the federal limits is close to the optimum, and lower weight limits reduce the net benefits to society.

<u>Secondary Benefits.</u> Finally, the analysis of secondary economic impacts illustrates how the cost decreases in trucking, resulting from the divisible-load permit system, will work their way through the economy, primarily because in the long run, nearly every sector of the State's economy utilizes the goods and services provided by the initial beneficiaries of trucking cost savings (construction, mining and quarrying, for hire transportation, and sanitation and utilities). Thus, these cost decreases have a beneficial impact, ultimately, on nearly everyone in NYS, including manufacturing, finance and services. While available economic data are not adequate to report precise estimates of the level of increase in values of output, earnings, and employment in various sectors of the economy as a result of trucking cost decreases, the illustrations presented. herein suggest that these benefits are significant and pervasive throughout the State's economy in the long run. Secondary economic benefits are examined in Chapter 6.

<u>Policy Implications.</u> Results of this study strongly support the continuation of the NYS divisible-load permit system. It was determined that the system in existence at the time of the surveys was complex and, therefore, difficult to understand and to comply with.

Certain assumptions had to be made about the degree of compliance in order to develop meaningful benefit and cost calculations. Recent changes in permit legislation and administration, which are to some degree based on preliminary results developed early in this study, have contributed to reducing these problems.

Policy implications are detailed in Chapter 9.

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Mr. Ray DeRocco was instrumental in helping us understand better the intricacies of the Divisible-Load Permit System. He was always ready with information and advice.

Of course, we are also grateful to the permit vehicle operators who responded to our request for confidential information in the three surveys. We recognize that the completion of the questionnaires was a time-consuming and difficult task. Their willingness to put in this extra effort was crucial in making the research project a success.

Finally, we also acknowledge the contributions to the early part of this project by graduate research assistant Mr. Darshan Patil.

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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,heatingfueldeliveries.

- 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 ($551 million/$l9 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 Potentia;=l 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.

Appendix B

Secondary Economic Impact Analysis Methodology

APPENDIX B

DETAILED DESCRIPTION OF METHODOLOGY FOR COMPUTING SECONDARY ECONOMIC IMPACTS

With the help of the input-output table described in Chapter 6 and reproduced in this Appendix as Table B.1, a simple linear model of the state's economy can be written. If we let X_c be the total dollar value of output produced by the construction industry in New York, then moving down the construction column we can write:

$$X_c = A_{cc} X_c + A_{mc} X_c + V_c \qquad \text{(B.1)}$$

Since A_{cc} represents the ratio of dollars of construction required to produce a dollar's worth of construction output, then $A_{cc}X_c$ is the total dollar volume of construction activity required to produce X_c dollar volume of construction output. Similarly $A_{mc}X_c$ is the total dollar amount of manufacturing input required to produce X_c dollar volume of production output. The sum of these terms represents the total payments to producers of inputs (intermediate goods) that are required to produce X_c dollar volume of construction output. If we subtract these payments for intermediate goods from the total value of output, we are left with the residual, V_c as shown in equation (B.1a), which is called value-added.

$$V_c = X_c - A_{cc} X_c - A_{mc} X_c \qquad \text{(B.1a)}$$

This residual represents the dollars available in the construction industry to pay the workers, taxes and interest and a profit on invested capital. The level of value added is also approximately equal to what is frequently called the gross state product (GSP) in that industry. It is, in this case, a measure of the net economic gain generated by the construction industry. Similarly, looking at the manufacturing industry, its production can be characterized by equation (B.2).

$$X_m = A_{cm} X_m + A_{mm} X_m + V_m \qquad \text{(B.2)}$$

Finally, if we add up the net gain (value added) for each industry, we can compute the total gross state product as in equation (B.3).

$$GSP = V_c + V_m \qquad \text{(B.3)}$$

A second way of looking at the input-output (Table B.1) is to read across each row. In this case, we can add up all of the construction used in New York State, as an example, as summarized in equation (B.4).

$$A_{cc} X_c + A_{cm} X_m + Y_c = X_c \qquad \text{(B.4)}$$

Here again, $A_{cc}X_c$ tells us the total amount of construction volume needed to produce X_c dollar's worth of construction. $A_{cm}X_m$ tells us how many dollars' worth of construction activity is used to produce the state's manufacturing output. In order to add up to the total dollar value of all construction activity in the state, we must add in the dollar volume delivered to consumers for their own use -- the final demand component, Y_c. A similar equation can be written to add up the dollar output for manufacturing as shown in equation (B.5).

$$A_{mc} X_c + A_{mm} X_m + Y_m = X_m \qquad (B.5)$$

Here Y_m represents the final consumer demand for the output of manufacturers. These final demand figures also provide an alternative way of adding up the GSP as shown in equation (B.6).

$$GSP = Y_c + Y_m \qquad (B.6)$$

Comparing equations (B.3) with (B.6) simply implies that what is spent on final demand must be earned through some productive activity.

Now for further economic analysis, combine equations (B.4) and (B.5), and re-write them as a simultaneous set of linear equations in matrix notation as shown in equation (B.7).

$$\begin{bmatrix} A_{cc} & A_{cm} \\ A_{mc} & A_{mm} \end{bmatrix} \begin{bmatrix} X_c \\ X_m \end{bmatrix} + \begin{bmatrix} Y_c \\ Y_m \end{bmatrix} = \begin{bmatrix} X_c \\ X_m \end{bmatrix} \qquad (B.7)$$

$$A \quad X + Y = X$$

Here A is the matrix of input-output coefficients, X is the vector of industry output levels, and Y is the vector of final demands. If we assume the level of final demand is given, and we want to know how much input is required from which industry in order to satisfy those levels of final demand, we can solve equation (B.7) as follows:

$$[I-A]^{-1} Y = X \qquad (B.8)$$

Where $[\ ]^{-1}$ is the inverse operator and I is the identity matrix. Finally, since it is anticipated that changed trucking regulations will alter the cost of doing business in most of the state's industries, and that those price changes will affect the state's demand for products, we are interested in determining how the state's total output will be affected by the estimated changes in final demand. These summary equilibrium effects, allowing for the interactions of intermediate goods throughout the state's economy, can be found by differentiating equation (B.8).

$$\frac{dX}{dY} = [I\text{-}A]^{-1} \quad \text{(B.9)}$$

It is precisely this matrix of total output effects that is used to develop the RIMS II coefficients reported in Table 6.1 in the body of the report.

In order to understand the information contained in these output mulitpliers, the algebraic solution is developed for the simple two-good economy illustrated in equations (B.4) and (B.5). Solving both equations for their final demands yields:

$$Y_c = (1\text{-}A_{cc})\, X_c - A_{cm}\, X_m \quad \text{(B.10)}$$

$$Y_m = A_{mc}\; X_c + (1\text{-}\, A_{mm})\, X_m$$

or: $$Y = [I\text{-}A]\; X$$

Now solving (B.10) simultaneously for X_c and X_m, as shown in equation (B.11), we develop the equations shown in matrix notation in equation (B.8).

$$X_c = \frac{(1\text{-}A_{mm})\, Y_c + A_{mc}\, Y_m}{(1\text{-}A_{cc})\,(1\text{-}A_{mm}) - A_{mc}\, A_{cm}} \quad \text{(B.11a)}$$

$$X_m = \frac{A_{cm}\; Y_c + (1\text{-}A_{cc})\, Y_m}{(1\text{-}A_{cc})\,(1\text{-}A_{mm}) - A_{mc}\, A_{cm}} \quad \text{(B.11b)}$$

$$X = [I\text{-}A]^{-1} Y$$

Finally, for simplicity if we call $(1\text{-}A_{cc})\,(1\text{-}A_{mm}) - A_{mc}\, A_{cm} = \Delta$, then we can differentiate equations (B.11) to find the effects of changes in final demand on the level of output. These partial effects are summarized in equations (B.12).

$$\frac{dX_c}{dY_c} = \frac{(1\text{-}A_{mm})}{\Delta} \; ; \; \frac{dX_c}{dY_m} = \frac{A_{mc}}{\Delta} \quad \text{(B.12a)}$$

$$\frac{dX_m}{dY_c} = \frac{(1\text{-}A_{cm})}{\Delta} \; ; \; \frac{dX_m}{dY_m} = \frac{(A_{cc})}{\Delta} \quad \text{(B.12b)}$$

The total output effects of a change in the final demand for a particular product is found by adding the relevant derivatives as shown in equations (B.13).

$$\frac{dX}{dY_c} = \frac{dX_c}{dY_c} + \frac{dX_m}{dY_c} = \frac{(1-A_{mm}) + A_{cm}}{\Delta} \qquad (B.13a)$$

$$\frac{dX}{dY_m} = \frac{dX_c}{dY_m} + \frac{dX_m}{dY_m} = \frac{A_{mc} + (1-A_{cc})}{\Delta} \qquad (B.13b)$$

These are precisely how the RIMS II output multipliers are computed that are summarized in Table 6.1 in the body of the report. A similar related procedure is used by the U.S. Department of Commerce to estimate the earnings and employment multipliers. Note, however, that the actual input-output table is not required if the multipliers are available.

B.l Estimating Secondary Economic Impacts - First Approximations

The first-order economic impacts are expressed in terms of a change in trucking cost for a particular industry that results from a change in the weight regulations. As an example, let C_c represent the lowered trucking costs that might be experienced in the construction industry as the legal weight limits were relaxed with the implementation of the current permit system. Similarly, many other industries like manufacturing would experience cost reductions, C_m. The total effect on New York's economy, however, would be greater than the sum of these independent expenditure reductions, $C_c + C_m$, since the changing industry costs induce offsetting changes in the demand for each industry's output. Again, taking construction as an example, the direct effect upon construction expenditures resulting from the changed regulation is shown as the first term on the right-hand side of equation (B.14), but in addition we have the offsetting changed demand effect shown by the second term.

$$\frac{dY_c}{dReg} = q_c \frac{dP_c}{dReg} + P_c \frac{dq_c}{dP_c} \frac{dP_c}{dReg} \qquad (B.14)$$

Note, for most goods and services dq/dP is negative. Now, if we assume that the initial consequence of the changed regulation does not change the volume of trucking services used by the construction industry nor the volume of construction activity, the effective initial price change in construction can be represented as:

$$\frac{\frac{dP_c}{dReg}}{P_c} = \frac{C_c}{X_c} \qquad (B.15)$$

Equation (B.15) merely represents the trucking cost change in construction as a fraction of the total value of production in the construction industry. If all quantities remain constant, initially, and the industry is highly competitive, this ratio represents the percentage change in the price of construction. Substituting equation (B.15) into (B.14) and manipulating terms results in equation (B.16).

$$\frac{dY_c}{dReg} = q_c P_c \frac{\frac{dP_c}{dReg}}{P_c} \left(1 + \frac{dq_c}{dP_c}\frac{P_c}{q_c}\right) = Y_c \left(\frac{C_c}{X_c}\right)(1 - \eta_c) \tag{B.16}$$

Y_C

where: $\eta_c = -\frac{dq_c}{dP_c}\frac{P_c}{q_c} =$ price elasticity of demand for construction.

Thus a key determinant of the direction of the total economic impact of a changed trucking regulation is the size of the price elasticity of demand for the output of New York State industries that use trucking services. In particular, if $(eta)_c > 1$ (demand is said to be elastic), a decrease in trucking costs ($C_c<0$) will result in expanded dollar volume of final demand for the construction industry; conversely, if $(eta)_c < 1$ (demand is inelastic), decreased trucking costs will result in a reduced dollar volume of final demand for construction. In this second case, the quantity of construction will have increased in response to the cost decrease, but not sufficiently to result in overall higher dollar revenues to the industry.

The use of this method for estimating the final demand impacts of changed regulations requires not only the estimates developed in this study of direct trucking cost impacts, C_c, but also estimates of final dollar demand, Y_c, and total dollar value of output, X_c, by NYS industry. The key variables, however, are estimates by industry of the price elasticities of those industry's demands, $(eta)_c$. In particular, if demand is elastic, changed regulations that reduce trucking costs will expand the dollar value of final demand for that industry's output, which in turn through the input-output model multipliers will have a multiplicative expansionary effect on all of the state's industries serving the construction industry, in this example. Conversely, an inelastic final demand will result in a multiplicative contraction of the state's economy as a result of the changed regulations that reduce trucking costs.

This procedure will be used to estimate the secondary (macroeconomic) economic impacts in this report; however, if a current detailed input-output model were available for New York State, a more detailed procedure could be used, as is outlined in the following section.

B.2 Estimating Secondary Economic Impacts -- An Alternative Method

What the methodology outlined in the previous section does not take into account is the fact that a change in trucking costs in the construction industry can affect not only the costs and prices of outputs in construction, but also because construction is used as an input in virtually all other NYS industries, it will in the long run affect the prices of all other outputs in the state. Similarly, the changing trucking costs in other New York State industries will affect the prices of construction -- as an example, through increased equipment prices as trucking costs rise in manufacturing.

These interactive price effects can be considered if. as in the preceding section, it is assumed that all physical flows of quantities remain constant, initially. In that case, the total industry price impacts can be estimated by moving down the columns of the input-output Table B.1. In particular, consider equation (B.1) in terms of its component parts:

$$x_c P_c = \left(\frac{x_{cc} P_c}{x_c P_c}\right) x_c P_c + \left(\frac{x_{mc} P_m}{x_c P_c}\right) x_c P_c + V_c \qquad \text{(B.17)}$$

X_c $\quad A_{cc}$ $\quad A_{mc}$

Here, x_c is the physical flow of construction services, x_{cc} is the physical flow of construction into construction, is the physical flow of manufacturing into construction, and P_c is the price of construction. Now, allow the prices in equation (B.17) to vary as a result of changed trucking regulations, which also imposes the direct percentage cost burden, C_c/x_c as in equation (B.15). The result is summarized as follows, where value-added V_c is assumed to remain constant , as are all of the physical product flows.

$$x_c \frac{dP_c}{dReg} = x_{cc} \frac{dP_c}{dReg} + x_{mc} \frac{dP_m}{dReg} + C_c \qquad \text{(B.18)}$$

Divide equation (B.18) by the total value of industry output, $X_C = x_C P_C$, and restate all price changes as percentages:

$$\frac{\frac{dP_c}{dReg}}{P_c} = \frac{x_{cc} P_c}{X_c} \left(\frac{\frac{dP_c}{dReg}}{P_c}\right) + \frac{x_{mc} P_m}{X_c} \left(\frac{\frac{dP_m}{dReg}}{P_m}\right) + \frac{C_c}{X_c} \qquad \text{(B.19)}$$

A_{cc} $\quad A_{mc}$

Similarly, equation (B.12) can be arranged as in (B.20):

$$\frac{\frac{dP_m}{dReg}}{P_m} = A_{cm} \left(\frac{\frac{dP_c}{dReg}}{P_c}\right) + A_{mm} \left(\frac{\frac{dP_m}{dReg}}{P_m}\right) + \frac{C_m}{X_m}$$

(B.20)

Now, equations (B.1 9) and (B.20) can be solved simultaneously for the percentage price changes in each industry that are induced by the trucking cost changes, C_c and C_m.

$$\frac{\frac{dP_c}{dReg}}{P_c} = \frac{(1 - A_{mm}) \left(\frac{C_c}{X_c}\right) + A_{cm} \left(\frac{C_m}{X_m}\right)}{\Delta} \qquad \text{(B.21)}$$

$$\frac{\frac{dP_m}{dReg}}{P_m} = \frac{A_{mc} \left(\frac{C_c}{X_c}\right) + (1 - A_{cc}) \left(\frac{C_m}{X_m}\right)}{\Delta} \qquad \text{(B.22)}$$

Here Δ is the determinant that was defined following equation (B.11). In matrix notation, the system of equations (B.21) and (B.22) can be represented as:

$$\frac{\frac{dP}{dReg}}{P} = [I - A']^{-1} \left(\frac{C}{X}\right) \qquad \text{(B.23)}$$

where A' is the transpose of the direct coefficients input-output matrix. This computational procedure is illustrated in this analysis by using an input-output matrix for the entire northeast region of the U.S., not just NYS. Therefore the results should not be used as actual estimates of secondary impacts; they are merely illustrative of the likely magnitude of effects.

I

TABLE B.l: STYLISTIC REPRESENTATION OF INPUT-OUTPUT COEFFICIENTS FOR A SIMPLE ECONOMY

		OUTPUT INDUSTRIES		
		Construction	Manufacturing	FINAL DEMAND
INPUT INDUSTRIES	Construction	Acc	Acm	Yc
	Manufacturing	Amc	Amm	Ym
	VALUE ADDED	Vc	Vm	

Appendix C

Literature Review and References

LITERATURE REVIEW

A comprehensive literature review with respect to heavy vehicle operations and their impacts was conducted as the first phase of the project. Since the Cornell research team had conducted such a survey covering the period up to 1987, the present effort concentrated on the period between 1987 and 1992. Given the focus of this research project, the literature search concentrated on a limited number of subareas of heavy vehicle impact analysis.

Needless to say, relatively little research work has been performed in the area of impact analysis of heavy vehicle operations Nevertheless, a number of papers and reports were identified and reviewed that have a bearing on our attempt to better understand the impacts of such operations. The discussion of the results of the literature search is arranged according to the following categories:

A. General Heavy Vehicle References
B. Economics and Regulation of Heavy Vehicle Operations
C. Infrastructure Impacts (Pavement)
D. Size/weight Regulations
E. Violations and Enforcement of Truck Weight Regulations

A. General Heavy Vehicle References

Monitoring the operations of heavy vehicles continues to be a major concern among operators and public agencies alike. Efficiency of operations and prevention of size/weight violations are the motivating factors behind these efforts. The following discussion provides a sample of recent investigations into this topic area.

Several studies are being carried out to examine the use of automatic technology to monitor traffic, to identify vehicles, to weigh vehicles, etc. This will reduce the time a vehicle spends waiting in line at weigh stations. It will allow the operator to keep track of the company's vehicles and will help in general road design purposes. Cumbersome manual efforts can be done away with due to the use of automatic systems. There is a general belief that the technology involved in this is feasible, but implementing it is expensive and will pay off only if there is sufficient participation from the state's heavy vehicle fleet.

For example, a study by Henion and Koos (1987) examines the use of Automatic Vehicle Identification (AVI) and Weigh-in-Motion (WIM)) technologies. An article in the July/August 1988 edition of Transportationion Research News discusses the Heavy Vehicle Electronic License Plate Program (HELP). Presently, 13 states and the Port Authority of NY/NJ have opted for HELP. A feasibility study of the technologies involved in HELP is completed and soon a practical demonstration is to be carried out. The study by Grenzeback, Stowers and Boghani (1988) deals with the feasibility of the Heavy Vehicle Monitoring System (HVM). It claims that HVM can be implemented in a number of ways with different degrees of participation from the private and the public sector.

A study by Woo and Hoel (1988) deals with the data collection aspect of heavy vehicles. Heavy Vehicle data are collected by D.O.T, as well as by a number of other agencies. This leads to the fact that data on heavy vehicles are very difficult to obtain, particularly with respect to uniform and compatible format, survey procedure, etc. A study by Reel (1987) examines the traffic data collected and compares them with those needed to forecast the 18-Kip Equivalent Single-Axle Load (E.S.A.L.).

A study by the National Highway Traffic Safety Administration (1987) developed guidelines for law enforcement agencies to ensure commercial vehicle safety needs . NAASRA (in Australia) did a study in 1987 in which it proposed guidelines to achieve uniformity of weighing procedures. These guidelines were intended to avoid prosecution when no weighing offense had occurred and to avoid inaccuracies which might prevent significant overloads from escaping prosecution.

In a study by Filseth (1987) about overloading of trucks in the nine member countries of the Southern Africa Transport and Communications Commission (SATCC), lack of proper regulations against overloading and lack of manpower and weighing equipment were cited as the main reasons for overloading.

The August 1989 edition of Distribution carried an article that restated the problems associated with the lack of uniformity of federal and state truck size/weight regulations . 48- and 53-foot trailers are permitted on Interstates . But their access to the state local roads is limited by a series of conflicting rules one of which limits the mileage beyond the interstate. The Interstate Truckload Carriers Conference urged the F.H.W.A. to accept trucks on the state and local roads having a length of 41 feet or less (from the kingpin to the center of the rear axle).

B. Economics and Regulation of Heavy Vehicle Operations

Four studies relating vehicle weight and dimensions to vehicle productivity, i.e. vehicle operating costs, were found. The study by Godwin, Morris, Cohen and Skinner (1987) deals with the so-called Turner proposal of allowing heavy vehicles to carry heavier gross loads, if the number of axles are increased, thereby decreasing the load per axle. The study concludes that the Turner proposal is very beneficial to both the vehicle operators as well as to the road maintenance authorities.

Another study carried out by Maine D.O.T. (1988) examines the effect of the introduction of the 100,000 pound general commodity vehicle. The study concluded that a total of 500 vehicles would shift to using this bigger vehicle, resulting in an increased pavement damage cost of about $450,000. [Note: Using the assumptions and parameters from this Maine study fer the data generated in our study would roughly correspond to an increased pavement damage cost of about $1 2 million per year for the 12,822 divisible-load permit vehicles of New York State.]

Neudorf and Sparks (1987) carried out a general productivity evaluation for heavy trucks in Canada. Their study found that 7- and 8-axle trucks, especially 7-axle trucks are more productive than the standard 5-axle eighteen-wheelers common in the U.S. Another interesting observation is that the same vehicle can be the most or the least productive, depending in which province of Canada it is operating, since regulations concerning heavy trucks differ from province to province. The same might very well hold true for the U.S. since heavy vehicle regulations differ from state to state.

A study by Croft and Miller (1987) about the so-called A-Trains and the B-Doubles operated long-distance in predominantly sparsely populated areas in Australia found that economic benefits are derived from the operation of these long vehicles. These vehicles do not cause any added pavement damage. However they do pose a safety hazard especially during passing maneuvers due to their extreme length. Recently, there has been talk of introducing such vehicles in the U.S., though opposition is expected from the railway industry and from automobile and safety lobbies.

Ever since deregulation of the Interstate trucking industry in 1980, one of the most debatable questions in trucking has been "Is deregulation good or bad?". It was believed at the time the deregulation was announced that it was going to lead to a lot of new entries into the trucking industry, thereby increasing the competition leading to decreased profits. But that does not seem to have happened judging from the results of the literature search. The article by Michel and Shaked (1987) states that since deregulation most trucking firms seem to have shown a gain but it also says that most of the gain has been due to factors that have had nothing to do with deregulation. According to this article, large regional firms seem to outperform small regional firms and national firms. It seems to be generally accepted that the truckload carriers that have performed best (20% return on equity) since deregulation are the so called "high-service truckload carriers". These combine high service with low operating costs. According to the article by Legg and Larkin (1988), these "high-service" truckload carriers have been created by private firms buying equipment and hiring drivers from companies that previously used to do their hauling themselves.

Another article by Daughety and Nelson (1988) examines the trucking scenario from 1953-82. Some observations that emerge are: 1) Similarities between early periods of regulation and early periods of deregulation are more pronounced than those between early and late periods of regulation, and 2) The heaviest burden of regulation was born by the firms which had the highest operating costs.

According to the article "Private Fleet Costs : Driving You to the Brink" (Distribution, August 1987), cost of operating shipper-owned vehicles (small operators) continue to rise, albeit moderately so. Privately owned straight trucks and vans are more expensive ($2.1/ mile) to operate than tractor trailers ($1.4/mile). Another article by Cavinato (1989) says that private fleets once regarded as a fixed part of the corporate landscape are coming under scrutiny more than ever before. The reason is that it is so much less hassle to hire an outside trucking firm than operating a private fleet of heavy vehicles.

According to a paper by Rakowski (1988), there is a general trend towards bigness in the "Less than Truckload" (LTL) sector. The smaller operators are getting forced out of business because of the nationwide operations of the larger companies. Rakowski claims that deregulation lead to increased profits rather than increased competition. A contrasting finding is reported by Hoffman (Distribution, May 1989) who states that truckload firms are competing fiercely. The "high service truckload carriers" still realize substantial growth rates as they withdraw business from their competition. As a result, the trucking industry in general has to be on the lookout for new markets continuously. The amount of freight is not expanding as rapidly as the number of truck operators and trucks looking for it. Ha, Khasnabis and Jackson (1988) found that deregulation has increased the cost of small Shipments in low volume markets. Freight consolidation is a good remedy for such small shipments as it reduces costs and increases the service quality.

Hoffman (Distribution, June 87 and August 1988) states that 1986 was a good year for the trucking industry. Operator profits and revenues went up. However, rising fuel costs and driver shortages forced profits to go down in 1987. Although the profits went down, the total freight carried in 1987 went up.

Martin (1989) examined the tank truck industry. The tank truck industry was in the red from 1982 to 1987. In 1988 things improved slightly. If things are to continue to look better, shippers will have to use carriers that provide safer and better service and they will have to pay higher rates.

McMullen's (1 987) findings about the effects of deregulation run counter to the results of several studies reviewed above. He claims that there has been a substantial number of entries into the market by small firms. This has been due to the tremendous increase in the number of I.C.C certified motor carrier property brokers who have eliminated the difficulty of obtaining information which was one of the main obstacles for small firms. Also, most studies claim that revenues have gone up since deregulation. However, McMullen determined that both real revenues per mile and operating costs per mile have fallen in the post-regulation period. The maximum change has been in the operating costs which have gone down by a third, indicating that deregulation is causing firms to become more cost efficient. The reduction in real revenues is not very large.

The effects of deregulation have probably been summarized best by Kling (1 988). He states that it is important to realize that the trucking industry is not yet stabilized since deregulation. Also, deregulation has led to the bankruptcy of a lot of small firms, both among pre- and post-deregulation entries into the trucking industry. Bigger firms are getting more and more powerful, since they can afford to offer lower rates because they have a larger market share. Especially in the LTL sector a transfer of power is taking place which may lead to the creation of an oligopoly. Also, lower freight rates are leading to the de unionization of the industry which, while partly responsible for the observed productivity gains, are also a possible cause for safety degradation resulting from increased work hours and decreased equipment maintenance, Kling states. Even though deregulation has led to positive aspects like lower freight rates and more competition, it seems that reregulation to counter some of the above mentioned negative aspects of deregulation may be a good idea, keeping in mind the efficiency and the equity distribution that are desired.

C. Infrastructure Impacts (Pavement)

A substantial number of studies examining the effect of the movement of heavy vehicles on the wear and tear of pavement were performed in recent years. Several of these deal with the general topic of the effect of trucks carrying different loads with different axle configurations and tire pressures on the various types of pavements under varied conditions, e.g. Austin Research Engineers (1987), University of Michigan (1991), Kentucky Transportation Research Program (1987). Other studies like those by the Texas Transportation Institute (1987) investigated how this loading consisting of different axle configurations and tire pressures is to be incorporated into pavement design. In a study by New York State Department of Transportation (1991), several roads were selected to monitor pavement performance and maintenance, as well as the traffic data on these roads to establish relationships between traffic loading and pavement maintenance.

A study by Thomas and La-Hue (1988) investigated the effect of increased truck traffic on pavement damage. Road traffic has increased much more than what the roads were initially designed to carry. Especially the truck composition which is the main contributor to the E.S.A.L.'s has gone up from 6% to about 40% of total traffic. Roads can be made to withstand this additional traffic. The author observes that an increase in thickness of the concrete pavement by 1 inch will double its load carrying capacity, i.e. E.S.A.L. life. Also, the cost of providing this additional thickness of 1 inch is much less if it is provided in the initial construction stage than if it is provided as a future rehabilitation of the roadway. Another interesting finding was that on average a 5% increase in gross vehicle weight causes a 23% increase in the E.S.A.L., a 10% increase causes a 49% increase in the E.S.A.L. and a 20% increase in weight causes a 114% increase in the E.S.A.L.

TerreII and Bell (1987) investigated the effect of overloading on pavements. Truck overloading is perceived as a moderate problem with about 20% of the trucks being overloaded costing the Federal Aid Highway System about $ 1 billion each year. Overload fines not being based on axle-weight-miles (i.e. not based on actual cost of pavement damage caused by the Overloaded trucks), insufficient personnel to identify overloaded vehicles and operators of overloaded vehicles often escaping fines because of the failure of the judicial or the administrative procedures are some of the main problems causing the overloading.

Two studies regarding equivalency factors (factors that convert different trucks with different axle configurations into comparable numbers) were found. One study performed by the Organization for Economic Co-operation and Development (O.E.C.D., 1988) gives the different values developed by different countries to which the power that the ratio (of the axle load of the truck to 18,000 pounds) is to be raised to give the E.S.A.L. of the axle for both flexible and rigid pavements. [Note: In this study of the NYS Permit Vehicle Fleet we have decided to use the 4th power as given by the AASHTO test, although a paper by Kenneth and Small suggests that it is the third power and not the 4th power which is correct].

A study by M.I.T. (1989) developed composite load equivalency factors, taking into consideration the vehicle characteristics, like axle configurations, suspension type and tire type, and also pavement characteristics, like pavement type and conditions.

The effect of tire pressure on the wear and tear of pavements is finding increasing attention in the research community. A study by Oregon State University (1987) found that 87% of the tires surveyed were of radial construction and had tire pressures of 102 psi, as opposed to 82 psi of bias ply tires. Also, the study indicated that a 20% increase in the tire pressure could result in a 40 to 60 % increase in the equivalency factors for dual-tire single axles of 18 kips and tandem axles of 34 kips.

A study by Bonaquist and Freund (1988) found that pavement damage depends more on the load of the vehicle than its tire pressure. Other studies have investigated the effect of different heavy vehicle suspension systems on pavements, e.g. Woodroofe and LeBlanc (1988), Cebon (1988), LeBlanc et al. (1988).

Another research area attempts to develop the optimum unit pavement damage costs per E.S.A.L. mile. Vitaliano and Held (1988) examined the time period between two pavement overlays and the cost of the pavement overlays carried out on 59 roads in a certain period of time (1982-85). Based on the functional category of the roads and their Average Annual Daily Traffic (AADT), the annual E.S.A.L. loadings for the roads were calculated.

The overlay costs as well as the average time between two overlays in this study were measured. The only data source here that is slightly doubtfulIis the annual E.S.A.L. loading which has been created from the A.A.D.T. and the axle load distribution based on the functional classification of the roads. The costs developed by this study vary from 1.15 cents per E.S.A.L. mile for Interstates to 28 cents for rural collector roads. Using a much simpler equation (Cost /E.S.A.L. mile = Cost of one mile of overlay /{Years between two overlays times the annual E.S.A.L loading }) and assuming that traffic is responsible for 75% of the damage (instead of the 50% assumed in this study), costs varying from 1.88 cents/E.S.A.L. mile for Interstates to 44.85 cents for rural collectors were obtained. An improvement to this approach would be one where it is possible to get both, the WIM data about the axle loads as well as the pavement overlay costs and the time intervals between overlays, about the same roads instead of having to reconstruct the E.S.A.L. loading of each road from its functional classification and its A.A.D.T. In the absence of research based on that information this study seems to be the best one available.

To a large extent our study is based on the methodology presented by Small and Winston (1989). The equations in the study by Vitaliano and Held (1988) are for all practical purposes the same as those by Small and Winston. The only difference is that Small and Winston attribute 100% of the pavement damage to traffic as against 50% in the paper by Vitaliano and Held. Small and Winston provide figures of cost/E.S.A.L mile of 1.48 cents for Rural Interstates to 125 cents for urban collector streets.

Another very important factor that went into consideration in deciding on the unit pavement damage costs per E.S.A.L. mile to be used for Interstates, state highways and local roads was the recommendation made by John Merris from Oregon State D.O.T. (personal communication, 1990). Merris, based on his extensive experience with determining unit pavement damage costs, suggested using values of about 5 cents per E.S.A.L mile for Interstates,10-30 cents for state highways and 40-50 cents for local roads. He also suggested that we might want to use slightly lower numbers than the ones he had quoted.

Based on these two sources (Vitaliano/Held and Merris), it was decided to use a cost of about two cents/E.S.A.L mile for Interstates, six cents for state highways, and 40 cents for local roads. These numbers mainly come from the study by Vitaliano and Held but differ from it in that a simpler cost equation, as explained earlier, was used. Also, 75% of the road damage has been attributed to the traffic instead of 50%.

The rest of the studies were helpful in telling us that the costs used in this study are in the ballpark of the costs used in similar studies elsewhere. The following are some of the other studies that were examined.

A study by Byrd, Tellamy, MacDonald, and Lewis (1988) determined the additional pavement damage costs, by computing from the pavement design principles the extra pavement thickness (.1 inch) required to withstand this increased annual E.S.A.L. mile loading due to the permit fleet operation. It then divided the cost of the increased pavement thickness for all the NYS highways by the number of years the road will last under the increased E.S.A.L. loading. The resulting costs are very low and are very theoretical. Hence, this methodology was not adopted for this study.

The Federal Highway Administration's cost allocation study of 1982 uses the methodology of dividing the costs of the pavement overlay by the E.S.A.L. life of the pavement until an overlay is required to arrive at the unit pavement damage costs per E.S.A.L. mile. This methodology is acceptable. However, we question the E.S.A.L. lives of the various categories of roads used in this study. The E.S.A.L. lives seem to be obtained through a theoretical process (i.e. a road having base course of "x" inches and "y" inches of asphalt should therefore have an E.S.A.L. life of "z" E.S.A.L.'s), as against actually measured E.S.A.L. life values. It is the opinion of other researchers too that the unit costs per E.S.A.L. mile obtained in the FHWA study are slightly on the high side, in addition to being outdated, given that the study was carried out in 1982. The costs obtained in the FHWA study are 5-15 cents for Interstates, 13-40 for state highways and 31-50 cents for local roads.

A study carried out by Maine D.O.T. (1988) has calculated a per E.S.A.L mile cost of 3.41 cents for all roads other than local roads. The life of the road (i.e. the time period between pavement overlays) has been taken to be 13.33 years for all the different types of roads.

Oregon D.O.T. (1986) came up with costs of 1 cent for Interstates, 26 cents for high volume urban arterials and 51 cents for local roads. A later study by the same agency (1989) recommended a cost of 5 to 10 cents per E.S.A.L. mile for the transportation of indivisible loads, since the roads involved were relatively high quality roads like interstates and major primary routes.

Idaho D.O.T. (1986) proposed costs per E.S.A.L. mile of 6.3 cents for Interstates, 36.7 cents for primary and 123.3 cents for secondary roads.

D. Size/Weight Regulations

One of the most important changes in truck regulations has been the deregulation of 1980. In order to examine the effect deregulation has had on the trucking industry, please refer to section "B. Economics and Regulation of Heavy Vehicle Operations" of this literature review. The following review section discusses the remaining discrepancy between federal and state regulations.

Ettorre (1988) observed that in spite of the federal deregulation of the interstate trucking industry in 1980, the majority of states retained their own regulations on intrastate trucking. An estimated 60% of trucking tonnage does not cross state lines. However, even states seem to be moving away slowly from rate regulation. A study by the Federal Highway Administration (1989) on state practices concerning permits and penalties for overweight vehicles summarized the findings about whether each state is enforcing the truck size/weight regulations and whether state truck weight laws enacted between October 1986 through September 1987 are in conformity with federal laws.

A study by Duncan (1988) concerning regulations stated that the list of proposed constraints aimed at the commercial trucking industry is long and it is likely to result in higher costs and new operating problems for carriers. Duncan claims that these regulations will not solve traffic congestion problems.

Humphrey (1988) discusses the non-uniformity that exists among the oversize/overweight permits across various states of the U.S. The report discusses the problems this non-uniformity causes, the reasons that lead to this non-uniformity and the efforts that are being made right now to achieve a greater degree of uniformity.

An article in Transportation Research News (July/August 1987) described an agreement made by 5 of the 6 New England States to establish common guidelines for issuing permits to non-divisible oversized trucks. The agreement took place through a consortium organized and managed by M.I.T. It is significant in that it marks the first time that states have formally cooperated to simplify size and weight permits for intrastate truck traffic.

Among the international studies reviewed in the course of this research effort were those performed in the U.K. (HMSO, 1987), in New Zealand (Edgar, 1987) and in Canada (Roads and Transportation Association of Canada, 1987). These studies also deal with the problem of developing an appropriate regulatory environment in which improved opportunities are provided to exploit the capacities of both the highway system and the motor carrier fleet.

E. Violations and Enforcement of Truck Weight Regulations

Very few studies exist that deal with the topic of "fines" for operating overloaded vehicles. Prentice and Hildebrand (1988) examine an economic approach to truck weight regulation enforcement. Their study discusses the best way of employing a fine structure. It is a known fact that the costs associated with enforcing complete compliance are excessive. In the absence of effective enforcement, individual truckers have an incentive to overload their vehicles. This study uses a game theory approach to establish the optimal minimum cost of regulation enforcement, i.e. "an equilibrium point where neither the truck operator nor the government have any incentive to alter their action irrespective of the other party's action."

Most of the other studies identified in this effort deal with the problem of overloading of trucks and express the opinion that a fine structure is unable to control these violations. For example, the paper by Euritt (1988) examined fine schedules in Texas and the effect they had on the overloading of vehicles. The paper found that fine schedules are inadequate. The fines are so small, the probability of being caught is so low, and the benefits obtained by operators from overloading their vehicles are so high that they are not sufficiently encouraged to abide by the legal weight limits.

An article in Traffic Safety (November 1987) reported a crackdown by Minnesota State Patrol on interstate truck operators who cheat on their log books. The crackdown was carried out in August and of the 190 inspections that were made, 8 drivers were put " out of service " and several others were issued warnings.

A study by FHWA (March 1989) examined containerized freight transportation involved in international maritime shipping. These containers tend to travel part of their distance by truck. If these containers are overloaded they cause increased pavement damage and violations of the bridge formula. The study concludes that overloading of freight containers is a problem and that, depending upon the size of the container, as many as 17-40% of them are overloaded. This overloading primarily occurs with high-density commodities and the shippers load the containers to capacity to take full advantage of the container's volume, ignoring weight implications.

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