UMTRI-82-34

FREQUENCY OF EMERGENCY-CAUSING INCIDENTS AND FATALITIES IN BUS ACCIDENTS

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FINAL REPORT
SEPTEMBER 1982

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-82-34		

4. Title and Subtitle	5. Report Date
Frequency of Emergency-Causing Incidents and Fatalities in Bus Accidents	September 1982
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Robert E. Scott	UMTRI-82-34
9. Performing Organization Name and Address	10. Work Unit No.
The University of Michigan Transportation Research Institute Ann Arbor, Michigan 48109	11. Contract or Grant No. Subcontract No. 2468-1
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Ketron, Inc. Hickory Hill Plaza 151 South Warner Road Wayne, Pennsylvania 19087	Final August-September 1982
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report covers a one-month sub-contract to study bus accidents. The objective was to examine the frequency in accident data of emergency-causing incidents which might restrict or impede egress of elderly or handicapped patrons.

The Fatal Accident Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA) and state traffic accident files from Michigan, Pennsylvania, Texas, and Washington were examined for the incidence of collision, rollover, fire, immersion, and incapacitating injury to drivers. In addition, the data of the National Crash Severity Study (NCSS) were used to compare the frequency of door jamming and the depth of crush of small vans and passenger cars.

It was found while most bus involvements are collisions, fire and rollover are very infrequent. No cases of immersion of vehicles used as buses were found in any of the files.

17. Key Words	18. Distribution Statement
Bus accident; Collision, Rollover Fire; Immersion; Elderly Patrons; Fatality	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		33	

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1.0 INTRODUCTION

The main objective of this study is to examine the incidence of emergency-causing incidence (ECI's) in intercity and transit bus accident involvements, to the extent that suitable accident data are available. In addition, the presence of elderly and/or handicapped patrons in accidents is examined. The structural performance of vans in terms of doors jamming and external crush is compared to passenger cars.

No single source of accident data is suitable for all these tasks, hence a number of accident files at the Transportation Research Institute of The University of Michigan were examined and used in the study. A total of six files were used. These are the Fatal Accident Reporting System (FARS) of the National Highway Traffic Safety Administration, files of data from the states of Michigan, Pennsylvania, Texas, and Washington, and data from the second phase of the National Crash Severity Study (NCSS).

The remainder of the report is organized in four sections. These are: a statement of the specific objectives; a discussion of the characteristics of accident data and their impact on the objectives of the study; the project findings; and conclusions.

2.0 OBJECTIVES

Data in computerized accident files at the Transportation Research Institute were used to address five individual tasks to the extent that relevant data are available. The task descriptions and desired level of detail are:

TASK 1. For all (quantify) highway transit vehicle accidents for which data exist, determine the probability of incidence for each of the following vehicle types:

- standard paratransit vans
- modified paratransit vans
- body-on-chassis small buses
- heavy duty small monocoque buses
- intercity motor coaches

TASK 2. For the accidents for which data exist for each of the vehicle types identified in Task 1, determine the probability of incidence for each of the following singular emergency-causing incidents (ECI):

- driver incapacitation
- collision
- rollover
- fire
- water immersion
- water submersion

Also determine the probability of incidence for the following possible ordered combinations of ECI's:

- driver incapacitation/collision
- driver incapacitation/rollover
- driver incapacitation/water immersion
- driver incapacitation/water submersion
- driver incapacitation/collision/rollover
- driver incapacitation/collision/water immersion
- driver incapacitation/collision/water submersion
- driver incapacitation/collision/rollover/water immersion
- driver incapacitation/collision/rollover/water submersion
- driver incapacitation/rollover/water/immersion
- driver incapacitation/rollover/water submersion
- collision/rollover
- collision/rollover/water immersion
- collision/rollover/water submersion
- collision/fire
- collision/water immersion

- collision/water submersion
- collision/rollover/fire
- fire/collision
- fire/rollover
- rollover/fire
- rollover/water immersion
- rollover/water submersion

Contrast these data with similar data for all (auto, truck, transit, etc.) highway vehicle accidents.

TASK 3. For the vehicle types identified in Task 1 and involved in accidents, determine the probability of incidence of the following types of patrons being on board:

- elderly
- handicapped
- elderly and handicapped
- surrogate handicapped (children under five years of age, etc.)

TASK 4. Determine and quantify if the doors on standard and modified paratransit vans and body-on-chassis small buses jam more frequently than automobile doors as a result of a collision, a rollover, or a combination collision/rollover.

TASK 5. Determine and quantify if vehicle crush (penetration) as a result of a collision, a rollover, or a combination collision/rollover is different on standard and modified paratransit vans and body-on-chassis small buses from that experienced by automobiles.

3.0 AVAILABLE DATA AND THEIR CHARACTERISTICS

3.1 GENERAL CHARACTERISTICS OF ACCIDENT DATA

The Institute has a large number of files of accident data of several types. The greatest amount of data is provided by several state files of police-reported investigations. The CPIR file contains reports prepared by in-depth investigations conducted from 1967 through 1978 by 44 multidisciplinary teams in the United States and Canada, and coded on the Collision Performance and Injury Report (CPIR) forms. The teams which have contributed to the CPIR file were, or are, sponsored by the National Highway Traffic Safety Administration, the Motor Vehicle Manufacturers Association, and the Ministry of Transport, Canada. The National Crash Severity Study (NCSS) which collected considerable detail on the structural performance of vehicles was expanded to include small vans during the period from April 1978 through March 1979. The NCSS project was replaced by the National Accident Sampling System (NASS) in 1979, and data are now available from the latter program. The Fatal Accident Reporting System (FARS) has been in operation since 1975 and provides data from police investigations of all fatal traffic accidents in the country. The latter three programs are all conducted by the National Highway Traffic Safety Administration.

Unfortunately, none of these data sets is ideal for all the tasks. Each has its strengths and is generally suitable for its intended purpose, but each also has limitations. In some cases the limitations become particularly acute for studies of bus involvements. For this reason, a number of accident files were used. In addition, data from the 1977 Nationwide Personal Transportation Study (NPTS) conducted by the Bureau of the Census for the Department of Transportation was used to provide additional information on the age characteristics of users of bus transportation.

Since each data bank has its own unique characteristics relevant to this project, it is appropriate to describe each individually, not only to explain why each was or was not used, but to also provide caveats that should be considered in interpreting the results.

There are a few general comments that should be made relevant to many, if not all, of the accident data sets. In general, they do not provide a specific description of the type of bus. The most common designation is school bus as opposed to all other types. Some files, e.g., Pennsylvania and FARS, denote intercity versus transit. Some of the state files allow identification of small vans, but only FARS and Texas identify vans used as buses. None of the files describe the structure of the buses. Consequently, the identification of specific types requested in Task 1 is not possible. Where school buses, transit and/or intercity buses, and vans can be identified, the results of Task 2 are presented separately for each category. Thus, the limited information that is provided on Task 1 is incorporated in Task 2 and no separate findings are given for Task 1.

In identifying the categories of emergency-causing incidents (ECI) specified in Task 2, collisions include collisions between buses and other motor vehicles or fixed objects. Impacts with pedestrians and pedalcycles were arbitrarily grouped with non-collisions . The rationale for doing this is that the physical damage to a bus from these types of accidents would typically be so small that the bus occupants would not be endangered. Substantial damage would be likely to occur only from the sequel to evasive maneuvers. The techniques used also resulted in cases of missing data on collision categorization to be interpreted as non-collisions. However, the amount of missing data in the variables used was very small. Usually the non-collision cases which did not involve one of the other ECI's were either pedestrian, pedalcycle, animal, or "other" non-collision accidents. While it was not specifically examined, it appears that buses may be overrepresented in pedestrian accidents. If this is true, it may result from their unique mode of operation and environment.

Mass data files, including the FARS data, describe the type of accident--including whether or not it involved a collision--in a number of variables. These may include such names as type of accident, object struck, etc. More specific information, particularly on the ECI's such as rollover, fire, and immersion are coded in many states as "first harmful event" in accordance with the Manual on Classification of Motor Vehicle Traffic Accidents.[1] The disadvantage of this is that the ECI's are then lost if they are subsequent events, e.g., a rollover following a two-vehicle collision. For this reason, post-crash fires and rollovers have historically been undercounted in computerized files of mass accident data. This limitation will be discussed again in relation to each specific data set.

One last general comment is that many states and police departments do not include all occupants on the report. They tend to concentrate on injured occupants, and do not always collect information on the uninjured with equal vigor. Even those jurisdictions that provide for a single entry giving the total number of occupants in the vehicle show low ratios for occupants per vehicle in buses. This will be evident in the figures to be given later. While it may result from low actual occupancy rates, the figures are nevertheless suspiciously low. This should not be surprising, since it is difficult for accident investigators to obtain accurate occupant counts for buses. The task would be particularly difficult in minor collisions in urban areas. By the time the police arrive, many occupants would have already mingled with onlookers or may even have sought alternate transportation.

Each of the data sources which were used is discussed below, along with two that were not used.

3.2 FARS DATA

The FARS data provide possibly the best collection of variables for this study of all the mass data (police investigations) sets available. It is a national census and has separate specific variables concerning fire and rollover. A composite file of 1975 through 1980 data are available and was used for this study. The FARS data also identify small vans, and further provide a variable denoting if they were used as either a school bus or other bus. Buses other than vans are classified

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[1]Manual on Classification of Motor Vehicle Traffic Accidents, ANSI Standard D161-1976, National Safety Council, Chicago, Illinois.

in five levels: school, cross-country, transit, other, and unknown. Although this classification is far from ideal for this study, it does separate intercity and transit services while many state files do not. The "first harmful event" for the accident, and in later years the "most harmful event" for each vehicle, also include fire, rollover, and immersion. The FARS data also indicate if extrication of occupants was required.

The information in FARS that is not universal to all state data is available because the FARS analyst in each state uses all information available including diagrams and narratives, and may even follow-up by contacting the investigating agency.

The greatest disadvantage of FARS, of course, is that it only includes vehicles involved in fatal accidents and thus provides a highly biased representation of accident experience. Nevertheless, it is extremely useful. In the context of the present study, it can be considered a worst-case representation of bus accidents. Note that not all buses included involved a fatality in the bus. On the contrary, it will be seen that only a small proportion of those in fatal accidents had a fatality in the bus. A second disadvantage is that the rollover variable has only been available starting with the 1978 data. Thus only one-half of the 1975 to 1980 data contain this variable. However, rollover was included in the "first harmful event" and could be used to identify some of the rollovers, especially those in single-vehicle accidents. Thus while the incidence of rollover in the composite 1975-1980 file may be low, one would expect the result would be at least half that which would have been obtained if the rollover variable were originally available. Multiplying the FARS rollover result by two should give the upper bound of an estimated rate among severe involvements.

3.3 MICHIGAN DATA

Michigan data for 1981 accidents were used because Michigan codes fire (and fuel leakage) as a separate variable as does FARS, and can thus provide information on the occurrence of fire as a subsequent event. The Michigan data have several disadvantages for this project, although they are not unique to Michigan. One is that the vehicle description is limited; buses are given as either school buses or commercial buses, and small vans cannot be identified. Only initial rollovers are coded, and no provision is made for immersion. A final limitation is that the variable giving the number of occupants is coded from 1 to 7 with 7 indicating 7 or more. Thus total occupancy is not reliable for buses.

3.4 PENNSYLVANIA DATA

The Pennsylvania data are attractive for several reasons. The state is large and might be expected to provide a large quantity of data. In fact, fewer bus accidents were reported in Pennsylvania in 1979 (the last year for which we have data) than in Michigan in 1981. Pennsylvania does separate intercity and transit buses, a characterization used infrequently in our other state files. A third advantage is that rather than providing a single "first harmful event" variable for each vehicle, up to three responses are available, each including codes for fire, rollover, and immersion. However, the missing data rates on these variables are large, at least for buses. In the first event variable, 48 percent of the buses have missing data. However, this may not be as serious as it appears. The coding instructions are to code at least one vehicle event for vehicle number 1, which is the offending vehicle. Other vehicles involved in the accident may or may not have an event variable coded. Thus it may be reasonable to assume that a large portion of the missing data group are innocent vehicles with no noteworthy consequences to code. If this is the case, they have correctly been assigned to the no-fire, no-rollover, no-immersion population. A second limitation of the Pennsylvania data is that small vans cannot be identified, i.e., they cannot be distinguished from van bodies on single-unit trucks.

3.5 STATE OF WASHINGTON DATA

The Washington 1980 file was examined because it provides for indicating immersion in two places; one in the accident section and one in the vehicle section. However, no immersions of buses were indicated.

Since the total quantity of data was limited (328 school buses and 404 other buses), only brief information is given from this set of data.

3.6 TEXAS DATA

The 1981 Texas file was examined because it is one of the few state files at the Transportation Research Institute that identify small vans. Furthermore, a separate classification is used for minibuses. However, the only ECI's that can be obtained from the Texas data are collision and rollovers, and rollovers are only coded for single-vehicle accidents. Since Texas only codes injured occupants, no occupant data were used. Thus the use of the Texas data should be limited to determination of the relative frequency of the various types of vehicles in accidents.

3.7 NCSS DATA

None of the state files provide data on either doors jamming (and thus complicating egress) or the amount of crush, as requested in Tasks 4 and 5, respectively. While several states employ a form of the TAD scale, as in Texas, this relative scale is not suitable for comparing vastly different vehicles such as cars and vans. In fact, it is not clearly defined for vehicles other than cars.

Phase 2 of the National Crash Severity Study (NCSS) includes vans. It also provides data on doors jammed closed, and includes a 2 to 6 point horizontal profile of crush measured in inches. In order to quantify crush in a concise manner, the maximum of the several measurements for each vehicle was used to represent the crush to that vehicle. These measurements were then averaged for each type of vehicle, i.e., small vans and buses. Unfortunately, the specific van construction is not given, and most of the 187 vans in the data set are probably recreational vans. Since the NCSS data is a stratified sample, the results given are weighted by the inverse of the sampling fraction. Unweighted numbers of cases are also presented, not to be used for inferential purposes, but to indicate the quantity of data available.

3.8 CPIR AND NASS DATA

Two potentially useful data sets are the CPIR and NASS data sets. The CPIR file contains 243 small vans, 30 percent more than the NCSS data, and includes information on both door jamming and crush. However, the CPIR data was not collected using sampling techniques, but is biased toward severe or unusual accidents. Severe injury is overrepresented, as are severe injury with minor damage and minor injury with severe damage. For this reason, the NCSS data was considered to provide more reliable estimates for Tasks 4 and 5, although even the weighted frequencies do not give a truly national representation.

The NASS data provide the best national estimates from in-depth investigations now available. However, door performance and crush are not included in the data sets at the Transportation Research Institute.

4.0 FINDINGS

4.1 FREQUENCY OF VEHICLES AND EMERGENCY-CAUSING INCIDENTS IN ACCIDENTS

The findings for Tasks 1 and 2 are presented in this section. The format is to present the frequencies and proportions of the combinations of ECI's for each data set by the type of vehicle.

The results are given in Tables 1-5 for FARS, Michigan, Pennsylvania, Washington, and Texas. In Tables 1-3, the number of accidents of each ECI combination is given, followed by the proportion of all involvements of each vehicle type that were of each combination. Slightly different formats were used for Washington and Texas

All possible combinations of the ECI's available from the data set are given first, followed by the aggregated frequency for each individual ECI. This is a more comprehensive listing of ECI combination than was originally requested, although some of the desirable characteristics were not available. For example, it was not possible to determine the chronological order of ECI and thus differentiate between collision/fire and fire/collision. In addition, no data set differentiated between immersion and submersion. It should be noted, however, that not one case of immersion of a bus or a van used as a bus was found in any data set that included such a code, i.e., FARS, Washington, and Pennsylvania.

None of the files described drivers incapacitated before impact except a "died before accident" code in FARS. However, there are so few of these--5 out of 63,467 vehicles in the 1980 file--that it is doubtful that any occurred in buses. On the assumption that a driver incapacitated by injury in the accident would have difficulty in aiding and supervising the rescue of passengers, any driver who received fatal or "A" (incapacitating) injuries was classes as driver incapacitation.[2]

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[2]This includes any who died prior to the accident in the FARS data, if any actually occurred.

TABLE 1

FARS 1975-1980 Buses

Number of Vehicles and Probability of Involvement in Each Type of Emergency-Causing Incident

Collisions	Rollovers	Fires	Driver Incapac.	School Buses N	School Buses P	Cross County Buses N	Cross County Buses P	Transit Buses N	Transit Buses P	Other Buses N	Other Buses P	Unknown Buses N	Unknown Buses P	Vans as School Buses N	Vans as School Buses P	Vans as Other Buses N	Vans as Other Buses P
N	N	N	N	300	0.382	46	0.209	439	0.553	18	0.196	35	0.321	10	0.313	5	0.217
N	N	N	Y	1	0.001	0	0	1	0.001	0	0	1	0.009	0	0	0	0
N	N	Y	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	N	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	Y	N	N	4	0.005	2	0.009	2	0.003	0	0	1	0.009	1	0.031	1	0.043
N	Y	N	Y	4	0.005	2	0.009	3	0.004	2	0.022	2	0.018	1	0.031	0	0
N	Y	Y	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	Y	Y	Y	0	0	0	0	0	0	1	0.011	0	0	0	0	0	0
Y	N	N	N	406	0.517	143	0.650	312	0.392	51	0.554	55	0.505	8	0.250	10	0.435
Y	N	N	Y	43	0.055	18	0.082	33	0.042	13	0.141	10	0.092	9	0.281	3	0.130
Y	N	Y	N	4	0.005	1	0.005	1	0.001	0	0	1	0.009	0	0	0	0
Y	N	Y	Y	2	0.003	0	0	2	0.003	0	0	1	0.009	1	0.031	0	0
Y	Y	N	N	13	0.017	6	0.027	1	0.001	3	0.033	2	0.018	1	0.031	2	0.087
Y	Y	N	Y	8	0.010	2	0.009	0	0	3	0.033	1	0.009	1	0.031	2	0.087
Y	Y	Y	N	0	0	0	0	0	0	1	0.011	0	0	0	0	0	0
Y	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Vehicles				785	1.00	220	1.00	794	1.000	92	1.000	109	1.000	32	1.000	23	1.000
Collisions				476	0.606	170	0.773	349	0.440	71	0.772	70	0.642	20	0.625	16	0.696
Rollovers				27	0.034	12	0.055	6	0.008	10	0.109	6	0.055	4	0.125	3	0.130
Fires				6	0.008	1	0.005	3	0.004	1	0.011	2	0.018	1	0.031	0	0
Driver Incapacitation				58	0.074	22	0.100	39	0.049	19	0.207	15	0.138	12	0.375	4	0.174
Immersions				0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 2
Michigan 1981 - Buses
Number of Types of Emergency-Causing Incidents

Collision	Rollover	Fire	Driver Incapacitated*	Number of Vehicles	Probability
School Buses:				1421	
No**	No	No	No	32	0.0225
No**	Yes	No	No	3	0.0021
No**	Yes	No	Yes	1	0.00070
Yes	No	No	No	1379	0.970
Yes	No	No	Yes	6	0.0042
Commercial Buses				1360	
No	No	No	No	62	0.0456
Yes	No	No	No	1290	0.949
Yes	No	No	Yes	6	0.0044
Yes	No	Yes	No	2	0.0015

*Drivers incapacitated by having received either Fatal or "A" (incapacitating) injuries in the accident.

**The non-collision accidents are primarily pedestrian and pedalcycle cases.

TABLE 2 (Continued)

	School Buses	Commercial Buses	Total
Collision	1385 (0.975)	1298 (0.954)	2683
Rollover	4 (0.0028)	0 (0)	4
Fire	0 (0)	2 (0.0015)	2
Driver Incapacitated*	7 (0.0049)	6 (0.0044)	13

*Drivers incapacitated by having received either Fatal or "A" (incapacitating) injuries in the accident.

TABLE 3
Pennsylvania 1979
Number of Vehicles and Probability of Emergency-Causing Incidents

Emergency Causing Incident				Intercity Buses		Transit Buses		Total	
Collision	Rollover	Fire	Driver Incapacitated	N	P	N	P	N	P
N	N	N	N	5	0.052	102	0.161	107	0.147
N	N	N	N	1	0.010	0	0	1	0.001
N	Y	N	N	1	0.010	0	0	1	0.001
Y	N	N	N	88	0.907	525	0.829	612	0.840
Y	N	N	Y	1	0.010	4	0.006	5	0.007
Y	Y	N	N	1	0.010	2	0.003	3	0.004
Total				97	1.000	633	1.000	729	1.000

TABLE 3 (Continued)

Emergency Causing Incidents	Intercity		Transit		Total	
	N	P	N	P	N	P
Collision	90	0.928	531	0.839	621	0.852
Rollover	2	0.021	2	0.003	4	0.005
Fire	1	0.010	0	0	1	0.001
Driver Incapacitated	1	0.010	4	0.006	5	0.007
Immersion	0	0.0	0	0.0	0	0.0

TABLE 4
Washington 1980

	Bus	School Bus	Total
Vehicles	404	328	732
Occupants			
(recorded)	565	413	978
(Total known)	767	413	1180
Fatals	0	0	0
A-Injury	15	4	19
Incap.Drivers			
(A-injury)	4	0	4
Occupant Ages 0-4			
# of Vehicles With:	0	1	1
# of Occupants In:	0	1	1
Occupant Ages 65+			
# of Vehicles With:	12	6	18
# of Occupants In:	14	6	20
Occupant Ages 70+			
# of Vehicles With:	10	1	11
# of Occupants In:	11	1	12

FIRE: Five accidents involving buses (none school buses) all in collisions with other vehicles which may have had the fire.

ROLLOVERS: Two buses, non-school buses, and no fires.

DRIVER DISABLED by Fatal or A Injuries:
Four buses, non-school buses.
One of these was a rollover.
One was a fire accident.
Two did not involve fire or rollover.

IMMERSION: No cases were listed for buses.

TABLE 5
Texas 1981 - Buses and Small Vans
Incidence of Collision, Rollover, and Incapacitated Driver

Vehicle	Numbers of Vehicles--Proportions in Parentheses						
	School Buses	Commercial Buses		Minibuses		Small Vans	
		Rural	Urban*	Rural	Urban*	Rural	Urban*
Total Number	1224	107	1467	44	266	4220	18,422
Collision Non-Rollover	1192	95	1412	35	256	3677	17,986
Non-Collision Non-Rollover	25	11	54	2	6	179	261
Rollover	7	1	1	7	4	364	175
Proportion with Incapacitated Driver (K or A Injury):							
All Vehicles	0.004	0.028	0.003	0.182	0.019	0.047	0.013
Collision	0.004	0.032	0.003	0.143	0.020	0.044	0.013
Non-Collision	0.0	0.0	0.0	0.0	0.0	0.011	0.011
Rollover	0.0	0.0	0.0	0.429	0.0	0.091	0.069

*Urban as used here includes all accidents that occurred in a community with a population of over 5,000. Otherwise, the accident was classed as rural.

With these limitations, only seven of the requested 23 combinations of ECI's can be examined. However, by including all combinations of dichotomous variables denoting collision, rollover, fire, and driver incapacitated, up to 16 combinations can be given. If fewer than the maximum (2^n where n is the number of variables listed) are given, the missing combinations were empty sets.

The FARS data show a high rate of non-collision, 56 percent for transit buses and 23 percent for cross-country buses. This is much higher than for Michigan, Pennsylvania, or Texas. Most of the non-collision cases are pedestrian or pedalcycle accidents, and the high incidence in the FARS data may be a consequence of a high fatality rate in pedestrian accidents compared to the collision accidents of all severities in the state files. Rollovers are about one percent for transit buses and five percent for cross-country buses. Because of the introduction of a separate rollover variable in 1978, these figures might be increased by a factor of nearly two to give a worst case estimate. Fires occurred in one percent or less of the involvements. The most prevalent ECI was driver incapacitation. However, it must be emphasized that these are the results in fatal accidents only.

The results for Michigan and Pennsylvania are representative of a broad spectrum of accident severities and have very low rates for all ECI's--generally less than one percent. It should be noted that while probabilities are shown in Tables 2 and 3, they are based on very small numbers of cases.

Washington data are shown in Table 4. This data were used because immersion is listed, but as an accident variable; no cases were found. The number of other ECI's are so low that a brief summary is included rather than a tabulation. This file appears to omit many of the occupants, with documentation of only 1.3 per bus.

The Texas data provide information on minibuses as well as vans and is shown in Table 5 separately for urban and rural accidents. Again, nearly all involvements are collisions. Rollovers are very infrequent except for vans and minibuses in rural areas. The small vans include private and recreational vehicles.

Corresponding results for passenger cars are included for comparison, but are located together following the results for buses in Tables 6-8. Although they are grouped together, they should be compared with the results for buses from the same data set, rather than with each other. Otherwise the comparison can be confounded by differences in the data sets. Since cases of immersion were found in cars, the maximum number of combinations of ECI's is 32 for cars.

4.2 INCIDENCE OF ELDERLY OR HANDICAPPED PATRONS

The probability of an elderly patron being on board at the time of an accident can be estimated from the accident data by examining the age of each documented occupant. The term documented is used here to denote occupants for whom age, injury, etc. were recorded by the investigating officer, and for whom a record is included in the computerized data files. The total number of occupants is the number of occupants listed as in the vehicle at the time of the accident, in those jurisdictions that include such a variable. In order to determine the presence of elderly patrons, the documented occupants must be used. Since these are frequently underreported, especially in the case of uninjured occupants, the probability of an elderly occupant computed from accident data may be low.

Handicapped occupants are not specified in any of the accident data sets examined. Instead, the presence of children under five years was used as a surrogate for handicapped.

The results are given in Tables 9 through 11 for FARS, Michigan, and Pennsylvania. Probabilities are given for the presence of at least one occupant 65 years or over, 70 years or over, 0-4 years, and at least one each 65 or over and 0-4 years. Note that the figures vary substantially between the three data sets, with Michigan the lowest. The set-to-set differences probably reflect local differences in the documentation policies and practices. The highest figures are from the FARS data. This may result from higher occupant injury rates in fatal accidents, and consequently more complete occupant documentation.

Because of the possible bias in occupant documentation in accident files, i.e., underreporting, the 1977 National Personal Transportation

TABLE 6
FARS 1975-1980
13% Random Sample of Passenger Cars

Collision	Rollover	Fire	Driver Incap.	Immersion	Number of Vehicles	Probability
No	No	No	No	No	4267	0.142
No	No	No	No	Yes	3	0.0001
No	No	No	Yes	No	97	0.0032
No	No	No	Yes	Yes	55	0.0018
No	No	Yes	No	No	7	0.0002
No	No	Yes	Yes	No	6	0.0002
No	Yes	No	No	No	292	0.0097
No	Yes	No	No	Yes	2	0.00007
No	Yes	No	Yes	No	1360	0.045
No	Yes	No	Yes	Yes	31	0.0010
No	Yes	Yes	No	No	4	0.0001
No	Yes	Yes	Yes	No	20	0.0007
Yes	No	No	No	No	6743	0.225
Yes	No	No	No	Yes	4	0.0001
Yes	No	No	Yes	No	14,940	0.498
Yes	No	No	Yes	Yes	24	0.00008
Yes	No	Yes	No	No	75	0.0025
Yes	No	Yes	Yes	No	497	0.017
Yes	No	Yes	Yes	Yes	1	0.00003
Yes	Yes	No	No	No	196	0.0065
Yes	Yes	No	No	Yes	1	0.00003
Yes	Yes	No	Yes	No	1268	0.042
Yes	Yes	No	Yes	Yes	16	0.0005
Yes	Yes	Yes	No	No	7	0.0002
Yes	Yes	Yes	Yes	No	72	0.0024
Yes	Yes	Yes	Yes	Yes	1	0.00003

TABLE 6 (Continued)

Emergency-Causing Incident	Number of Vehicles	Probability
Collision	23,845	0.795
Rollover	3270	0.109
Fire	690	0.023
Driver Incapacitated	18,388	0.613
Immersion	138	0.0046

TABLE 7
Michigan - Passenger Cars for Comparisons With Buses
Numbers of Types of Emergency-Causing Incidents

A 20% Sample of All Passenger Cars in the 1981 File

Collision	Rollover	Fire	Driver Incap.	Number of Vehicles	Probability
No	No	No	No	1125	0.0583
No	No	No	Yes	2	0.00010
No	No	Yes	No	1	0.00005
No	Yes	No	No	231	0.0120
No	Yes	No	Yes	32	0.0017
No	Yes	Yes	No	1	0.00005
No	Yes	Yes	Yes	1	0.00005
Yes	No	No	No	17,439	0.9031
Yes	No	No	Yes	397	0.0206
Yes	No	Yes	No	25	0.0013
Yes	No	Yes	Yes	11	0.0006
Yes	Yes	No	No	42	0.0022
Yes	Yes	No	Yes	4	0.0002
Total				19,311	1.000

TABLE 7 (Continued)

Emergency-Causing Incident	Number of Vehicles	Probability
Collision	17,918	0.928
Rollover	311	0.016
Fire	38	0.0020
Driver Incapacitated	468	0.024

TABLE 8
Pennsylvania - Passenger Cars for Comparison With Buses

An 11% Sample of Passenger Cars in the 1979 File

Emergency Causing Incident					Number of Vehicles	Probability
Collision	Rollover	Fire	Driver Incap.	Immersion		
N	N	N	N	N	722	0.035
N	N	N	N	Y	8	0.00039
N	N	N	Y	N	4	0.00020
N	N	Y	N	N	10	0.00049
N	Y	N	N	N	145	0.0071
N	Y	N	Y	N	4	0.00020
Y	N	N	N	N	18,570	0.912
Y	N	N	N	Y	22	0.0011
Y	N	N	Y	N	365	0.018
Y	N	N	Y	Y	1	0.00005
Y	N	Y	N	N	14	0.00069
Y	N	Y	N	Y	1	0.00005
Y	N	Y	Y	N	5	0.00025
Y	Y	N	N	N	471	0.023
Y	Y	N	N	Y	3	0.00015
Y	Y	N	Y	N	27	0.0013
Y	Y	Y	N	N	1	0.00005
Total					20,373	1.000

TABLE 8 (Continued)

Emergency-Causing Event	Number of Cars	Probability
Collision	19,480	0.956
Rollover	651	0.032
Fire	31	0.0015
Driver Incapacitated	406	0.020
Immersion	35	0.0017

TABLE 9

FARS 1975-1980

Probability of Elderly or Handicapped Patrons on Buses

Probability of at least one occupant of given age group being in vehicle

	School Bus	Cross Country Bus	Transit Bus	Other Bus	Unknown Bus	Van as School Bus	Van as Other Bus	Total
Total Vehicles	786	220	795	91	109	32	23	2056
Vehicles with at least one occupant of age:								
Age 65+	29	51	58	9	13	2	4	166
Prob.	0.037	0.232	0.073	0.099	0.119	0.063	0.174	0.081
Age 70+	14	39	31	4	7	0	2	97
Prob.	0.018	0.177	0.039	0.044	0.064	0.000	0.087	0.047
Age 0-4	1	16	9	1	5	1	4	37
Prob.	0.001	0.073	0.011	0.011	0.046	0.031	0.174	0.018
Age 0-4 & 65+	0	12	2	0	2	0	2	18
Prob.	0.000	0.055	0.003	0.000	0.018	0.000	0.087	0.009

NOTE: Probability = Number of vehicles with occupants/Number of vehicles.

TABLE 10
Michigan 1981
Probability of Elderly or Handicapped Patrons on Buses

Probability of at least one occupant of given age group being in vehicle

	School Bus	Other Bus	Total
Total Vehicles	1427	1365	2792
Vehicles with at least one occupant of age:			
Age 65+	28	32	60
Prob.	0.020	0.023	0.021
Age 70+	10	13	23
Prob.	0.007	0.010	0.008
Age 0-4	2	3	5
Prob.	0.001	0.002	0.002
Age 65+ & 0-4	0	0	0
Prob.	0.000	0.000	0.000

Probability = Number of vehicles with occupants of given age group/ Number of vehicles.

TABLE 11
Pennsylvania 1979
Probability of Elderly or Handicapped Patrons on Buses

	Intercity Buses	Transit Buses	Total
Number of Vehicles	97	633	730
Total Occupants	720	2056	2776
Number of Vehicles With at Least One Occupant of:			
65+ Years	19	49	68
Prob.	0.196	0.077	0.093
70+ Years	11	35	46
Prob.	0.113	0.055	0.063
0-4 Years	6	18	24
Prob.	0.062	0.028	0.033
0-4 & 65+ Years	4	7	11
Prob.	0.041	0.011	0.015
Number of Vehicles With at Least One Occupant Requiring Extrication	1	8	9
Prob.	0.010	0.013	0.012

Survey was used to obtain national estimates of bus patron ages. Passenger miles were used as the measure of exposure for estimating the probability of a patron of a given age level being on board at the time of an accident. It is not possible to differentiate between intercity or transit bus use, but school buses are noted and have been excluded. The results are given in Table 12. The vehicle miles are weighted by sample expansion factors to give national estimates of bus travel. The actual number of trips in the sample is also shown to give an indication of the amount of data upon which the national estimates are based. The proportions of the travel--in passenger miles--that are accrued by the age groups of interest are also given.

Computation of the probability that at least one occupant of a particular age group would be on board at the time of an accident would require knowledge of the distribution of the number of occupants by vehicle mile, and this information is not available. However, we can arrived at some crude but useful estimates by making a simple assumption. If we assume that a given number, n, of patrons are in a bus at the time of an accident, the probability that at least one occupant of age group i is aboard is:

$$P = 1 - (1-p_i)^n$$

Where p_i is the probability that an individual patron is of age group i. Using the proportions given in Table 12 for p_i and an assumed load of 20 patrons, the probabilities of at least one elderly or surrogate handicapped patron on board are for:

65 or over	P = 0.919
70 or over	P = 0.762
0-4 years	P = 0.097
0-4 and 65 or over	P = 0.928

We may also ask how many patrons must be on board for the expectation of an elderly or young occupant to be at least 0.5. Then:

$$(1-p_i)^n = 0.5$$

or for 65 or over and 0-4 years, (p_i = 0.123), n = 5.3 patrons.

The probabilities of elderly patrons obtained from the accident data are much lower than obtained by the above approximations.

TABLE 12

1977 National Personal Transportation Survey

Bus Riders - Transit and Intercity Buses

Age	Actual Number (Unweighted)	Weighted Passenger Miles ($x10^6$)	Proportion of Travel
0-4	31	156.218	0.005112
5-9	142	1042.195	
10-14	328	275.651	
15-19	440	6341.583	
20-24	215	3404.381	
25-29	187	2334.479	
30-34	133	1917.129	
35-39	126	1338.063	
40-44	85	1600.164	
45-49	71	885.460	
50-54	100	1629.408	
55-59	129	1501.318	
60-64	91	2050.447	
65-69	110	1495.109	0.0489
70-74	72	1656.172	0.0542
75-79	32	311.727	0.0102
80 & over	19	148.609	0.00486
Total	2311	30558.1	
65 & over	233	3611.6	0.118
70 & over	123	2116.5	0.0693

Furthermore, it is not likely that underreporting in the accident data would result in such a large discrepancy unless occupancy rates are very low. A check of the Pennsylvania data indicates that 45 percent of the intercity and 42 percent of the transit buses were reported to have only one occupant--presumably the driver--at the time of the accident.

4.3 JAMMING OF VAN DOORS DURING COLLISIONS

The NCSS data (Phase 2) collected by seven teams from April 1, 1978 to March 31, 1979, were used to compare the incidence of doors jamming closed on vans and passenger cars. The results are shown in Table 13. Doors on vans jammed closed at about the same rate as on cars in rollovers, about two-thirds of such cases. In non-rollovers the rates were lower, but vans had a substantially higher rate than cars, 50 percent as compared to 32 percent. However, while only 4.3 percent of the cars were rollovers, 21.7 percent of the vans were rollovers. In the aggregate, doors jammed closed on 33.4 percent of the cars and 54.0 percent of the vans.

These results are based on weighted data and exclude cases of missing data on door jamming. The unweighted numbers of vehicles are shown in parentheses in Table 13 to indicate the number of observations.

It should be noted that the vans in the NCSS data are standard small vans. Probably few, if any, have been modified for use as buses. Only intermediate, standard/full-sized, and luxury model passenger cars are included in the comparison. Compacts and subcompacts were excluded because of the large size discrepancy.

4.4 COMPARISON OF CRUSH TO VANS AND PASSENGER CARS

The NCSS Phase 2 data were also used to compare crush to passenger cars and vans, as shown in Table 14. The crush to each vehicle (for which crush data are available) was characterized by a horizontal profile specified by either 2, 4, or 6 individual crush measurements. For this comparison, the maximum of the crush measurements on each vehicle was assigned to that vehicle. These measurements were then averaged across all vehicles of each type, thus giving the mean maximum crushes shown in the table.

TABLE 13
Doors Jamming Closed

Weighted Data From the NCSS Program, Phase 2

	Cars		Vans	
	N*	%	N*	%
Rollovers				
Jammed**	262 (82)	66.8	85 (20)	67.5
Not Jammed	130 (43)	33.2	41 (8)	32.5
Total	392 (125)	100.0	126 (28)	100.0
M.D.	11 (2)	-	0	-
Non-Rollovers				
Jammed**	2800 (902)	31.9	229 (49)	50.3
Not Jammed	5982 (1183)	68.1	226 (118)	100.0
Total	8782 (2085)	100.0	455 (118)	100.0
M.D.	2089 (414)	-	208 (40)	-

*The numbers of vehicles shown are the numbers after weighting by the inverse of the sampling fraction. The unweighted actual numbers of observations are shown in parentheses.

**At least one door in the vehicle jammed closed.
Unweighted numbers are given in parentheses.

TABLE 14
Comparison of Crush to Vans and Cars

Weighted Data From the NCSS Program, Phase 2

Collision/Rollover	Mean Maximum Crush			
	Cars*		Vans	
	N**	Crush (in.)	N**	Crush (in.)
No Collision No Rollover	5 (5)	24.2	0 (0)	-
No Collision Rollover	189 (43)	7.4	27 (6)	5.6
Collision No Rollover	8444 (1989)	16.9	391 (110)	12.5
Collision Rollover	67 (36)	22.7	80 (15)	13.6

*The cars that are included are intermediates, standard fullsize, and luxury models.

**The numbers of vehicles shown are the numbers after weighting by the inverse of the sampling fraction. The unweighted actual numbers of observations are shown in parentheses.

Passenger cars received greater crush in all crash categories. The difference was most pronounced in collisions accompanied by rollover, where the rate was 70 percent greater for vans (22.7 percent versus 13.6 percent).

4.5 INJURY

While the incidence of fatal or incapacitating injury was not among the original objectives except as an indication of an incapacitated driver, the rates are of interest and help place the bus accident experience in perspective. The number of occupants fatalities, and the sum of fatalities and "A" (incapacitating) injuries is given in Tables 15 though 17 for the FARS and Michigan data.

The FARS data give a census of all in-bus fatalities in the nation over a six-year period. The A injuries do not represent all such injury, but only those that occurred in buses involved in fatal accidents. Thus the A injuries in Table 15 are overrepresented in comparison with all bus accident involvements. The fatalities of the FARS data are shown by each ECI in Table 16. Because of the overrepresentation of A injuries in FARS, the experience in Michigan in 1981 is given in Table 16.

It is clear from these tables that although spectacular bus accidents do occur, they are rare. Only 116 fatalities occurred in intercity and transit buses over a six-year period, or an average of 19 per year. Only 17 per year occurred in school buses. Single states are not suitable for examining fatalities. Michigan had only one fatality in 1981, and this is not atypical.

Even the number of A injuries is low, with only 26 in Michigan in 1981. These are about equally divided between school and commercial buses.

TABLE 15
FARS 1975-1980
Bus Occupancy and Injury

Vehicle Type	Vehicles	Occupants	Fatalities	Fatalities and "A" Injuries
School Bus	785	7556* 2271**	101	392
Cross-Country Bus	220	2981* 1385**	51	229
Transit Bus	794	4754* 1618**	65	203
Other Bus	92	693* 381**	56	124
Unknown Bus	109	784* 410**	20	87
Vans Used as School Buses	32	114*	15	30
Vans Used as Other Buses	23	110*	14	51
All Vans	9661	18,932* 18,062**	4943	9274
Total	11,661	35,699* 24,627**	5236	10,310

*The number of occupants is missing data on 23% of the buses, but only 0.1% of the vans.

**Occupants with recorded documentation on each.

TABLE 16
FARS 1975-1980
Bus Occupant Fatalities by Emergency-Causing Incidents

Bus Type	Emergency Causing Incident			
	Collisions	Rollovers	Fires	Driver Incapacitated
School Buses	80	23	0	55
Cross-Country	43	10	1	34
Transit	33	7	1	22
Other	51	8	0	51
Unknown	14	4	0	10
Vans as School Bus	11	5	1	9
Vans as Other Bus	13	7	0	9

TABLE 17
Michigan 1981
Bus Occupancy and Injury

	School Bus	Commercial Bus	Total
Number of Vehicles	1427	1365	2792
Documented Occupants*	1551	1601	3152
Number of Fatalities	1	0	1
Number of "A" Injuries	13	12	25

*The total number of occupants in buses is not available for Michigan.

5.0 CONCLUSIONS

It has not been possible to distinguish types of bus construction in any accident data set available. School buses can be differentiated from other buses in all files, but vans are not universally detectable. Thus the objectives of Task 1 are largely unfulfilled.

The incidence of emergency-causing incidents has been examined in a number of files, and although the results vary somewhat among the data sources, general conclusions are possible. No immersions of buses were found in the national FARS data, nor in the states of Washington and Pennsylvania. Collisions are the most frequent emergency-causing incident, since nearly all bus involvements are collisions except for pedestrian, pedalcycle, and otherwise unclassified involvements. The other ECI's are all infrequent events.

Rollovers in the FARS data are most frequent in cross-country buses (6 percent) and vans (13 percent). These figures might be increased by twice if allowance is made for a change in documentation starting in 1978. These again are all serious accidents and substantial overrepresentation of dangerous ECI's is likely. In the Michigan and Pennsylvania data, rollovers occurred in less than two percent of the bus involvements.

Fires were even less frequent than rollover. In FARS the maximum fire rate was three percent for vans used as school buses. The rate is less than one percent among all bus involvements in Michigan and Pennsylvania.

Incapacitation of bus drivers by either fatal or incapacitating non-fatal (A) injury is also infrequent. In intercity and transit buses in FARS, the rate was 10 percent. It was considerably higher (32 percent) in vans used as school buses, but only 12 such instances are in the six years of data.

In the full spectrum of bus involvements in Michigan and Pennsylvania, the rate was about one percent or less.

Most intercity and transit bus accidents are not dangerous to the bus occupants. This is true even in most cases that involve fatalities to occupants of the other vehicle. Over the last six years the average number of fatalities per year has been 16.8 in school buses, 8.5 in intercity buses, and 10.8 in transit buses.