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16. Abstract

This report contains the summarized results of the major research tasks in this study. The tasks, which have been reported in detailed separate reports, were:

1) annotated bibliography on truck elements (Report 397-1);
2) truck accident frequencies and severities (Report 397-4);
3) effects of larger trucks on passenger car equivalents - PCE (Report 397-2); and
4) channelization of trucks at at-grade intersections (Report 397-3).

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Trucks, accidents, passenger car equivalents, channelization, bibliography, research issues

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Larger Trucks on Texas Highways

by

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Research Economist

Research Report 397-5F
Research Study Number 2-18-85-397
"Longer and Wider Trucks on the Texas
Highway System"

Sponsored by
Texas State Department of Highways and Public Transportation
in cooperation with
the United States Department of Transportation
Federal Highway Administration

November, 1986

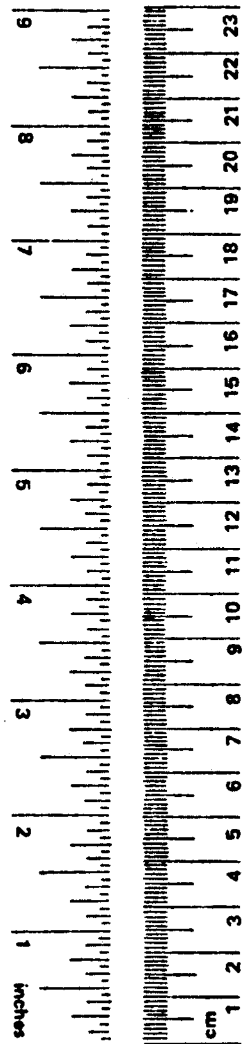
Texas Transportation Institute
The Texas A&M University System
College Station, Texas

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

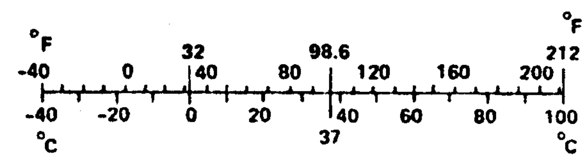
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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

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



Approximate Conversions from Metric Measures

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



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College Station, TX
November 30, 1986

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Introduction

In 1978, the Texas SDHPT initiated a study of the truck weights that the highway system could safely and efficiently accommodate. This "Texas Truck Study" was the beginning of a continuing research effort to identify, analyze, and document a myriad of selected effects of the highway-truck nexus: pavements, bridges, trucking firm operations, costs and benefits, car/truck accident analysis, specialized vehicles, exclusive truck routes, truck lane needs, truck routing regulations, truck optimization, highway cost allocation, and economic analysis.

The dynamics of the legislative, regulatory, and technological trends that define the major tendencies of highway freight movements are incessant. New laws have legalized longer and wider trucks. De-regulation is propelling economic incentives toward much more efficient vehicles; these are characterized by ever greater carrying capacities, both cubic and tonnage. Furthermore, technological breakthroughs in vehicle and power plant design are producing fleet mix changes that are likely to affect vehicular performances and operations.

To keep abreast of this dynamic segment of highway users, current information about the nature of the vehicles, their operations, their accident experience, and their impacts on highway design standards, procedures, and policies has been developed. The research being reported is a logical, complementary extension of the past and current truck-related analysis that have kept the SDHPT among the national leaders in this research effort.

Objective of the Study

To develop current information describing the crucial implications accommodating longer and wider trucks on the Texas highway system.

Major sub-objectives include:

1. To prepare and publish an extensive annotated bibliography.

2. To prepare interim technical reports describing the implications of larger vehicles regarding geometric design and traffic operations.

3. To prepare an interim technical report analyzing the accident experience of larger vehicles.

4. To synthesize the results into a summary and publish this synthesis as the final report of this research effort.

Annotated Bibliography

The annotated bibliography (Report 397-1) summarized selective research that is helpful in assessing the implications of longer and wider trucks. Both operational characteristics and geometric considerations were presented. The primary contents included pertinent literature on vehicle characteristics and performance, sight distance, horizontal and vertical alignment, cross section elements, capacity, safety, and truck regulation and enforcement. Each annotation was presented as a separate citation under a specific sub-topic heading for quick references.

The Annotated Bibliography was arranged under seven unique main topic headings:

1.0 Highway Functions
2.0 Design Control and Criteria
3.0 Elements of Design
4.0 Cross Section Elements
5.0 Operational Design
6.0 Operational Safety/Truck Accidents
7.0 Regulations, Restrictions, and Enforcement

Each major heading was divided into unique sub-topics to clearly segregate pertinent sections of the cited literature. The user can quickly review the Table of Contents in Report 397-1 to identify an area of interest. Since each piece of research was reviewed following the outline of the Table of Contents, a particular reference (number in parenthesis) may appear under several sub-topic headings. Only the related portions of the cited reference were summarized under each category. The references under each sub-topic were arranged by publication date from most recent to oldest.

Several sub-sections do not have annotated references. It was anticipated that these citations can be added when pertinent information became available. Future research findings can be conveniently added to the references. This document is stored on IBM-PC microcomputer diskettes and can be easily retrieved and modified. The Texas Transportation Institute plans to add new research findings as they become available.

The annotated bibliography attempts to establish a "status quo" on truck research regarding operational characteristics and geometric design implications of longer and wider trucks. Creation of this synthesis will improve the efficiency of future efforts that require a state-of-the-art literature assessment on the impacts of trucks on the highway system.

Truck Accident Frequency and Severity

A major objective of the research being synthesized here involved a detailed quantitative analysis of the accident experience of trucks on the Texas Highway System. The results were reported in their entirety in Report 397-4. What follows here is a summary of some of those detailed results.

To assess the impact of truck accidents, both their accident frequency and severity must be addressed. Roadways with high traffic volume are more likely to show high frequencies of accident involvements than those with low traffic volume due to higher "exposure" to accidents. However, severity of truck accidents depends, among other things, on the energy involved in the crash. Low-volume roadways with higher attainable speeds may therefore be associated with more serious consequences than are high volume roadways or roadways with lower attainable speeds.

Frequency and severity analyses were presented in Report 397-4. Results concerning the prevalence of truck accidents under various conditions, potential accident characteristics on each road class, and accident severity were documented. These results provided a more complete picture of the impact of truck accidents under various conditions. For example, in the following table (row 1) indicates that the expected percentages of van-semitrailer accident involvements that are collisions with passenger vehicles at non-intersections during the day are 1.73, 2.21, and 5.22 (or 1: 1.3: 3.0) for rural interstate, rural US/State, and city streets, respectively. Adjusting for severity yielded the following expected probabilities that a van-semitrailer accident involvement will be either a fatal/incapacitating-injury (row 2), a non-incapacitating injury (row 3), or a PDO collision (row 4), at non-intersections during the day for the three road classes:

Collisions	Rural IH		Rural US/State		City Streets
Expected # of such collisions	1.0	:	1.3	:	3.0
Expected # of such collisions being fatal/incap. injurious	1.0	:	2.6	:	0.8
Expected # of such collisions being non-incap. injurious	1.0	:	1.3	:	2.2
Expected # of such collisions being PDO	1.0	:	1.1	:	3.6

It can be seen that there were far more collisions between van-semitrailers and passenger vehicles at non-intersections during the day, on city streets than on either rural interstate highways or rural US/State highways. However, the numbers of such collisions that were incapacitating injurious was actually higher on rural interstate highways and particularly higher on rural US/State highways. This was so because the conditions on rural US/State and on rural interstate highways tend to result in more serious consequences. The collisions on city streets were mainly PDO and non-incapacitating injury collisions which occurred at relatively low speeds and low energy. The high number of these collisions was probably due to high traffic volume and/or low geometric standards of city streets. At the other extreme, collisions on rural interstate highways usually happen at high speeds and high energy levels, resulting in serious consequences to drivers and occupants of the vehicles involved. Rural US/State highways are usually of lower design standard than are interstate highways--undivided, less than full access-control, inferior shoulders, inferior geometrics. These plus a high traffic volume as well as the relatively high speeds attainable on rural US/State highways probably contribute to a higher number of collisions than on rural interstate highways and more serious consequences than collisions on both rural interstate highways and city streets.

The findings in the detailed analyses were voluminous (See Report 397-4) and some are highlighted in the following paragraphs. It is to be noted that all rural and urban highways were defined to include the main lanes and frontage roads but not entrance or exit ramps. Ramps were treated separately in the analyses.

A. Accident involvements of semitrailers (**as used throughout, semitrailer means combination tractor and semitrailer truck**) on rural interstate highways only accounted for less than 10 percent among all six road classes considered. This was true for all vehicle body styles, except van semitrailers which showed 12 percent of their accident involvements to be on interstate highways.

B. While the accident frequency on rural interstate highways was relatively smaller (if not the smallest) than those on other road classes, severity of accidents involving semitrailers on rural interstate highways tended to be the most severe among all road classes, particularly for non-collision and fixed object accidents. This was likely to be due to higher speeds and thus higher energy involved in the crashes. For every seven semitrailers involved in non-collision or fixed-object accidents (in dry conditions), one can be expected to result in fatalities and/or incapacitating injuries. The fatality and/or incapacitating injury probability was one in five for night-time collisions between semitrailers and passenger vehicles on rural interstate highways; it was one in 13 for day-time collisions. The probability of fatal/incapacitating injury collisions on rural interstate highways at night was nearly three times that for day-time.

C. The number of semitrailer accident involvements on rural US/State highways was much higher than that on rural interstate highways. About 15 to 24 percent of total semitrailer accident involvements were on this road class. Of these, about 22 percent are expected to be non-collision accidents, 10-20 percent fixed-object accidents, and 40-50- percent collisions with passenger vehicles. The notable exception was for van semitrailers, which had a very high (40%) percent of their accident involvements on rural US/State highways to be non-collision accidents, 20 percent fixed-object accidents, and only 27 percent collisions with passenger vehicles.

D. The number of non-collision and fixed-object accidents of semitrailers on rural US/State highways tended to be higher during the day than at night, except for van semitrailers which showed an even split for day and night. The number of collisions between semitrailers and passenger vehicles on rural US/State highways was considerably higher during the day than at night, regardless of the vehicle body styles. This probably reflected a high volume of general traffic during the day on this road class. About 30-35 percent of the collisions occurred at intersections.

E. Collisions between semitrailers and passenger vehicles on rural US/State highways resulted in the most serious consequences among such collisions on all six road classes. At night, one out of every 3-4 such collisions was fatal and/or incapacitating injurious; during the day, this probability was about one in six collisions. This high severity level coupled with a high incidence of collisions on rural US/State highways produced the high casualty toll being reported on this highway class. Non-collision and fixed-object accidents on rural US/State highways showed a lower chance of fatalities and/or incapacitating injuries than do those on rural interstate highways. About one in nine such accidents can be expected to be fatal and/or incapacitating injurious in dry conditions, compared to one in 14 under wet conditions.

F. There are 2-5 times more semitrailer accident involvements on farm-to-market roads during the day than at night. This is likely to reflect a higher traffic volume, as well as a higher number of semitrailers, during the day than at night on this road class. About 20-25 percent of the non-collision/fixed-object accidents and about 40 percent of the collisions occurred at intersections.

G. Overall, the severity extent of accidents on urban interstate highways was less serious than the severity on all rural highways, except the severity for non-collision and fixed-object accidents in wet conditions, which was less to that on rural highways. In dry conditions, about one in 16 non-collision and fixed-object accidents can be expected to be fatal and/or incapacitating injurious. For collisions between semitrailers and passenger vehicles, about one in 12 can be expected to be fatal and/or incapacitating injurious at night and one in 33 during the day.

H. For all semitrailers, the chance of fatalities and/or incapacitating injuries in non-collision or fixed-object accidents in wet conditions was similar among all rural highways, urban interstate highways, and farm-to-market roads. It was usually lower than the chance in dry conditions. This uniformity among road classes was not indicated for dry conditions where the probabilities decrease with decreasing design standard of the road classes and increasing degree of urbanization. This probably implies that single-truck accidents may occur at lower speeds in wet conditions than in dry conditions and that such speeds in wet conditions are attainable on all the above road classes.

I. Severity of accidents involving single-unit (SU) trucks was different from that of accidents involving semitrailers. For non-collision accidents, single-unit trucks showed higher severity levels than do semitrailers on similar road classes, especially at night. This may have been due to the difference in occupant protection provided by the trucks and/or that non-collision accidents of single-unit trucks occurred at higher speeds. The latter reason may have been attributable to lower stability thresholds for some semitrailers. Severity of non-collisions for single-unit trucks also decreased with roadways of decreasing design standard and increasing degree of urbanization. For fixed-object accidents during the day, the severity extent of single-unit trucks and of semitrailers only differed in that the former resulted in more minor injuries. For fixed-object accidents at night, however, single-unit trucks showed higher severity than semitrailers involved in similar accidents. For collisions with passenger vehicles, single-unit trucks showed a lower severity level than do semitrailers on all road classes, both day and night.

A wealth of tabular and graphical data are presented in Report 397-4 to give a complete analysis of the frequency and severity characteristics of accidents involving trucks. These data will be very useful in evaluating policies and programs regulating movements of larger trucks on the Texas Highway System.

Larger Trucks: Effects Upon Passenger Car Equivalencies (PCE)

A significant effort in this study was directed at determining current measurements of the passenger car equivalencies of trucks presently operating on the highway system. The methodology and results were presented in detail in Research Report 397-2 and are summarized here.

This research determined the delay effects of a truck on a queue of vehicles as the position of the truck within the queue varied. The method used to analyze this effect was to measure the time required for a queue of passenger cars and one truck to cross the stop line as compared to the time required for the same sized queue composed of all-passenger cars to cross the same point. This approach obtained the total effect of a truck on a queue of passenger cars.

Three factors primarily influence the size of the PCE for a truck at a signalized intersection. Firstly, the PCE value will increase as the length of vehicle increases, since the vehicle is physically occupying roadway space that would otherwise be available to passenger cars. The acceleration characteristics of a truck will also influence the size of the PCE. As the acceleration rate increases, the PCE value will decrease, since the truck will delay the passenger cars less, and of course, the converse will result in a higher PCE value. The final factor affecting the PCE is the behavior of motorists. The available information indicated that drivers "shy away" from large trucks. This results in drivers following further back from the truck which increases the delay on the passenger car drivers which, in turn, results in a higher PCE value.

The development of PCE's for signalized intersections was examined in depth. The most common method used for developing the PCE at signalized intersections was found to be the headway method. This method takes the ratio of the average headway for a truck and passenger car as the PCE for the truck. The PCE values developed for large trucks using this method were found to range between 1.6 to 2.3.

Using the results of previous research, this study developed a formulation to calculate the PCE based on the headway method. However, the headway method assumes all of the delay due to the large trucks can be accounted for in the truck's headway. This research developed an equation to determine the PCE of a truck based on the total delay it inflicted on all the vehicles traveling behind it. Therefore, this equation is based on the difference in total travel time for a queue with a truck in it as compared to an all-passenger car queue. The equation has the following form:

$$PCE_{j_k} = [(TT_{j}\ ,\ b_{i_k} - TT_{b_1}\ ,\ b_i)/h_b] + 1$$

where:

TT = total travel time measured from start of green, sec;
j = truck type;
k = position of the truck in the queue;
b_i = passenger car in position "i" in the queue;
b_1 = passenger car in position one in the queue; and
h_b = saturation flow headway, sec.

In this equation, the PCE value was calculated at vehicle position "i" where i is the last passenger car behind the truck that has an incremental increase in delay.

In developing the PCE values, data collected for each vehicle included: the position of vehicle in queue, the size of queue the vehicle was in, the type of vehicle, and the total travel time of the vehicle from its position in queue to the stop line. This measurement was referenced to the onset of green and was measured to the point when the vehicle's rear axle crossed the stop line. Regression equations were developed to predict the total travel time for the vehicle of interest and the succeeding string of passenger cars.

A regression equation was developed for each vehicle type as the position of the vehicle in queue varied. As a result, PCE values were developed according to vehicle type and position of vehicle type in queue. The resulting PCE matrix was then condensed into a single PCE value for a light truck and a heavy truck class. The light truck class was selected to represent the small delivery trucks (i.e., single-unit trucks) while the heavy truck class represents the large, heavily loaded truck population (i.e., combination trucks with 5-axles or more). The PCE values for these two classes are given in the following table.

PCE Values for Final Two Truck Classes	
Truck Type	PCE Value
Light Truck	1.7
Heavy Truck	3.7

An examination of the PCE values per truck class found a relationship between number of axles and the PCE value of a truck. Using this relationship, a regression equation was developed to predict the PCE value based on the number of axles. However, this equation was limited in that it is only applicable to large vehicles. In other words, the data collection system must be able to screen out passenger cars and motorcycles.

In summary, this part of the study looked at the effect of a truck on the saturation flow of a signalized intersection. This study developed PCE's for four truck types with each truck type varying in position within the queue. Based on the results of this study, the following can be concluded:

1. Truck type affects the size of the PCE. The smaller 2-axle, single unit trucks had a smaller impact on delay than the larger 5-axle combination truck.

2. Position of vehicle in queue was not found to significantly affect the PCE value for the 2- and 3-axle, single-unit trucks. This is because trucks of this size are not typically hauling a great deal of weight with respect to the power of their engine. Therefore, the acceleration characteristics of these trucks are close enough to a passenger car's that their position in queue has very little effect on the PCE value.

3. Position of vehicle in queue has a very pronounced effect on the PCE value for large 5-axle combination trucks. These trucks are typically heavily loaded in addition to their greater length with respect to passenger cars. These two factors result in a large initial PCE value; however, as the position of the truck is further back in the queue, the truck has the opportunity to accelerate up

to speed thereby reducing its PCE value.

4. The position of the last vehicle incrementally affected by the truck varies with truck type and position of the truck in the queue. Generally, for the first two positions in queue, the last vehicle affected by the truck can be up to eight vehicle positions behind the truck, or in other words, the "shadow" of the truck can extend up to 200 feet (assuming 25 feet per passenger car). If the truck is located after the second position in queue, its "shadow" extends no further than three vehicle positions or approximately 75 feet.

5. The number of axles of a truck can be used to approximate its PCE values. The PCE of a truck was found to be fairly well correlated to the number of axles.

The results from this study indicated that there is a need to distinguish between different truck types when analyzing the capacity of a signalized intersection. Large, 5-axle truck combinations were found to have a significantly higher effect on the capacity of an intersection than the smaller single-unit trucks. The 1985 Highway Capacity Manual accounts for the presence of heavy vehicles (i.e., trucks, buses, and recreational vehicles) through the use of a heavy vehicle adjustment factor. This factor is based on a PCE of 1.5 which is assumed to be the average PCE for trucks, buses, and recreational vehicles. Based on the results of Study 397, the following are recommended:

1. The heavy vehicle adjustment factor equation should be modified to analyze the effects of light and heavy trucks separately in addition to buses and recreational vehicle.

2. PCE values of 3.7 and 1.7 should be used for heavy and light trucks, respectively, to calculate the heavy vehicle adjustment factor for capacity at a signalized intersection.

The PCE values developed in this research are applicable only to straight-through trucks on signalized intersections with level approaches. The effects of grades and turning maneuvers were considered outside the scope of this research.

Further research into the development of PCE's for large trucks at signalized intersections is recommended. The effects of turning maneuvers and grades on the PCE value of large trucks needs to be examined. In addition, future research should study the effects of heavily loaded vehicles as compared to lightly loaded vehicles in the development of PCE's.

In particular to the methodology used in this study, a more precise method of determining the position of the "ith" vehicle is needed. This may be accomplished by collecting both headway data and spot speed data. The spot speed data would be used to determine when the queue of passenger cars behind a large truck reached saturation flow speed. Saturation flow speed would be the speed reached by the all-passenger car queue at saturation flow headway. Position "i" would be defined as the vehicle position of the first passenger car to achieve saturation flow speed. This method would add more accuracy to determining the "ith" position.

In addition to the three activities (annotated bibliography, accident analysis, truck PCE) summarized above, this research study involved another geometric design effort. Reported in Research Report 397-2, a study was undertaken to evaluate channelization guidelines to accomodate longer and wider trucks at at-grade intersections.

Truck Channelization

This part of the research study addressed the information necessary to design the turning radius for large trucks at an at-grade intersection. It was limited to trucks larger than those covered by current AASHTO Policy. The goal was to establish a set of guidelines for intersection channelization to accomodate these larger vehicles. Results of the research included turning templates for five "larger" design vehicles; tables similar to those in the AASHTO "Green Book" containing cross street width occupied and swept width for various combinations of design vehicle, curb radii, and degree of turn; and recommendations for the use of channelization when designing for the larger design vehicles.

This research was necessary because even though research concerning offtracking had been reported on the newly approved, longer and wider truck configurations, offtracking needed to be specifically related to intersection geometry. For example, the AASHTO "Green Book" contains pages of information on vehicle characteristics, intersection design, and channelization. But because longer and wider trucks legalized by the Surface Transportation Act of 1982 were not included in the "Green Book," none of the figures and tables therein consider the effects of the new larger vehicles on the system.

The selection of a design vehicle is a critical decision in intersection design. It is generally based on the largest standard or typical vehicle type that would regularly use the intersection. For this study, five new "larger" design vehicles were defined--two single trailer combinations, two double trailer combinations, and one triple trailer combination. In AASHTO terminology these vehicles would be referred to WB-50, WB-55, WB-70, WB-105, and WB-100, respectively.

Truck Offtracking Model (TOM) simulation program developed by Caltrans was used to determine the turning characteristics of those vehicles for various combinations of intersection geometry. The program was particularly advantageous for use in this study because it was capable of simulating various large truck number paths in a relatively short period. It is a powerful program once the user is familiar with all of the input variables which may be varied and the effects of these variations.

Because the designer can specify any design vehicle, degree of turn, and curb return radius, the procedure used in this research could be used for design of individual intersections, especially where there are significant numbers of large trucks in the traffic stream. For example, it might be appropriate to design some special at-grade intersections adjacent to the Interstate System for the larger truck combinations. Also, concentrations of larger vehicles in other areas, i.e. truck terminals and lumber yards, may warrant special design consideration, such as: intersections between a logging area and a lumber yard which experience high turning movements could be designed using turning templates for a typical logging truck.

Summary of Results

The work represented here (and more fully in the individual reports) has produced valid information to be used in evaluating aspects of the issues involving larger trucks. Particularly, the detailed accident data will help in a complete assessment of the safety implications surrounding operations of larger trucks on the highway system. Frequencies and severities of truck accidents are documented and are in a usable format.

New data and concepts have been developed to aid highway designers in their work to allow for the effects of larger trucks on the facilities being planned. Passenger car equivalents have been recalculated to a more realistic standard for use in design calculations.

Additional analysis evaluating turning movements of larger trucks through at-grade intersections has produced usable insight regarding channelization guidelines to control these movements. These results are implementable in design offices now.

Finally, researchers will benefit from use of an annotated bibliography that utilizes a sensible classification scheme to catalog information on large truck issues. Formatted for updating on a mirocomputer, this bibliography will, if kept current, become a standard reference for those engaging in truck related research. But, much remains to be undertaken.

Recommendations for Extended Research

The Texas DHT has, by its interest in and support of truck related research, established its pre-eminence in this issue area. A vigorous truck research program will perpetuate the DHT's leadership among its sister departments.

The following seven issue areas represent fruitful opportunities to continue producing useful, implementable, and important research results:

A. Safety
   1. Hazardous Materials
   2. Traffic Operations
   3. Accidents

B. Urban Truck Movements
   1. Operations
   2. Design
   3. On-Off System

C. Revenues/Expenditures
   1. Taxes (Weight/Distance)
   2. Highway Cost Allocation
   3. Cost/Benefits

D. Legal Status
   1. Evidence of Pavement/Structural Damage
   2. Network Designations
   3. Enforcement Strategies
   4. Current Statutes/Assessment

E. Data
   1. Traffic/Truck
   2. Costs
   3. Commodity
   4. Inventory of Highway Network

F. Facilities: Pavement/Structures
   1. Bridge Fatigue
   2. Pavement Design
   3. Geometric Design
   4. Vehicle/Components

G. Strategic Issues
   1. Re-industrialization of Texas and Truck Movements
   2. Modal Substitutions
   3. Public and Private Cooperative Ventures
   4. Trucking Industrial Structure
   5. Operating Strategies of Trucking Firms

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