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THE EFFECT OF USING A 'TOWAWAY' THRESHOLD IN STUDYING TRAFFIC ACCIDENTS

Amitabh K. Dutt

Donald W. Reinfurt

September 30, 1979

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THE EFFECT OF USING A 'TOWAWAY' THRESHOLD IN STUDYING TRAFFIC ACCIDENTS

Amitabh K. Dutt
Donald W. Reinfurt

HIGHWAY SAFETY RESEARCH CENTER
MCMLXV

FINAL REPORT
October 1, 1977 - December 31, 1978

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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
Washington, D.C. 20590

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16. Abstract

The Restraint Systems Evaluation Program (RSEP) and the National Crash Severity Study (NCSS) utilized a "towaway" threshold for inclusion of accident vehicles in their samples. It is also going to be the major criterion for much of the National Accident Sampling System (NASS). In this report, the effect of using such a threshold rather than "all accidents" is investigated.

In the first part of the report, the independent variables which are most closely associated with post-crash vehicle drivability are identified. Two different data sources, 1976 North Carolina accident data and 1975 New York accident data, were examined. The variables identified in single vehicle and multi-vehicle accidents in the two files were very comparable. A log-linear model was fitted to the North Carolina data and predicted towaway odds as a function of the identified independent variables presented. For example, the odds of being towed versus the vehicle being drivable in high speed, front impact single vehicle crashes are from four to ten-fold greater depending on the object struck.

In the second part of the report, accident and injury characteristics along with seat belt usage and effectiveness estimates are compared as a function of the sampling criterion. For the accident characteristics (i.e., rural-urban area; highway class; accident type; vehicle impact site) the towaway vs. all accidents distributions are

(Con't on following page)

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16. ABSTRACT (Con't)

virtually identical for serious (A+K) vehicle severity accidents. This is the case since only 1.5 percent of the fatals (K) and 4.6 percent of the serious (A+K) crashes are excluded from the towaway sampling frame (i.e., appear in the drivable sample). Contrarily, when comparing towaway versus all accidents without regard to vehicle severity, the distributions differ markedly with a preponderance of rural accidents, ran off road accidents, and frontal impacts in the towaway sample. Serious (A+K) driver injury rates are from two to three-fold greater in the towaway sample with the difference decreasing as car size decreases. On the other hand, belt usage rates and corresponding effectiveness estimates are consistently lower for the towaway sample. The magnitude of these differences by car size, model year, and/or driver injury level is given in Table 4.7 and 4.8.

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Finally, the authors are greatly indebted to Mr. Donald F. Mela, the Contract Technical Manager, for his helpful guidance through all phases of the project.

I. INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) collects statistical data on accidents for use in developing, evaluating and implementing vehicle and highway safety standards. Specifically, NHTSA will be depending on the National Accident Sampling System (NASS) established by the National Center for Statistics and Analysis (NCSA) to collect this data. Under the National Accident Sampling System (NASS), relatively thorough investigations are being carried out on a probability sample of towaway traffic accidents, where towaway means non-drivable.

Because NASS relies on the "towaway" criterion for the inclusion of an accident into its sample, NHTSA is interested in investigating the possible biases which may be introduced by this procedure. For example, one would like to know if rural accidents are over-represented in the towaway crashes or if driver characteristics are different in a NASS-type file from the overall accident population. Unfortunately, very little work has been done to answer such questions, even though several studies (Reinfurt, Silva and Seila, 1976; Scott, Flora and Marsh, 1976) have been carried out using the Restraint Systems Evaluation Program (RSEP) data, which is a prototype of NASS.

Accordingly, the purpose of this study is to investigate the possible effects of biases in a data base restricted to towaway accidents. This requires an accident file containing both towaway and non-towaway accidents, along with information on vehicle drivability. The 1976 North Carolina and 1975 New York accident files meet these criteria, and were therefore selected for use in the analysis.

The remainder of this report discusses the data sources utilized in this study, the analysis procedure employed, the principal findings, and implications of these findings. More specifically, Chapter II describes both the North Carolina and New York data sources in greater detail and the procedures followed in setting up the final working files. Chapter III presents the analysis procedures and results. In Chapter IV, some accident characteristics, injury rates, belt usage rates and belt effectiveness measures are examined and comparisons made as a function of sampling criterion. Finally, Chapter V summarizes the study findings and their implications.

It should be noted that the results could be compared across states with New York representing a more urban state than North Carolina. The reporting threshold for North Carolina accidents is any motor vehicle collision resulting in injury or death or total property damage of at least two hundred dollars. New York State requires all accidents causing death, personal injury or damage over two hundred dollars to the property of any one person to be reported. The New York police, however, restrict their investigations to injury and high property damage accidents only. The remaining less severe accidents are reported by motorists themselves. Thus, there is more between-reporting-source variation in the New York data.

II. THE DATA

Data Sources

Although many states have towaway information on their accident forms, only a few have stored this data on their computerized accident tapes. The 1976 North Carolina accident tapes contain towaway information for all reportable 1976 motor vehicle accidents in North Carolina (see Appendix A). Similarly, the State of New York has collected and computerized towaway information on its revised 1975 accident report form. The latter data was made available to the Highway Safety Research Center by the New York Department of Motor Vehicles and provides an excellent complement to the North Carolina data set.

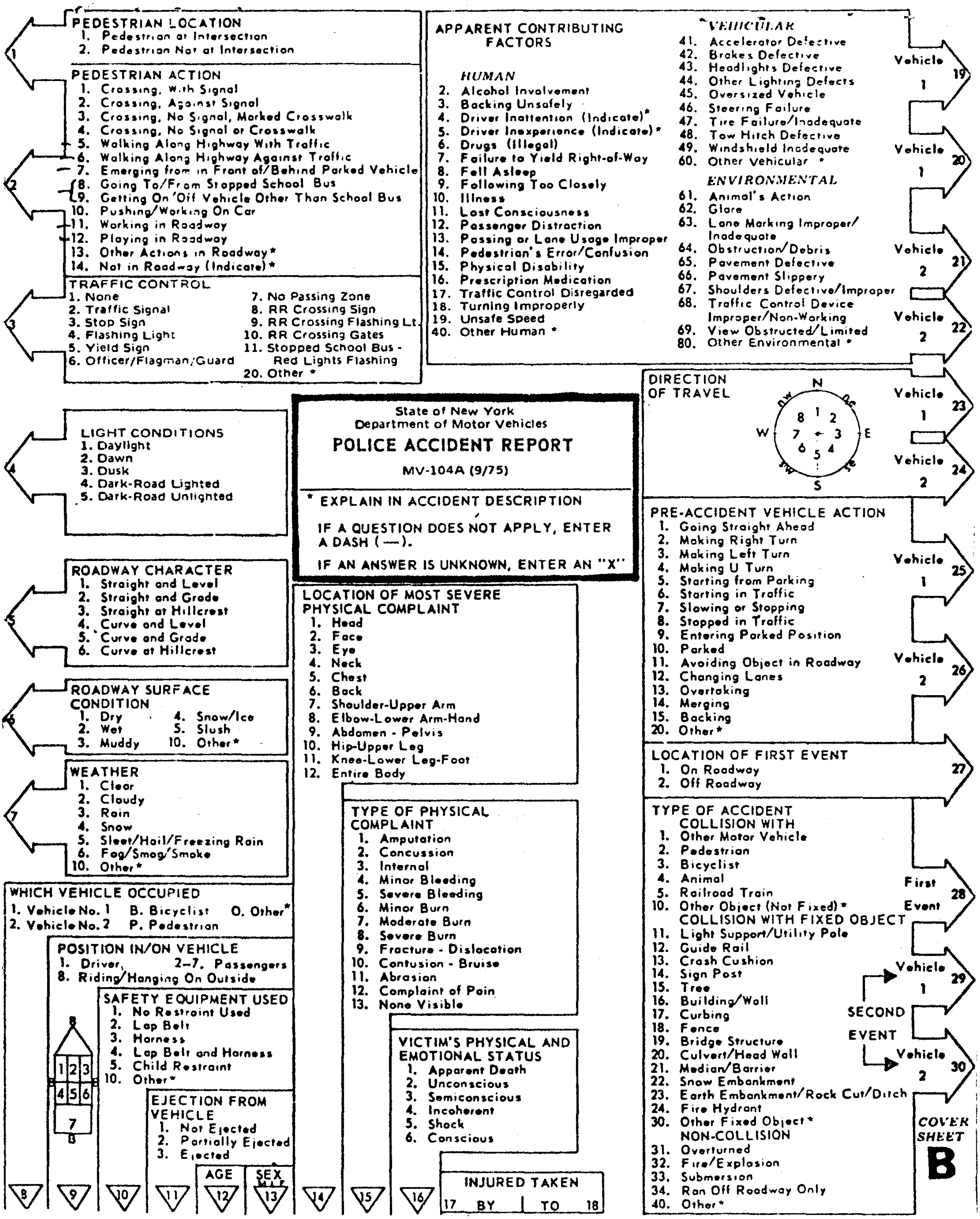
The New York accident form specifically indicates if the vehicle was towed from the scene while the North Carolina form indicates vehicle drivability. Although there may be cases where the distinction in the two criteria could make a difference, in this report they are considered equivalent and are used interchangeably.

Data Editing

While the North Carolina 1976 accident data had already been converted into an SPSS-usable format, the New York data involved a considerable amount of processing before it could be used for data analysis. Figures 2.1 and 2.2 show 1975 New York police and motorist accident report forms, respectively.

The police accident form in New York consists of two sheets. The first sheet is used as a template and overlaid within the bold-lined boundary on the second sheet. The cells along the edges of the second sheet are filled from the corresponding items on the template. Once this has been done, the template is removed and the data items within the bold outline on the second sheet are filled in.

The purpose of the motorist report form is to cover non-injury accidents thus restricting its use to non-serious accidents. Data editing problems arose because the 1975 New York accident tape contained data from both types of forms. As may be seen, the motorist report forms do not contain information on some important variables. For example, the motorist form has no information on apparent contributing factors, point of impact, occupant injury by seat location, usage of safety equipment or location of first event. Unfortunately, even for data items provided on the motorist report form, a substantial proportion were left blank.



PEDESTRIAN LOCATION
1. Pedestrian at Intersection
2. Pedestrian Not at Intersection

1

PEDESTRIAN ACTION
1. Crossing, With Signal
2. Crossing, Against Signal
3. Crossing, No Signal, Marked Crosswalk
4. Crossing, No Signal or Crosswalk
5. Walking Along Highway With Traffic
6. Walking Along Highway Against Traffic
7. Emerging from in Front of/Behind Parked Vehicle
8. Going To/From Stopped School Bus
9. Getting On/Off Vehicle Other Than School Bus
10. Pushing/Working On Car
11. Working in Roadway
12. Playing in Roadway
13. Other Actions in Roadway*
14. Not in Roadway (Indicate)*

2

TRAFFIC CONTROL
1. None
2. Traffic Signal
3. Stop Sign
4. Flashing Light
5. Yield Sign
6. Officer/Flagman/Guard
7. No Passing Zone
8. RR Crossing Sign
9. RR Crossing Flashing Lt.
10. RR Crossing Gates
11. Stopped School Bus - Red Lights Flashing
20. Other *

3

LIGHT CONDITIONS
1. Daylight
2. Dawn
3. Dusk
4. Dark-Road Lighted
5. Dark-Road Unlighted

4

ROADWAY CHARACTER
1. Straight and Level
2. Straight and Grade
3. Straight at Hillcrest
4. Curve and Level
5. Curve and Grade
6. Curve at Hillcrest

5

ROADWAY SURFACE CONDITION
1. Dry
2. Wet
3. Muddy
4. Snow/Ice
5. Slush
10. Other*

6

WEATHER
1. Clear
2. Cloudy
3. Rain
4. Snow
5. Sleet/Hail/Freezing Rain
6. Fog/Smog/Smoke
10. Other*

7

WHICH VEHICLE OCCUPIED
1. Vehicle No. 1
2. Vehicle No. 2
B. Bicyclist
P. Pedestrian
O. Other*

POSITION IN/ON VEHICLE
1. Driver, 2–7. Passengers
8. Riding/Hanging On Outside

SAFETY EQUIPMENT USED
1. No Restraint Used
2. Lap Belt
3. Harness
4. Lap Belt and Harness
5. Child Restraint
10. Other*

EJECTION FROM VEHICLE
1. Not Ejected
2. Partially Ejected
3. Ejected

AGE

SEX M F

8 9 10 11 12 13

APPARENT CONTRIBUTING FACTORS

HUMAN
2. Alcohol Involvement
3. Backing Unsafely
4. Driver Inattention (Indicate)*
5. Driver Inexperience (Indicate)*
6. Drugs (Illegal)
7. Failure to Yield Right-of-Way
8. Fell Asleep
9. Following Too Closely
10. Illness
11. Lost Consciousness
12. Passenger Distraction
13. Passing or Lane Usage Improper
14. Pedestrian's Error/Confusion
15. Physical Disability
16. Prescription Medication
17. Traffic Control Disregarded
18. Turning Improperly
19. Unsafe Speed
40. Other Human *

VEHICULAR
41. Accelerator Defective
42. Brakes Defective
43. Headlights Defective
44. Other Lighting Defects
45. Oversized Vehicle
46. Steering Failure
47. Tire Failure/Inadequate
48. Tow Hitch Defective
49. Windshield Inadequate
60. Other Vehicular *

ENVIRONMENTAL
61. Animal's Action
62. Glare
63. Lane Marking Improper/Inadequate
64. Obstruction/Debris
65. Pavement Defective
66. Pavement Slippery
67. Shoulders Defective/Improper
68. Traffic Control Device Improper/Non-Working
69. View Obstructed/Limited
80. Other Environmental *

Vehicle 1 19

Vehicle 1 20

Vehicle 2 21

Vehicle 2 22

State of New York
Department of Motor Vehicles

POLICE ACCIDENT REPORT

MV-104A (9/75)

* EXPLAIN IN ACCIDENT DESCRIPTION

IF A QUESTION DOES NOT APPLY, ENTER A DASH (—).

IF AN ANSWER IS UNKNOWN, ENTER AN "X"

LOCATION OF MOST SEVERE PHYSICAL COMPLAINT
1. Head
2. Face
3. Eye
4. Neck
5. Chest
6. Back
7. Shoulder-Upper Arm
8. Elbow-Lower Arm-Hand
9. Abdomen - Pelvis
10. Hip-Upper Leg
11. Knee-Lower Leg-Foot
12. Entire Body

14

TYPE OF PHYSICAL COMPLAINT
1. Amputation
2. Concussion
3. Internal
4. Minor Bleeding
5. Severe Bleeding
6. Minor Burn
7. Moderate Burn
8. Severe Burn
9. Fracture - Dislocation
10. Contusion - Bruise
11. Abrasion
12. Complaint of Pain
13. None Visible

15

VICTIM'S PHYSICAL AND EMOTIONAL STATUS
1. Apparent Death
2. Unconscious
3. Semiconscious
4. Incoherent
5. Shock
6. Conscious

16

INJURED TAKEN
17 BY | TO 18

DIRECTION OF TRAVEL

Vehicle 1 23

Vehicle 2 24

PRE-ACCIDENT VEHICLE ACTION
1. Going Straight Ahead
2. Making Right Turn
3. Making Left Turn
4. Making U Turn
5. Starting from Parking
6. Starting in Traffic
7. Slowing or Stopping
8. Stopped in Traffic
9. Entering Parked Position
10. Parked
11. Avoiding Object in Roadway
12. Changing Lanes
13. Overtaking
14. Merging
15. Backing
20. Other*

Vehicle 1 25

Vehicle 2 26

LOCATION OF FIRST EVENT
1. On Roadway
2. Off Roadway

27

TYPE OF ACCIDENT

COLLISION WITH
1. Other Motor Vehicle
2. Pedestrian
3. Bicyclist
4. Animal
5. Railroad Train
10. Other Object (Not Fixed)*

COLLISION WITH FIXED OBJECT
11. Light Support/Utility Pole
12. Guide Rail
13. Crash Cushion
14. Sign Post
15. Tree
16. Building/Wall
17. Curbing
18. Fence
19. Bridge Structure
20. Culvert/Head Wall
21. Median/Barrier
22. Snow Embankment
23. Earth Embankment/Rock Cut/Ditch
24. Fire Hydrant
30. Other Fixed Object*

NON-COLLISION
31. Overturned
32. Fire/Explosion
33. Submersion
34. Ran Off Roadway Only
40. Other*

First Event 28

SECOND EVENT

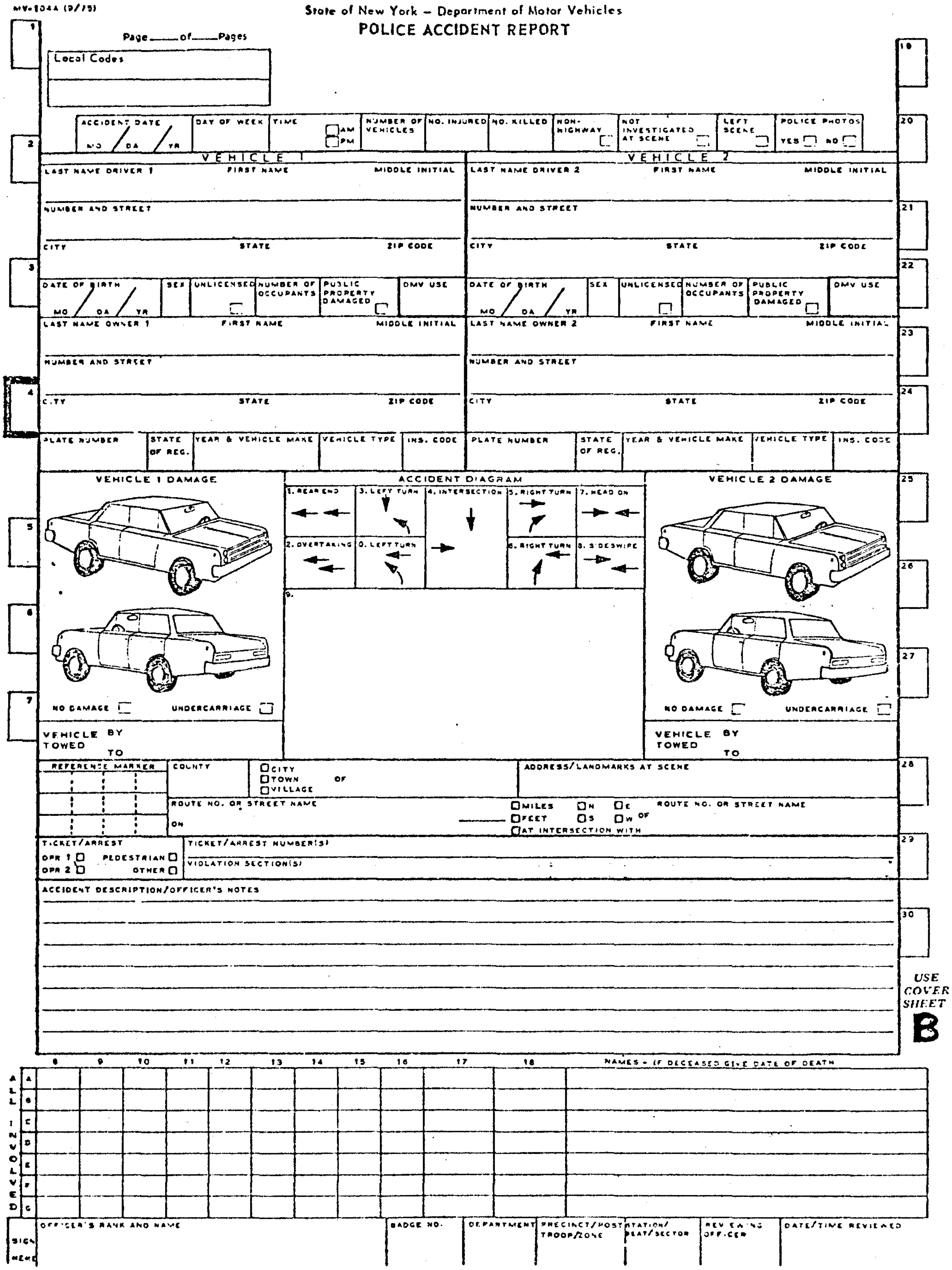
Vehicle 1 29

Vehicle 2 30

COVER SHEET

B

Figure 2.1 New York police accident report form.



MV-104A (9/75)

State of New York – Department of Motor Vehicles

POLICE ACCIDENT REPORT

Page____of____Pages

Local Codes

1 2 3 4 5 6 7

19 20 21 22 23 24 25 26 27 28 29 30

ACCIDENT DATE MO / DA / YR | DAY OF WEEK | TIME ☐AM ☐PM | NUMBER OF VEHICLES | NO. INJURED | NO. KILLED | NON-HIGHWAY ☐ | NOT INVESTIGATED AT SCENE ☐ | LEFT SCENE ☐ | POLICE PHOTOS YES ☐ NO ☐

VEHICLE 1

LAST NAME DRIVER 1 | FIRST NAME | MIDDLE INITIAL

NUMBER AND STREET

CITY | STATE | ZIP CODE

DATE OF BIRTH MO / DA / YR | SEX | UNLICENSED ☐ | NUMBER OF OCCUPANTS | PUBLIC PROPERTY DAMAGED ☐ | DMV USE

LAST NAME OWNER 1 | FIRST NAME | MIDDLE INITIAL

NUMBER AND STREET

CITY | STATE | ZIP CODE

PLATE NUMBER | STATE OF REG. | YEAR & VEHICLE MAKE | VEHICLE TYPE | INS. CODE

VEHICLE 2

LAST NAME DRIVER 2 | FIRST NAME | MIDDLE INITIAL

NUMBER AND STREET

CITY | STATE | ZIP CODE

DATE OF BIRTH MO / DA / YR | SEX | UNLICENSED ☐ | NUMBER OF OCCUPANTS | PUBLIC PROPERTY DAMAGED ☐ | DMV USE

LAST NAME OWNER 2 | FIRST NAME | MIDDLE INITIAL

NUMBER AND STREET

CITY | STATE | ZIP CODE

PLATE NUMBER | STATE OF REG. | YEAR & VEHICLE MAKE | VEHICLE TYPE | INS. CODE

VEHICLE 1 DAMAGE

NO DAMAGE ☐ UNDERCARRIAGE ☐

VEHICLE TOWED BY TO

ACCIDENT DIAGRAM

1. REAR END
3. LEFT TURN
4. INTERSECTION
5. RIGHT TURN
7. HEAD ON
2. OVERTAKING
0. LEFT TURN
6. RIGHT TURN
8. SIDESWIPE
9.

VEHICLE 2 DAMAGE

NO DAMAGE ☐ UNDERCARRIAGE ☐

VEHICLE TOWED BY TO

REFERENCE MARKER | COUNTY | ☐CITY ☐TOWN ☐VILLAGE OF | ADDRESS/LANDMARKS AT SCENE

ROUTE NO. OR STREET NAME

ON ______ ☐MILES ☐FEET ☐AT INTERSECTION WITH ☐N ☐S ☐E ☐W OF ROUTE NO. OR STREET NAME

TICKET/ARREST OPR 1 ☐ OPR 2 ☐ PEDESTRIAN ☐ OTHER ☐ | TICKET/ARREST NUMBER(S)

VIOLATION SECTION(S)

ACCIDENT DESCRIPTION/OFFICER'S NOTES

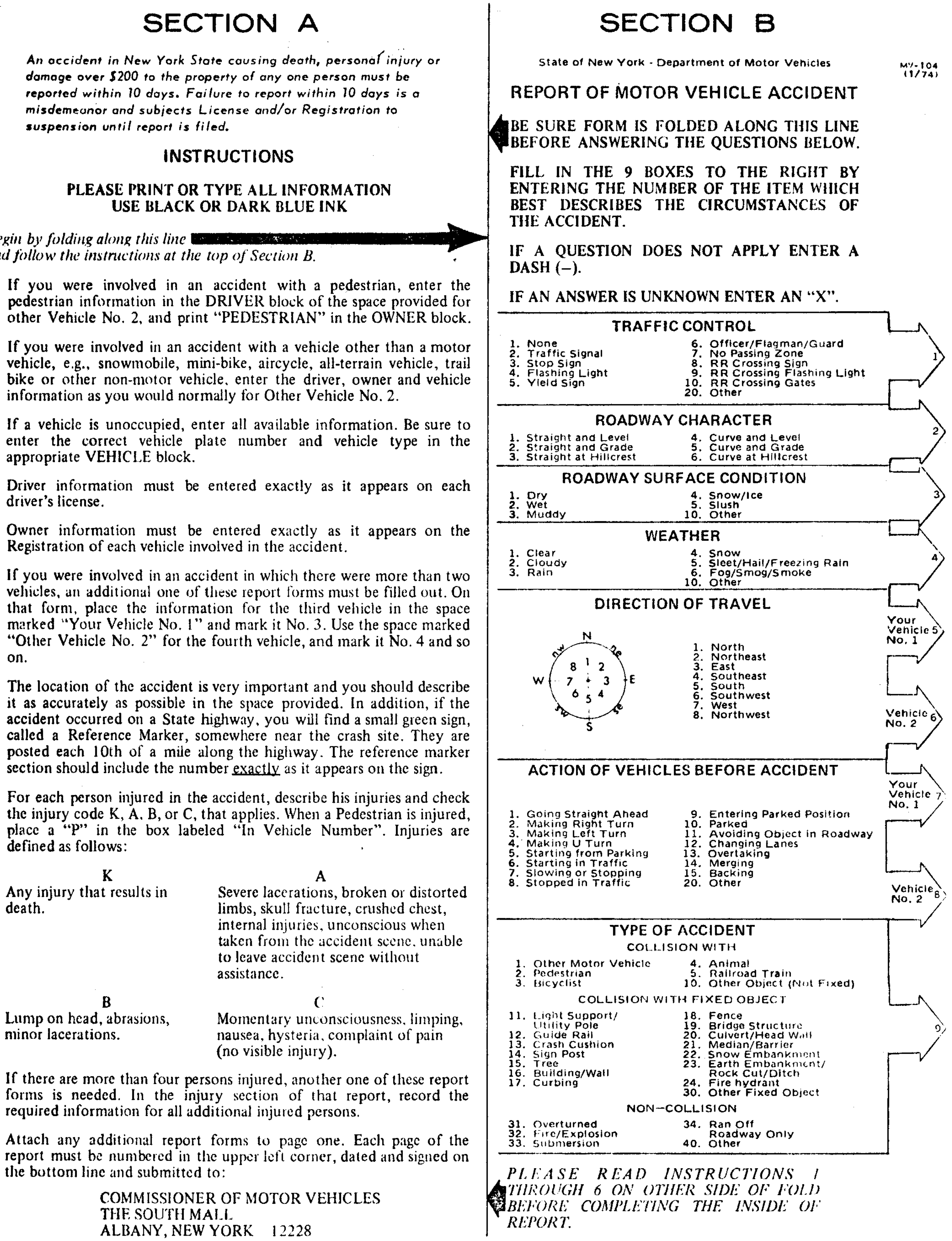
USE COVER SHEET

B

		8	9	10	11	12	13	14	15	16	17	18	NAMES – IF DECEASED GIVE DATE OF DEATH
ALL INVOLVED	A												
	B												
	C												
	D												
	E												
	F												
	G												

SIGN HERE | OFFICER'S RANK AND NAME | BADGE NO. | DEPARTMENT | PRECINCT/POST TROOP/ZONE | STATION/BEAT/SECTOR | REVIEWING OFFICER | DATE/TIME REVIEWED

Figure 2.1 (Con't)



SECTION A

An accident in New York State causing death, personal injury or damage over $200 to the property of any one person must be reported within 10 days. Failure to report within 10 days is a misdemeanor and subjects License and/or Registration to suspension until report is filed.

INSTRUCTIONS

PLEASE PRINT OR TYPE ALL INFORMATION
USE BLACK OR DARK BLUE INK

Begin by folding along this line
and follow the instructions at the top of Section B.

1. If you were involved in an accident with a pedestrian, enter the pedestrian information in the DRIVER block of the space provided for other Vehicle No. 2, and print "PEDESTRIAN" in the OWNER block.

   If you were involved in an accident with a vehicle other than a motor vehicle, e.g., snowmobile, mini-bike, aircycle, all-terrain vehicle, trail bike or other non-motor vehicle, enter the driver, owner and vehicle information as you would normally for Other Vehicle No. 2.

   If a vehicle is unoccupied, enter all available information. Be sure to enter the correct vehicle plate number and vehicle type in the appropriate VEHICLE block.

2. Driver information must be entered exactly as it appears on each driver's license.

   Owner information must be entered exactly as it appears on the Registration of each vehicle involved in the accident.

3. If you were involved in an accident in which there were more than two vehicles, an additional one of these report forms must be filled out. On that form, place the information for the third vehicle in the space marked "Your Vehicle No. 1" and mark it No. 3. Use the space marked "Other Vehicle No. 2" for the fourth vehicle, and mark it No. 4 and so on.

4. The location of the accident is very important and you should describe it as accurately as possible in the space provided. In addition, if the accident occurred on a State highway, you will find a small green sign, called a Reference Marker, somewhere near the crash site. They are posted each 10th of a mile along the highway. The reference marker section should include the number exactly as it appears on the sign.

5. For each person injured in the accident, describe his injuries and check the injury code K, A, B, or C, that applies. When a Pedestrian is injured, place a "P" in the box labeled "In Vehicle Number". Injuries are defined as follows:

K	A
Any injury that results in death.	Severe lacerations, broken or distorted limbs, skull fracture, crushed chest, internal injuries, unconscious when taken from the accident scene, unable to leave accident scene without assistance.
B	**C**
Lump on head, abrasions, minor lacerations.	Momentary unconsciousness, limping, nausea, hysteria, complaint of pain (no visible injury).

   If there are more than four persons injured, another one of these report forms is needed. In the injury section of that report, record the required information for all additional injured persons.

6. Attach any additional report forms to page one. Each page of the report must be numbered in the upper left corner, dated and signed on the bottom line and submitted to:

COMMISSIONER OF MOTOR VEHICLES
THE SOUTH MALL
ALBANY, NEW YORK 12228

SECTION B

State of New York - Department of Motor Vehicles

MV-104
(1/74)

REPORT OF MOTOR VEHICLE ACCIDENT

BE SURE FORM IS FOLDED ALONG THIS LINE BEFORE ANSWERING THE QUESTIONS BELOW.

FILL IN THE 9 BOXES TO THE RIGHT BY ENTERING THE NUMBER OF THE ITEM WHICH BEST DESCRIBES THE CIRCUMSTANCES OF THE ACCIDENT.

IF A QUESTION DOES NOT APPLY ENTER A DASH (–).

IF AN ANSWER IS UNKNOWN ENTER AN "X".

TRAFFIC CONTROL

1. None
2. Traffic Signal
3. Stop Sign
4. Flashing Light
5. Yield Sign
6. Officer/Flagman/Guard
7. No Passing Zone
8. RR Crossing Sign
9. RR Crossing Flashing Light
10. RR Crossing Gates
20. Other

1

ROADWAY CHARACTER

1. Straight and Level
2. Straight and Grade
3. Straight at Hillcrest
4. Curve and Level
5. Curve and Grade
6. Curve at Hillcrest

2

ROADWAY SURFACE CONDITION

1. Dry
2. Wet
3. Muddy
4. Snow/Ice
5. Slush
10. Other

3

WEATHER

1. Clear
2. Cloudy
3. Rain
4. Snow
5. Sleet/Hail/Freezing Rain
6. Fog/Smog/Smoke
10. Other

4

DIRECTION OF TRAVEL

N, ne, E, se, S, sw, W, nw

1. North
2. Northeast
3. East
4. Southeast
5. South
6. Southwest
7. West
8. Northwest

Your Vehicle No. 1 5

Vehicle No. 2 6

ACTION OF VEHICLES BEFORE ACCIDENT

1. Going Straight Ahead
2. Making Right Turn
3. Making Left Turn
4. Making U Turn
5. Starting from Parking
6. Starting in Traffic
7. Slowing or Stopping
8. Stopped in Traffic
9. Entering Parked Position
10. Parked
11. Avoiding Object in Roadway
12. Changing Lanes
13. Overtaking
14. Merging
15. Backing
20. Other

Your Vehicle No. 1 7

Vehicle No. 2 8

TYPE OF ACCIDENT

COLLISION WITH

1. Other Motor Vehicle
2. Pedestrian
3. Bicyclist
4. Animal
5. Railroad Train
10. Other Object (Not Fixed)

COLLISION WITH FIXED OBJECT

11. Light Support/ Utility Pole
12. Guide Rail
13. Crash Cushion
14. Sign Post
15. Tree
16. Building/Wall
17. Curbing
18. Fence
19. Bridge Structure
20. Culvert/Head Wall
21. Median/Barrier
22. Snow Embankment
23. Earth Embankment/ Rock Cut/Ditch
24. Fire hydrant
30. Other Fixed Object

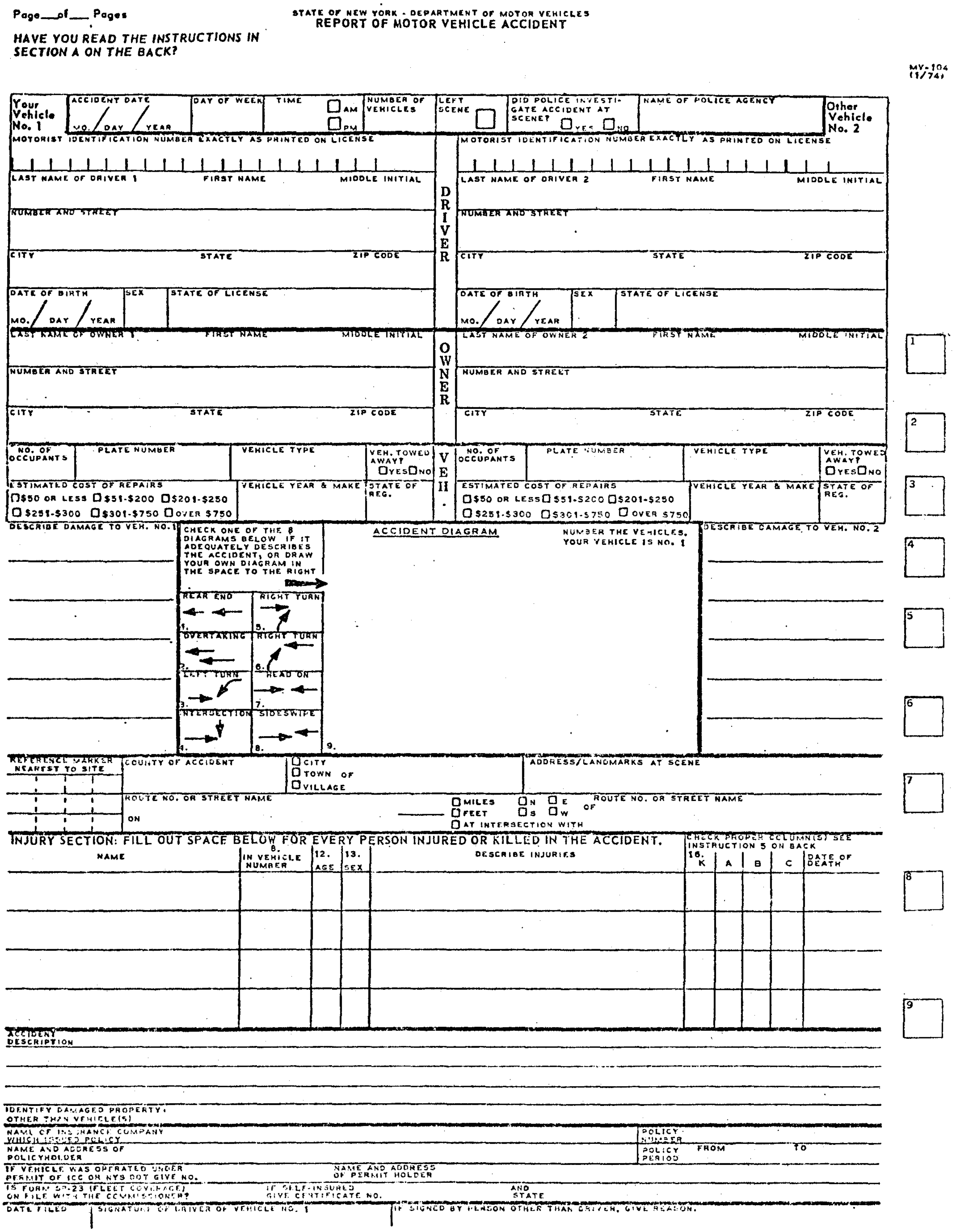
NON–COLLISION

31. Overturned
32. Fire/Explosion
33. Submersion
34. Ran Off Roadway Only
40. Other

9

PLEASE READ INSTRUCTIONS 1 THROUGH 6 ON OTHER SIDE OF FOLD BEFORE COMPLETING THE INSIDE OF REPORT.

Figure 2.2 New York motorist-reported accident form.



Page___of___ Pages

STATE OF NEW YORK - DEPARTMENT OF MOTOR VEHICLES
REPORT OF MOTOR VEHICLE ACCIDENT

HAVE YOU READ THE INSTRUCTIONS IN SECTION A ON THE BACK?

MV-104 (1/74)

Your Vehicle No. 1

ACCIDENT DATE MO. / DAY / YEAR | DAY OF WEEK | TIME ☐ AM ☐ PM | NUMBER OF VEHICLES | LEFT SCENE ☐ | DID POLICE INVESTIGATE ACCIDENT AT SCENE? ☐ YES ☐ NO | NAME OF POLICE AGENCY

Other Vehicle No. 2

DRIVER

MOTORIST IDENTIFICATION NUMBER EXACTLY AS PRINTED ON LICENSE
LAST NAME OF DRIVER 1 | FIRST NAME | MIDDLE INITIAL
NUMBER AND STREET
CITY | STATE | ZIP CODE
DATE OF BIRTH MO. / DAY / YEAR | SEX | STATE OF LICENSE

MOTORIST IDENTIFICATION NUMBER EXACTLY AS PRINTED ON LICENSE
LAST NAME OF DRIVER 2 | FIRST NAME | MIDDLE INITIAL
NUMBER AND STREET
CITY | STATE | ZIP CODE
DATE OF BIRTH MO. / DAY / YEAR | SEX | STATE OF LICENSE

OWNER

LAST NAME OF OWNER 1 | FIRST NAME | MIDDLE INITIAL
NUMBER AND STREET
CITY | STATE | ZIP CODE

LAST NAME OF OWNER 2 | FIRST NAME | MIDDLE INITIAL
NUMBER AND STREET
CITY | STATE | ZIP CODE

VEH.

NO. OF OCCUPANTS | PLATE NUMBER | VEHICLE TYPE | VEH. TOWED AWAY? ☐ YES ☐ NO
ESTIMATED COST OF REPAIRS ☐ $50 OR LESS ☐ $51-$200 ☐ $201-$250 ☐ $251-$300 ☐ $301-$750 ☐ OVER $750 | VEHICLE YEAR & MAKE | STATE OF REG.

NO. OF OCCUPANTS | PLATE NUMBER | VEHICLE TYPE | VEH. TOWED AWAY? ☐ YES ☐ NO
ESTIMATED COST OF REPAIRS ☐ $50 OR LESS ☐ $51-$200 ☐ $201-$250 ☐ $251-$300 ☐ $301-$750 ☐ OVER $750 | VEHICLE YEAR & MAKE | STATE OF REG.

DESCRIBE DAMAGE TO VEH. NO. 1

CHECK ONE OF THE 8 DIAGRAMS BELOW IF IT ADEQUATELY DESCRIBES THE ACCIDENT, OR DRAW YOUR OWN DIAGRAM IN THE SPACE TO THE RIGHT

ACCIDENT DIAGRAM

NUMBER THE VEHICLES, YOUR VEHICLE IS NO. 1

DESCRIBE DAMAGE TO VEH. NO. 2

REFERENCE MARKER NEAREST TO SITE | COUNTY OF ACCIDENT | ☐ CITY ☐ TOWN ☐ VILLAGE OF | ADDRESS/LANDMARKS AT SCENE

ROUTE NO. OR STREET NAME ON ____ ☐ MILES ☐ FEET ☐ N ☐ S ☐ E ☐ W OF ☐ AT INTERSECTION WITH ROUTE NO. OR STREET NAME

INJURY SECTION: FILL OUT SPACE BELOW FOR EVERY PERSON INJURED OR KILLED IN THE ACCIDENT.

CHECK PROPER COLUMN(S) SEE INSTRUCTION 5 ON BACK

NAME	8. IN VEHICLE NUMBER	12. AGE	13. SEX	DESCRIBE INJURIES	16. K	A	B	C	DATE OF DEATH

ACCIDENT DESCRIPTION

IDENTIFY DAMAGED PROPERTY, OTHER THAN VEHICLE(S)

NAME OF INSURANCE COMPANY WHICH ISSUED POLICY | POLICY NUMBER
NAME AND ADDRESS OF POLICYHOLDER | POLICY PERIOD FROM TO
IF VEHICLE WAS OPERATED UNDER PERMIT OF ICC OR NYS DOT GIVE NO. | NAME AND ADDRESS OF PERMIT HOLDER
IS FORM SP-23 (FLEET COVERAGE) ON FILE WITH THE COMMISSIONER? | IF SELF-INSURED GIVE CERTIFICATE NO. | AND STATE
DATE FILED | SIGNATURE OF DRIVER OF VEHICLE NO. 1 | IF SIGNED BY PERSON OTHER THAN DRIVER, GIVE REASON.

Figure 2.2 (Con't)

Thus, even though the police-reported cases tend to be more serious, the analysis of the New York data is necessarily limited to police-reported accidents.

Data Files

The 1976 North Carolina accident tape had over 286,000 vehicle-oriented accident records. To facilitate data analysis a 20 percent sample of cases (N = 60,000) was selected from this tape. Furthermore, as the original accident record was 215 characters long and contained a number of variables that were not of interest in this study, for convenience, an extract was created from the 20 percent sample tape. Table 2.1 gives a listing of the variables included on the final North Carolina data file extract.

The 1975 New York accident tape contained over 600,000 vehicle-oriented accident records. Once again to facilitate data handling, a 25 percent sample (N 150,000) was created from this tape. This sample tape contained data from both police-reported and motorist-reported cases. As stated previously, because the motorist-reported cases lacked some important variables and also had significant portions blank, it was decided to consider only police-reported cases. Therefore, the extract tape that was created from this 25 percent sample contained over 78,000 police-reported cases. Since the vehicle-oriented record in the New York file was only 101 characters long, it was retained in its entirety (see Appendix B).

Table 2.1 Variables included on the 20 percent sample file of 1976 North Carolina accidents.

Variable Name

1. Day of week
2. Time of day
3. Investigating agency
4. Highway class
5. Light condition
6. Object struck
7. Accident severity
8. Accident type
9. Initial point of contact
10. Roll-over
11. Vehicle maneuver
12. Vehicle defect
13. Estimated speed prior to impact
14. TAD rating--impact site
15. TAD rating-severity
16. Amount of damage to vehicle
17. Vehicle model year (officer reported)
18. HSR vehicle size
19. Body style
20. Model year (HSR)
21. Total number of occupants
22. Physical condition of driver
23. Sobriety of driver
24. Violation charged to driver
25. Vehicle drivability
26. Vehicle severity
27. Injury class of driver
28. Restraint of driver
29. Race of driver
30. Sex of driver
31. Age of driver
32. Means of involvement
33. Region of impact
34. Speed of accident

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[1] For a listing of the levels for those variables utilized in the analysis, see Appendix A.

III. ANALYSIS: PROCEDURES AND RESULTS

Variables of Interest

Table 3.1 lists the independent variables and their levels that were utilized in this analysis of the sample of 1976 North Carolina accidents. Appendix A shows the original format for these variables of interest on the sample tape. Some variables such as "accident type" were excluded from the list because the variable "means of involvement" was derived from accident type and included all of its information. Similarly, "initial point of contact" was replaced by "region of impact".

The variable levels were categorized by one of three methods. If the towaway, non-towaway percentages were similar for two levels in a given variable, then these levels were combined. A second basis for combining levels within a variable was low frequencies for some of the levels. Finally, some levels for a few variables were combined on an *a priori* basis; for example, the levels of the variable "investigating agency" were combined to form a dichotomous variable indicating accident location, rural or urban.

In addition to these independent variables, there is another set of variables which may be described as co-response variables. These variables (such as dollar damage to vehicle, TAD severity score, driver injury and vehicle severity) along with vehicle drivability are all "outcomes" or consequences of the accident. It is likewise of interest to study the relationship between these co-response variables and vehicle drivability. This is addressed in a later section of this chapter.

Appendix B shows the format for the vehicle-oriented New York accident data with only the variables of interest for this study included. For the New York file, the data was first partitioned into single vehicle accidents and multi-vehicle accidents and then appropriate variable levels were defined for each group. Table 3.2 shows the various levels for the two groups. These levels were combined on the same basis as the North Carolina data.

Variable Selection

One of the primary goals of this study was to determine which independent variables listed in Tables 3.1 and 3.2 most affected vehicle drivability resulting from a crash. Thus, for example, if it were determined that front-end impacts resulted in a higher proportion of towaway accidents, then an

Table 3.1 Independent or environmental variables of interest from the N.C. sample data and their levels.

1. Day of Week

	Values	
1	1,2,3,4,5	weekday
2	6,7	weekend

2. Time of Day

1	700- 959	morning rush
2	1600-1759	evening rush
3	2200-2359 0000-0159	late night
4	1000-1559	mid day
5	0200-0659 1800-2159	early morning and early evening

3. Investigating Agency

1	2,3,4	Rural
2	1,5	Urban

4. Highway Class

1	1	Interstate
2	2	U.S.
3	3	N.C.
4	4,5	Rural roads
6	6	City street

5. Light Conditions

1	1	Daylight
2	2	Dusk
3	3	Dawn
4	4	Darkness - street lit
5	5	Darkness - street unlit

6. Object Struck*

	Initial Grouping	Final Grouping
1	1,2	1,2,11
2	3,4,9	3,4,9
3	5,6,8	5,6,8
4	7,10,12	7,10,12,14
5	11	13,15
6	13	
7	14	
8	15	

7. Vehicle Maneuver*

	Values
1	1,7
2	2,3,15
3	4
4	5,14
5	6,8,9
6	11,12
7	10,13

8. Vehicle Defect

1	1,2,3,4,5,6	some defect
2	7	no defect

9. HSR Vehicle Size*

	Initial Grouping	Final Grouping
1	1,2	1,2
2	3	3,4
3	4	5
4	5	6,7,8,9
5	6,7,8,9	10,11
6	10	
7	11	

10. Body Style*

1	1,3
2	2
3	4,8,9
4	5,6
5	10,11,12,13

11. Model Year

1	60-65
2	66-68
3	69-72
4	73-77

12. Physical Condition

1	1,2,3,4,5	Abnormal
2	6	Normal

*See Appendix A for descriptions of the variable levels.

Table 3.1 (Continued).

13. Sobriety

	Values	
1	1	Not drinking
2	2,3	Had been drinking

14. Restraint of Driver

1	1	No belt
2	2,3,4	Belt

15. Sex of Driver

1	1	Male
2	2	Female

16. Age of Driver

5	16-20
6	21-30
7	31-60
8	61-97

17. Means of Involvement

2	1,2,3	Single vehicle
4	4,5	Two vehicles
6	6	More than two vehicles
7	7	Other

18. Region of Impact

1	1	Front
2	2,3	Side
4	4	Rear

19. Speed of Accident

1	1	Low
2	2	Medium
3	3	High

Table 3.2 Independent or environmental variables of interest, from the 1975 N.Y. sample data and their levels.

Single Vehicle Accidents			Multi-Vehicle Accidents		
1. Hour			1. Hour		
	Values	Description		Values	Description
1	1-7, 21-24	Late evening, dawn	1	23,24, 1-5	Late night, dawn
2	8-20	Other	2	6-10	Morning
			3	11-20	Evening
			4	21,22	Late evening
2. Land Usage			2. Land Usage		
1	1-5, 7	Residential, industrial	1	1-5, 7	Residential, industrial
2	6	Agricultural	2	6	Agricultural
3. Weather			3. Weather		
1	1	Clear	1	1	Clear
2	2	Cloudy	2	2	Cloudy
3	3	Rain	3	3	Rain
4	4,5,6	Snow, sleet, hail	4	4,5,6	Snow, sleet, hail
4. Road Character			4. Road Character		
1	1	Straight-level	1	1	Straight-level
2	2,3	Straight-other	2	2,3	Straight-other
3	4,5,6	Curved	3	4,5,6	Curved
5. Road Surface Condition			5. Road Surface Condition		
1	1	Dry	1	1	Dry
2	2,3	Wet, muddy	2	2,3	Wet, muddy
3	4,5	Snow, ice, sleet	3	4,5	Snow, ice, sleet
6. Type of Road System*			6. Type of Road System*		
1	1		1	1	
2	2		2	2	
3	3		3	3	
4	4,9,10		4	4	
5	5,6,7,8,11		5	5,6,7,8,11	
			6	9,10	
7. Manner of Collision			7. Manner of Collision*		
Inadequate data			1	1,5,6	
			2	2	
			3	3	
			4	4	
			5	7	
			6	8	
			7	9	

*See Appendix B for descriptions of the variable levels.

Table 3.2 (Continued).

Single Vehicle Accidents			Multi-Vehicle Accidents		
8. Age of Driver			8. Age of Driver		
	Values			Values	
1	1-29		1	1-29	
2	30-76		2	30-59	
			3	60-76	
9. Model Year			9. Model Year		
1	pre-66		1	pre-66	
2	66-68		2	66-68	
3	69-72		3	69-72	
4	73-77		4	73-79	
10. Apparent Contributing Factors*			10. Apparent Contributing Factors*		
1	1, 41-60 61-80		1	1	
2	2,6,8,10 11,16,4,5 12,14,15		2	2,6,8,10,11 16,4,5,12 14,15	
3	3,7,40 9,13,18		3	7	
4	17,19		4	3,40	
			5	9,13,18	
			6	17,19	
			7	41-60	
			8	61-80	
11. Pre-Accident Vehicle Action			11. Pre-Accident Vehicle Action*		
1	1	Going straight	1	1	
2	2-20	Other	2	2,7,8	
			3	3,4,12,14 13	
			4	5,6,9,10	
			5	11,15,20	
12. Area of Impact			12. Area of Impact		
1	10,20,80	Front	1	10,20,80	Front
2	30,70	Side	2	30,70	Side
3	40,50,60	Rear	3	40,50,60	Rear
13. Number Occupants			13. Number Occupants		
1	1		1	1	
2	2		2	2	
3	3-98		3	3-98	
14. Restraint Use of Driver			14. Restraint Use of Driver		
1	1	No	1	1	No
2	2,3,4,5	Yes	2	2,3,4,5	Yes

*See Appendix B for descriptions of the variable levels.

Table 3.2 (Continued).

Single Vehicle Accidents		Multi-Vehicle Accidents	
15. Total#of Injuries		15. Total#of Injuries	
	Values		Values
1	1	1	1
2	2-98	2	2
		3	3-98
16. Second Event*		16. Second Event*	
1	1-10	1	1-10
2	11-40	2	11-40

*See Appendix B for descriptions of the variable levels.

overrepresentation of front-end impact accidents would be expected in the NASS files.

In this study, the procedure as described by Higgins and Koch, 1977 was used to determine the relative strengths of associations of the independent variables with the outcome measure, vehicle drivability. This procedure utilizes appropriately constructed Pearson Chi-square statistics divided by their degrees of freedom, which provides measures of the relative importance of certain combinations of variables in a multivariate relationship. The selection algorithm proceeds in the same spirit as forward stepwise regression.

More specifically, the first independent variable selected is the one having the largest Chi-square per degree of freedom with respect to its first order relationship with vehicle drivability. Table 3.3 shows the overall Chi-square, degrees of freedom and Chi-square per degree of freedom for each of the independent variables listed. These results indicate that speed of accident has the highest Chi-square per degree of freedom.

Before further variables were selected, the accidents were split into two groups, single vehicle accidents and multi-vehicle accidents. This was done because certain interim frequency tables showed that the towaway proportions were consistently higher for single vehicle accidents for all the independent variables in the study. This was true of both North Carolina and New York data.

Subsequent variables were selected by similar rules using the Chi-square per degree of freedom computed for the appropriate higher order contingency tables for the eligible combined set of variables (e.g., at the second stage, two-way tables with one dimension being the outcome variable and the other being all combinations of levels of the first variable chosen (speed) with those of a candidate second independent variable, say, day of week).

The procedure for both determining the significance of including a particular variable at a given stage and for terminating the selection of statistically important variables involves two types of statistics:

(i) The Pearson Chi-square statistic for examining the relationship (two-way tables) of a specific variable with the dependent variable summed over all possible combinations of variables already selected with the sum then being divided by the sum of the degrees of freedom.

(ii) A modified Mantel-Haenszel statistic which combines information with respect to the effect of a given variable on the outcome variable over all possible combinations of previously selected variables (see Stewart and Stutts, 1978, p. 25-28).

Table 3.3 Chi-squares for N.C. data; vehicle drivability by independent variable. (Source: 20% North Carolina data)

Variable Name	χ^2	D.F.	χ^2/D.F.
Day of week	271.85	1	271.85
Time of day	1550.46	4	387.62
Rural/urban	1406.93	1	1406.93
Highway class	1406.93	4	351.70
Light condition	1986.87	4	496.72
Object struck	4629.57	7	661.36
Vehicle maneuver	3560.95	6	593.50
Vehicle defect	475.40	1	475.40
Vehicle size	656.77	6	109.50
Body style	271.82	4	67.96
Model year	164.16	3	54.72
Physical condition	575.70	1	575.70
Sobriety	2174.79	1	2174.79
Restraint of driver	74.51	1	74.51
Sex of driver	108.13	1	108.13
Means of involvement	7012.29	4	1753.07
Region of impact	2901.90	2	1450.95
Speed of accident	5894.50	2	2947.25
Age of driver	613.80	3	204.60

In the preliminary selection process (i) was used, but, as the cell frequencies became smaller, (ii) was followed as the selection criteria. Although more complicated, an advantage of (ii) is that it also detects consistency in the relationships. The procedure was terminated when none of the variables not yet selected was significant according to (i) or (ii), as in forward stepwise regression. Table 3.4 summarizes the independent variables most closely associated with vehicle drivability for single vehicle and multi-vehicle accidents for the North Carolina data.

Table 3.4 Independent variables (listed in order of importance) affecting vehicle drivability for single and multi-vehicle accidents (North Carolina data).

Single Vehicle	Multi-Vehicle
Speed of accident	Speed of accident
Region of impact	Region of impact
Object struck	Vehicle maneuver
	Vehicle size

A similar analysis was carried out on the New York police-reported data to identify the variables most clearly related to vehicle drivability. Table 3.5 presents the results for single vehicle and multi-vehicle accidents.

Table 3.5 Independent variables (listed in order of importance) affecting vehicle drivability for single and multi-vehicle accidents (New York data).

Single Vehicle	Multi-Vehicle
Location of first event (on road/off road)	Manner of collision
Type of road system	Area of impact
Area of impact	Type of road system
Apparent contributing factor	Pre-accident vehicle action
	Driver age

The variables in Tables 3.4 (North Carolina) and 3.5 (New York) are fairly similar for corresponding types of accidents. Thus, for example, the variable "type of road system" in Table 3.5 is basically a surrogate for speed of accident. Unfortunately, the New York data had no variable indicating vehicle size. In addition, Table 3.5 does not have object struck in single vehicle accidents because this variable was used to define such accidents for the New York data. That is, a single vehicle accident was defined by the number of vehicles involved being one and the type of accident being greater than ten, i.e., collision with fixed object (refer to Appendix B).

Analysis of Independent Variables

Once the variables of interest had been identified for each accident type, the data was set up as multi-way contingency tables and analyzed. The purpose of this analysis was to take into account the relationship between the various factors of the multi-way tables. The analysis was based on fitting a hierarchial log-linear model to the cell frequencies. These models were fit by an iterative proportional fitting algorithm developed by Haberman (1972).

The section on variable selection indicated that the variables of most interest for single vehicle accidents in the 1976 North Carolina data were vehicle drivability, speed of accident, region of impact and object struck. Table 3.6 shows the corresponding four-way table. A log-linear model was fit to this table using the Biomedical Computer Programs (BMDP, 1977). The three-way and higher level interactions were non-significant, and a model including all the two-way interactions was found adequate (likelihood ratio Chi-square of 59.7 with 52 degrees of freedom and $p = 0.2$). Table 3.7 shows the predicted values using this model.

A convenient way to summarize the information presented in Table 3.7 is to consider the odds ratio of a vehicle not being drivable: the ratio of the (fitted) number of vehicles towed away to the (fitted) number of vehicles that were not towed away. For example, in Table 3.7 the odds of being towed away when object struck is tree, utility pole, etc. for low speed, front impacts is $151.4/69.1 = 2.2$. Thus, as expected, the odds of being towed is high for front-end high speed impacts regardless of the object struck, while the odds of being towed is low for almost all rear-end impacts. This implies that, for example, a sample based on towaway accidents will have an overrepresentation of front-end high speed impacts and an underrepresentation of virtually all rear-end impacts when compared to a data base consisting of all reportable accidents.

Table 3.6 Frequencies of non-drivable vs. drivable vehicles in single vehicle accidents by object struck, accident speed, and region of impact. (Source: 20% 1976 North Carolina data)

Impact Site	Accident Speed	Drivable	Object Struck				
			Tree, Utility Pole, Ditch Bank	Rollover	Fence, Guardrail in Median, Sign	Guardrail on Shoulder Bridge, Median or Curb	Underpass, Animal, Parked Veh. Other Obj.
Front	0-29	No	157	12	14	20	28
		Yes	78	3	13	8	23
	30-49	No	850	43	110	108	132
		Yes	168	16	46	29	48
	50+	No	1131	63	131	126	145
		Yes	123	5	39	22	26
Side	0-29	No	32	16	6	6	7
		Yes	40	14	9	5	23
	30-49	No	252	65	34	36	29
		Yes	115	23	38	17	34
	50+	No	450	80	64	44	55
		Yes	80	23	37	9	23
Rear	0-29	No	4	2	1	3	2
		Yes	7	3	4	0	7
	30-49	No	27	3	3	5	3
		Yes	16	3	6	4	8
	50+	No	69	6	1	5	3
		Yes	11	1	2	2	5

Table 3.7 Fitted frequencies and odds ratio for non-drivable vs. drivable vehicles in single vehicle accidents by object struck, accident speed, and region of impact. (Source: 20% 1976 North Carolina data)

Impact Site	Accident Speed	Drivable	Object Struck				
			Tree, Utility Pole, Ditch Bank	Rollover	Fence, Guardrail in Median, Sign	Guardrail on Shoulder, Bridge, Median or Curb	Underpass, Animal, Parked Veh., Other Obj.
Front	0-29	No	151.4	12.9	14.4	19.3	30.7
		Yes	69.1	6.6	16.4	11.0	29.3
		(Odds Ratio)	(2.2)	(2.0)	(0.9)	(1.8)	(1.0)
	30-49	No	848.1	49.9	102.5	113.9	122.8
		Yes	172.9	11.3	52.1	29.1	52.3
		(Odds Ratio)	(4.9)	(4.4)	(2.0)	(3.9)	(2.3)
	50+	No	1151.2	57.8	136.1	126.5	140.1
		Yes	117.3	6.6	34.6	16.2	29.8
		(Odds Ratio)	(9.8)	(8.8)	(3.9)	(7.8)	(4.7)
Side	0-29	No	41.6	14.1	4.9	5.1	8.6
		Yes	39.4	14.9	11.5	6.1	17.0
		(Odds Ratio)	(1.1)	(0.9)	(0.4)	(0.8)	(0.5)
	30-49	No	254.3	59.4	37.8	32.9	37.4
		Yes	107.7	28.0	39.9	17.5	33.1
		(Odds Ratio)	(2.4)	(2.1)	(0.9)	(1.9)	(1.1)
	50+	No	436.7	87.1	63.5	46.2	54.0
		Yes	92.4	20.5	33.5	12.3	23.9
		(Odds Ratio)	(4.7)	(4.2)	(1.9)	(3.8)	(2.3)
Rear	0-29	No	8.6	1.9	0.7	1.3	2.0
		Yes	11.0	2.6	2.2	2.2	5.4
		(Odds Ratio)	(0.8)	(0.7)	(0.3)	(0.6)	(0.4)
	30-49	No	30.6	4.6	3.2	5.0	5.2
		Yes	17.4	2.9	4.5	3.6	6.1
		(Odds Ratio)	(1.6)	(1.6)	(0.7)	(1.4)	(0.9)
	50+	No	54.1	6.9	5.5	7.3	7.7
		Yes	15.4	2.2	3.9	2.6	4.6
		(Odds Ratio)	(3.5)	(3.1)	(1.4)	(2.8)	(1.7)

A similar model fitting procedure was carried out for multi-vehicle accidents where the variables of interest were vehicle drivability, speed of accident, region of impact, vehicle maneuver and vehicle size. The fitted model included all two-way interactions and the three-way interactions involving all the variables mentioned above except vehicle size. For this model the likelihood ratio Chi-square was 481.4 with 480 degrees of freedom and p = 0.5. Appendix C shows the fitted frequencies. As mentioned earlier in the variable selection section, the towaway proportions and correspondingly the towaway odds were much lower for multi-vehicle accidents than for single vehicle accidents.

Table 3.8 presents the predicted towaway odds by speed, impact site, and vehicle size for the case where the cars were going straight ahead (vehicle maneuver = 3).

Table 3.8 Towaway odds for passenger cars by speed, impact site and vehicle size for multi-vehicle accidents with vehicles going straight ahead. (Source: 20% 1976 North Carolina data)

			Speed		
Impact Site		HSRC Vehicle Size Group*	Low 0-29	Medium 30-49	High 50+
	1	Lux., Med.	0.4	0.9	1.8
Front	2	Std., Int.	0.4	1.0	2.1
	3	Compact	0.5	1.4	2.8
	4	Sub-Compact	0.7	1.8	3.6
	1	Lux., Med.	0.1	0.4	0.6
Side	2	Std., Int.	0.2	0.4	0.7
	3	Compact	0.2	0.5	0.9
	4	Sub-Compact	0.3	0.7	1.2
	1	Lux., Med.	0.1	0.2	0.4
Rear	2	Std., Int.	0.1	0.2	0.5
	3	Compact	0.2	0.3	0.7
	4	Sub-Compact	0.2	0.4	0.9

*See Appendix D for vehicle makes included in size groups.

This particular maneuver was selected because, for multi-vehicle accidents, more than half the sample fell in this category. Thus, for example, from Appendix C the towaway odds for front-end low speed impacts for luxury and medium-sized cars was 0.4 (=140.0/397.0).

Table 3.8 shows that, for all impact site and speed combinations, smaller vehicles have higher towaway odds. Similarly, for any given speed and car size, front-end impacts have higher towaway odds than side impacts which, in turn, have higher odds than rear-end impacts. Also, as expected, high speed impacts have higher towaway odds than low speed impacts.

Hence, in a sample based on towaway accidents involving more than one vehicle, one would expect to have an overrepresentation of front-end impacts, high speed impacts and also accidents involving smaller cars. Overrepresentation of small cars should especially be kept in mind when any accident rate comparisons are being made across different vehicle sizes from data based on towaway crashes only, such as will be done in NASS.

Analysis of Co-Response Variables

It was mentioned in an earlier section that, in addition to the independent variables examined thus far, there is a set of variables, each of which is a consequence of the accident. Variables such as driver injury, vehicle severity, TAD severity and vehicle dollar damage are included in this set of co-response variables. This section presents the results of an analysis which examines the relationships between these co-response variables and vehicle drivability.

Table 3.9 shows the levels of the co-response variables used in this study. It should be pointed out here that the variables, vehicle severity and driver injury, are very closely related since vehicle severity describes the worst occupant injury in the vehicle--including the driver.

Table 3.9 Co-response variables and their levels. (N.C. data)

Variable	Level
Driver injury	1 Not injured 2 Injured (K,A,B,C)
Vehicle severity	1 Not injured 2 Injured
Vehicle dollar damage	1 0-199 2 200-599 3 600-1199 4 1200+
TAD severity score	1 TAD 1,2 2 TAD 3,4 3 TAD 5,6,7
Vehicle drivability	1 Towed 2 Not towed

To examine the relationships between the co-response variables, the Mantel-Haenszel procedure was used. Here the response variable was vehicle drivability and Mantel-Haenszel statistics were computed to measure the strength and consistency of the relationship between vehicle drivability and the co-response variables listed in Table 3.9. The results of the Mantel-Haenszel tests are presented in Table 3.10.

Table 3.10 Mantel-Haenszel tests for consistency of differences in towaway proportions in North Carolina co-response variables. (Source: 20% 1976 North Carolina data)

Variable	M-H χ^2 (1 d.f.)
Damage Severity	
(1) TAD (1,2,3,4) vs. (5,6,7)	469.5
(2) TAD (1,2) vs. (3,4,5,6,7)	1162.8
Vehicle Dollar Damage	
(1) (0-199) vs. (200+)	1544.9
(2) (0-599) vs. (600+)	2385.8
Driver Injury	169.3
Vehicle Severity	118.1

The Mantel-Haenszel tests indicate that, even after controlling for each level of each of the remaining co-response variables, towaway accidents do appear to be associated with higher TAD scores, higher vehicle dollar damages, and higher percentages of driver injuries and vehicle occupant injuries than the non-towaway accidents. In addition, as Table 3.11 shows, the analysis indicates that there was a consistently lower proportion of vehicles towed away when the injury occurred to an occupant other than the driver.

A similar analysis was carried out on the New York data. Table 3.12 shows the co-response variables and the corresponding Mantel-Haenszel statistics. The three variables included here from the New York data were vehicle drivability, extent of vehicle damage, and driver injury. Once again, the Mantel-Haenszel tests indicated that towaway accidents do appear to be associated with a higher

Table 3.11 Frequencies (percentages) of vehicles towed away by TAD severity and dollar damage (Source: 20% 1976 North Carolina data)

Dollar Damage ($)	TAD Severity	Driver Injury N (%)	Injury to Occupant Other Than Driver N (%)
0-199	1,2	110 (22.5)	12 (6.1)
	3,4	22 (71.0)	5 (62.5)
	5,6,7	13 (81.3)	1 (20.0)
200-599	1,2	540 (49.9)	138 (34.4)
	3,4	762 (74.0)	145 (52.4)
	5,6,7	241 (89.9)	32 (64.0)
600-1199	1,2	230 (76.7)	56 (65.9)
	3,4	1044 (88.5)	193 (74.5)
	5,6,7	876 (94.7)	120 (86.3)
1200+	1,2	106 (87.6)	9 (69.2)
	3,4	530 (94.8)	67 (88.2)
	5,6,7	1240 (98.1)	101 (97.1)

Table 3.12 Mantel-Haenszel tests for consistency of differences in towaway proportions in New York co-response variables.

Variables	Levels	M-H χ^2 (1d.f.)
Extent of damage	(a) 1 None 2 Damaged or demolished	1220.6
	(b) 1 None or light 2 Moderate, severe or demolished	4514.9
	(c) 1 None, light, moderate 2 Severe or demolished	2396.3
Driver injury	1 Injured 2 Not injured	5030.3

proportion of driver injury and more severe vehicle damage, even after controlling for each level of the co-response variables. In addition, Table 3.13 shows that the proportion of vehicles towed was higher for each level of vehicle damage when the driver was injured.

Table 3.13 Frequencies (percentages) of vehicles towed, by vehicle damage and driver injury (Source: 25% 1975 New York police-reported accidents)

Vehicle Damage	Driver Injured N (%)	Driver Not Injured N (%)
None	31 (10.4)	62 (1.3)
Light	1649 (30.5)	2089 (11.1)
Moderate	6706 (54.4)	5072 (26.7)
Severe or Demolished	3291 (73.8)	1207 (49.7)

IV. EFFECT OF TOWAWAY CRITERION ON SOME IMPORTANT COMPARISONS

Chapter III presented the effect of some independent and co-response variables on whether or not a vehicle was drivable. For example, it was shown (Table 3.8) that in multi-vehicle accidents, for all impact site and speed combinations, smaller vehicles have higher towaway odds. Similarly Table 3.7 showed that in single vehicle accidents, the odds of being towed is high for front-end, high-speed impacts regardless of the object struck. This implied that in a data source based on a towaway reporting threshold, there would be an overrpresentation of front-end high speed impacts and an underrepresentation of almost all rear-end impacts. In this chapter the emphasis is on comparing accident and injury measures in a towaway data set with similar measures from a data source without such a threshold.

Vehicle Comparisons

Table 4.1 shows the distribution of accidents by area, vehicle severity (most severe injury to occupant of the vehicle) and sampling criterion. When vehicle severity is not controlled for, the percentage of rural accidents is higher (56.1 percent (towaway criterion) against 44.3 percent (no restriction)). For severe injuries (A+K), the distribution of vehicles is virtually identical by area for the two sampling criteria. This is expected, since, as mentioned in Chapter III, given that there is a serious injury involved, it is highly likely that the vehicle reqired towing. Hence for serious injury accidents the two populations are nearly the same.

Table 4.1 Vehicle frequencies (percentages) by vehicle severity, area and sampling criterion. (Source: 1976 North Carolina data)

Vehicle Severity	Any + P.D.O.		(A+K)	
Sampling Criterion	Towaway	All Acc.	Towaway	All Acc.
Area				
Urban	28502 (43.9)	105762 (55.7)	1279 (24.4)	1404 (25.3)
Rural	36488 (56.1)	84130 (44.3)	3971 (75.6)	4146 (74.7)

Tables 4.2, 4.3 and 4.4 show the distribution by vehicle severity and sampling criterion by highway class, region of impact, and accident type, respectively. The three tables show that, while the distributions were quite different when vehicle severity was not controlled for, they are almost identical for serious injuries (A+K).

Table 4.2 Frequencies (percentages) by vehicle severity, highway class, and sampling criterion. (Source: 1976 North Carolina data)

Vehicle Severity	Any + P.D.O.		(A+K)	
Sampling Criterion	Towaway	All Acc.	Towaway	All Acc.
Highway Class				
Interstate	1444 (2.3)	3643 (2.0)	152 (2.9)	158 (2.9)
U.S.	11635 (18.2)	30616 (17.0)	1194 (22.8)	1240 (22.4)
N.C.	8803 (13.8)	20176 (11.2)	998 (19.0)	1038 (18.7)
Rural Roads	17353 (27.1)	36880 (20.5)	1832 (34.9)	1924 (34.7)
City Streets	24776 (38.7)	88504 (49.2)	1071 (20.4)	1186 (21.4)

Table 4.3 Frequencies (percentages) by vehicle severity, region of impact and sampling criterion. (Source: 1976 North Carolina data)

Vehicle Severity	Any + P.D.O.		(A+K)	
Sampling Criterion	Towaway	All Acc.	Towaway	All Acc.
Region of Impact				
Front	40193 (67.0)	88427 (51.8)	3336 (68.7)	3458 (67.5)
Right Side	7179 (12.0)	23831 (14.0)	629 (13.0)	660 (12.9)
Left Side	8239 (13.7)	28182 (16.5)	694 (14.3)	732 (14.3)
Rear-end	4399 (7.3)	30356 (17.8)	198 (4.1)	270 (5.3)

Table 4.4 Frequencies (percentages) by vehicle severity, accident type and sampling criterion. (Source: 1976 North Carolina data)

Vehicle Severity	Any + P.D.O.		(A+K)	
Sampling Criterion	Towaway	All Acc.	Towaway	All Acc.
Accident Type				
Ran off Road	18,660 (28.7)	23,080 (12.2)	2259 (43.0)	2335 (42.1)
Hit Fixed Object	589 (0.9)	935 (0.5)	52 (1.0)	56 (1.0)
Hit Non-Fixed Object	608 (0.9)	984 (0.5)	35 (0.7)	54 (1.0)
Car vs. Car	28,420 (43.7)	104,795 (55.2)	1669 (31.8)	1771 (31.9)
Car vs. Truck	8638 (13.3)	33,747 (17.8)	686 (13.1)	733 (13.2)
> 2 Vehicles Involved	5472 (8.4)	15,138 (8.0)	389 (7.4)	425 (7.7)
Other Involvement	2603 (4.0)	11,213 (5.9)	160 (3.0)	176 (3.2)

Thus, if the purpose of a given study was to determine the extent to which, say, a particular Federal Motor Vehicle Safety Standard (FMVSS) such as the side door beam standard, prevented serious injuries, restriction to towaway crashes would not produce serious biases. However, if the outcome measure was "any injury" or even "total accident-involved vehicles," relatively fewer would arise from an underrepresentation of city street accidents, rear-end crashes and/or car vs. car accidents in the towaway sample than in the population of all accidents.

Belt Usage and Injury Comparisons

Towaway accidents are in general more severe than non-towaway accidents. As a result, one would expect that a data source which includes only towaway vehicles in crashes would miss very few serious occupant injuries and would exclude many less severe and no injury cases. Table 4.5 confirms this and shows that a towaway data set is likely to miss only 1.5 percent of occupant fatalities as opposed to 64 percent when the injury threshold includes all levels (injured + not injured). As stated before this will be a problem if one is specifically interested in less severe accidents such as rear-end crashes or other low speed impact situations.

Table 4.5. Occupant injury by vehicle drivability.
(Source: 1976 North Carolina data)

Vehicle Drivability	Occupant Injury					Total
	K	A	B	C	Not Injured	
No	794 (98.5)*	6192 (95.4)	17,708 (88.4)	15,723 (76.0)	65,086 (35.8)	105,503 (35.8)
Yes	12 (1.5)	325 (4.6)	2,903 (11.6)	9,498 (24.0)	176,753 (64.2)	189,491 (64.2)
Total	806	6517	20,611	25,221	241,839	294,994

*Percent with occupant injury <u>at least</u> as serious as given level. For example,

for A, $95.4 = \frac{794 + 6192}{806 + 6517} \times 100$

Table 4.6 presents driver injury rates (per 1000 drivers) by model year, vehicle size and sampling criterion. As expected, for more serious injuries, the rates are approximately two to four fold higher in the towaway data set for each model year and vehicle size combination. Table 4.6 shows that, within each vehicle size group, both A + K rates (towaway and all accidents) decrease for newer model cars. In addition, Table 4.6 indicates that the serious injury rates are somewhat higher for smaller vehicles. For minor and moderate (B+C) injuries, the two rates differ generally by a factor of two while, as expected, for non-injury cases the relative rates are reversed with fewer drivers being uninjured in towaway crashes.

An important parameter often studied in injury analysis is restraint usage and subsequent effectiveness in reducing injuries. Table 4.7 shows the restraint usage rates calculated on a towaway basis and on an overall basis where essentially no threshold has been used. The restraint usage rates are consistently higher when all accidents are used. This is expected since a lack

Table 4.6 Driver injury frequencies and rates (per 1000 drivers) by sampling criterion, model year and vehicle size. (Source: 1976 North Carolina data)

Vehicle Size	Model Year	Sampling Criterion	Driver Injury					
			(A+K)		(B+C)		(None)	
			N	Rate	N	Rate	N	Rate
Luxury, Medium	1960-1965	Towaway	97	63.7	490	321.9	935	614.3
		All Acc.	100	24.7	656	161.7	3300	813.6
	1966-1968	Towaway	161	53.5	997	331.3	1851	615.2
		All Acc.	166	18.5	1393	155.1	7422	826.4
	1969-1972	Towaway	245	52.9	1401	302.5	2986	644.6
		All Acc.	266	17.0	2070	132.3	13312	850.7
	1973-1977	Towaway	127	47.9	831	313.2	1695	638.9
		All Acc.	139	13.5	1376	134.0	8754	852.5
	All Years	Towaway	630	53.3	3719	314.7	7467	632.0
		All Acc.	671	17.2	5495	141.1	32788	841.7
Standard, Intermediate	1960-1965	Towaway	465	85.2	1792	328.5	3198	586.3
		All Acc.	489	38.5	2328	183.5	9868	778.0
	1966-1968	Towaway	776	67.5	3643	317.1	7072	615.4
		All Acc.	815	29.1	4795	171.3	22383	799.6
	1969-1972	Towaway	839	56.5	4668	314.4	9342	629.1
		All Acc.	883	20.6	6484	151.0	35563	828.4
	1973-1977	Towaway	525	59.3	2902	327.8	5426	612.9
		All Acc.	554	17.2	4587	142.4	27066	840.4
	All Years	Towaway	2605	64.1	13005	319.9	25038	616.0
		All Acc.	2741	23.7	18194	157.1	94880	819.2
Compact	1960-1965	Towaway	168	87.0	627	324.7	1136	588.3
		All Acc.	174	43.2	806	200.2	3046	756.6
	1966-1968	Towaway	264	76.3	1129	326.5	2065	597.2
		All Acc.	272	36.8	1422	192.4	5696	770.8
	1969-1972	Towaway	441	69.6	2051	323.6	3847	606.8
		All Acc.	451	32.0	2562	181.6	11092	786.4
	1973-1977	Towaway	303	63.4	1614	337.7	2862	598.9
		All Acc.	314	24.4	2281	177.4	10262	798.2
	All Years	Towaway	1176	71.2	5421	328.4	9910	600.4
		All Acc.	1211	31.6	7071	184.2	30096	784.2

Table 4.6 (Con't)

Vehicle Size	Model Year	Sampling Criterion	Driver Injury					
			(A+K)		(B+C)		(None)	
			N	Rate	N	Rate	N	Rate
Sub-compact	1960-1965	Towaway	64	68.9	347	373.5	518	557.6
		All Acc.	70	40.8	420	244.8	1226	714.4
	1966-1968	Towaway	108	68.3	628	397.2	845	534.5
		All Acc.	114	39.0	740	253.2	2069	707.8
	1969-1972	Towaway	492	73.5	2335	348.7	3870	577.8
		All Acc.	505	35.6	2942	207.3	10744	757.1
	1973-1977	Towaway	686	73.0	3296	350.6	5418	576.4
		All Acc.	708	32.1	4294	194.6	17062	773.3
	All Years	Towaway	1350	72.6	6606	355.0	10651	572.4
		All Acc.	1397	34.2	8396	205.3	31101	760.5
	Overall	Towaway	5671	64.8	28751	328.3	53066	605.9
		All Acc.	6020	25.7	39156	167.3	188865	807.0

of restraint use would usually lead to a more severe injury, and as mentioned earlier the towaway data set is characterized by having a higher proportion of severe vehicle damage and corresponding driver injuries. Both (towaway and all accidents) restraint usage rates for lap and for lap and shoulder belts increase for newer model cars. Lap belt usage tends to decrease with decreasing car size except for sub-compacts whereas lap and shoulder belt use, if anything, increases with decreasing car size.

In summary, lap and lap and shoulder belt usage rates for drivers in all accidents are somewhat higher than those for the subset of drivers in towaway crashes where the belts would be more important due to the increased crash severity. But what about the corresponding injury-reducing effectiveness of belts in the two accident populations?

One of the most often examined measures in automobile injury analysis is belt effectiveness. Belt effectiveness is generally computed using the following expression:

$$\text{Belt Effectiveness} = \frac{\begin{pmatrix}\text{Proportion injured} \\ \text{with } \underline{\text{no}} \text{ restraint}\end{pmatrix} - \begin{pmatrix}\text{Proportion injured} \\ \underline{\text{with}} \text{ restraint}\end{pmatrix}}{\begin{pmatrix}\text{Proportion injured} \\ \text{with } \underline{\text{no}} \text{ restraint}\end{pmatrix}} \qquad (4.1)$$

Table 4.7 Driver restraint usage frequencies and rates (per 1000 drivers) by sampling criterion, model year and vehicle size. (Source: 1976 North Carolina data)

Vehicle Size	Model Year	Sampling Criterion	Restraint Usage					
			Lap		Lap & Shoulder		None	
			N	Rate	N	Rate	N	Rate
Luxury, Medium	1960-1965	Towaway	47	30.9	0	--	1503	969.1
		All Acc.	138	33.3	3	0.7	4133	966.0
	1966-1968	Towaway	124	40.2	4	1.3	2942	958.5
		All Acc.	465	49.7	24	2.8	9004	947.5
	1969-1972	Towaway	336	70.4	35	7.3	4322	922.3
		All Acc.	1396	85.2	131	8.0	15,000	906.8
	1973-1977	Towaway	295	110.4	96	35.1	2312	854.5
		All Acc.	1282	118.5	495	45.7	9087	835.8
	All Years	Towaway	802	66.6	135	11.1	1079	922.3
		All Acc.	3281	80.4	653	16.0	27,224	903.6
Standard, Intermediate	1960-1965	Towaway	101	18.0	10	1.6	5448	980.4
		All Acc.	290	21.4	12	0.9	12,989	977.7
	1966-1968	Towaway	364	31.2	17	1.5	11,254	967.3
		All Acc.	1164	39.9	51	1.8	28,190	958.3
	1969-1972	Towaway	808	53.8	70	4.5	14,215	941.7
		All Acc.	3045	67.5	232	5.1	42,177	927.4
	1973-1977	Towaway	776	86.4	395	44.1	7784	869.5
		All Acc.	3274	96.8	1689	49.9	29,005	853.3
	All Years	Towaway	2049	49.7	492	11.9	38,701	938.4
		All Acc.	7773	64.0	1984	16.3	112,361	919.7
Compact	1960-1965	Towaway	40	20.7	1	0.5	1922	978.8
		All Acc.	123	29.6	3	0.7	4084	969.7
	1966-1968	Towaway	111	31.8	4	1.2	3405	967.0
		All Acc.	288	38.0	14	1.8	7409	960.2
	1969-1972	Towaway	319	50.0	39	5.8	6094	944.2
		All Acc.	896	60.9	78	5.0	13893	934.1
	1973-1977	Towaway	84	79.7	170	35.8	4294	884.5
		All Acc.	1171	88.4	599	45.3	11744	866.3
	All Years	Towaway	854	51.4	214	12.9	15715	935.7
		All Acc.	2478	62.4	694	17.4	37130	920.2

Table 4.7 (Con't)

Vehicle Size	Model Year	Sampling Criterion	Restraint Usage					
			Lap		Lap & Shoulder		None	
			N	Rate	N	Rate	N	Rate
Sub-compact	1960-1965	Towaway	25	26.9	4	4.3	965	968.8
		All Acc.	55	30.9	4	2.2	1723	966.9
	1966-1968	Towaway	57	36.1	4	2.5	1544	961.4
		All Acc.	110	35.9	16	5.1	2978	959.0
	1969-1972	Towaway	422	62.0	118	17.8	6287	920.3
		All Acc.	1039	70.9	268	18.6	13593	910.5
	1973-1977	Towaway	829	87.0	556	58.4	8163	854.6
		All Acc.	2188	95.7	1421	62.5	19448	841.9
	All Years	Towaway	1333	70.7	682	36.3	16839	893.0
		All Acc.	3392	80.1	1709	40.6	37607	879.3
Overall		Towaway	4671	56.8	1503	17.2	81104	926.0
		All Acc.	16215	69.3	4839	20.7	212977	910.0

Table 4.8 shows belt effectiveness for the two sampling criteria for various combinations of model year, injury severity and vehicle size.

The effectiveness measures are rather consistently lower when a towaway sampling criterion is used. This is consistent with the hypothesis put forward by Campbell and Reinfurt (1979). Figure 4.1, which appears in this paper, shows belt effectiveness as a function of the cumulative injury distribution (X). From Table 4.5 the percentage of (A+K) injuries when no sampling criterion is used is 2.5 percent ($= \frac{806 + 6517}{294,994} \times 100$). The corresponding percentage for the towaway subset is 6.6.

Thus, if the hypothesized relationship holds, the belt effectiveness estimate from Figure 4.1 should shift from approximately 0.67 for the former case to 0.53 in the towaway subset. The corresponding values from Table 4.8, for an average size vehicle (standard and intermediate) for all model years combined are 0.66 and 0.56, respectively!

Table 4.8 shows that in general, both effectiveness measures (i.e., for towaway threshold and for all accidents) for serious injuries decrease with increasing car size and decrease for newer models within the same car size group. Thus, although there may be a difference in the effectiveness of

Table 4.8 Belt effectiveness (lap or lap and shoulder) by model year, sampling criteria, driver injury and vehicle size. (Source: 1976 N.C. data)

Vehicle Size	Driver Injury	Sampling Criterion	'60-'65	'66-'68	'69-'72	'73-'77	All Years
Luxury Medium	(A+K)	Towaway	0.67	0.26	0.39	0.33	0.39
		All Acc.	0.71	0.44	0.52	0.43	0.52
	Any Injury	Towaway	0.35	-0.15	0.17	0.08	0.11
		All Acc.	0.39	0.05	0.19	0.12	0.18
Standard Intermediate	(A+K)	Towaway	0.78	0.61	0.57	0.47	0.56
		All Acc.	0.74	0.71	0.67	0.50	0.66
	Any Injury	Towaway	0.35	0.32	0.21	0.15	0.21
		All Acc.	0.38	0.35	0.25	0.10	0.25
Compact	(A+K)	Towaway	0.72	0.78	0.49	0.63	0.62
		All Acc.	0.82	0.82	0.58	0.67	0.70
	Any Injury	Towaway	0.23	0.16	0.20	0.17	0.18
		All Acc.	0.30	0.27	0.31	0.15	0.24
Subcompact	(A+K)	Towaway	0.51	0.53	0.33	0.55	0.48
		All Acc.	0.59	0.58	0.43	0.58	0.55
	Any Injury	Towaway	-0.18	0.16	0.24	0.25	0.24
		All Acc.	-0.07	0.12	0.27	0.24	0.26
All Sizes	(A+K)	Towaway	0.73	0.56	0.47	0.52	0.52
		All Acc.	0.74	0.66	0.58	0.55	0.61
	Any Injury	Towaway	0.25	0.18	0.21	0.19	0.19
		All Acc.	0.31	0.25	0.26	0.16	0.23

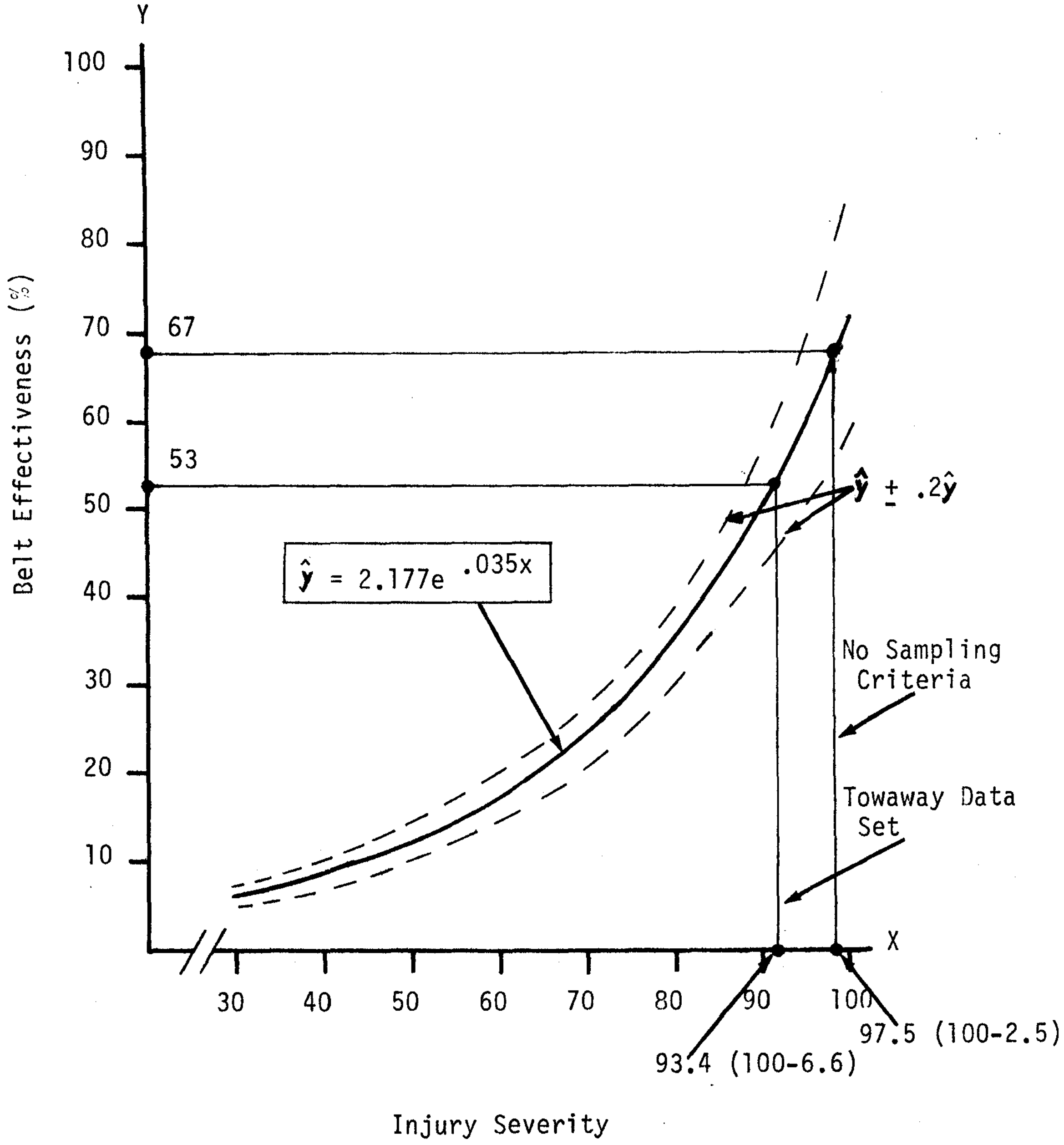

Figure 4.1 Belt effectiveness (%) as a function of injury severity, Campbell and Reinfurt, 1979.

restraints in the two data bases, the trends across car sizes and model years are preserved for the two crash populations.

In summary, the results in this section indicate that, for serious injury accidents, accident characteristics (e.g., rural-urban area, highway class, accident type, region of vehicle impact) are independent of sampling criterion. However, there are some differences when injury is not controlled for. Injury rates are overestimated in towaway data sets relative to all accidents, while the opposite is true for restraint usage rates. However these rates, in towaway data sets and data sets that also include non-towaway crashes, show consistent trends across different vehicle sizes and model years.

Belt effectiveness is underestimated in towaway data sets compared with an all accidents data set. For serious driver injury, this ranges from 25 percent for luxury and medium-sized cars to about 13 percent for sub-compacts, for all model years combined. For any injury accjdents, belt effectiveness is underestimated by nearly 39 percent for luxury and medium-sized cars and 7 percent for sub-compacts. This is to be expected if the hypothesis put forward by Campbell and Reinfurt (1979) is valid. Here, too, the trends across car sizes and model years are similar for the two sampling criteria.

V. SUMMARY AND CONCLUSIONS

The aim of this study was to investigate the effect of using a data set consisting of towaway crashes when compared to all accidents in the same sampling frame. This was done in two parts. First, the effects of certain independent variables on vehicle drivability were studied to determine which of these variables were most highly associated with drivability. Secondly, the relationships between vehicle drivability and some measures of accident severity were examined.

This study used data from two states. A 20 percent systematic random sample was obtained from the North Carolina 1976 accident data. A similar sample was obtained from the New York 1975 accident data for police-reported cases only.

The first portion of the analysis using North Carolina data showed that, for single vehicle accidents, the independent variables speed of accident, region of impact, and object struck (listed in order of importance) were most highly related to vehicle drivability. For multi-vehicle accidents, speed of accident, region of impact, vehicle maneuver, and vehicle size were most crucial. Similarly for the New York data, location of first event, type of road system, area of impact, and apparent contributing factor were most important for single vehicle accidents, and manner of collision, area of impact, type of road system, pre-accident vehicle action, and driver age for multi-vehicle accidents.

The variables selected from the two data sources were fairly comparable. For example, type of road system in the New York data should be essentially a proxy variable for speed of accident which was not available in the New York data. For the New York data, object struck was used to determine whether or not an accident was a single vehicle crash. Hence this variable does not appear in the list. The only major difference is the fact that driver age was not important for North Carolina accidents.

A log-linear model fitting procedure (BMDP, 1977) showed that, for single vehicle accidents in North Carolina, front-end, high speed impacts would be relatively more frequent (four-fold or more) in a NASS-type file. Similarly, for multi-vehicle accidents in North Carolina, it was found that, for vehicles going straight ahead, one would expect a higher proportion (two to four-fold) of front-end impacts, high speed impacts and accidents involving smaller cars in a towaway file.

In the second step of the analysis the relationships between vehicle drivability and driver injury, vehicle severity, TAD severity score and vehicle dollar damage were examined for the North Carolina data. It was observed that each of these variables had a more serious consequence (e.g., driver injured, severe vehicle damage) when towing was required, even after controlling for all of the remaining measures of accident severity. In addition, the analysis indicated a consistently lower proportion of vehicles towed when injury occurred to an occupant other than the driver.

In a comparable analysis of the New York data, it was feasible to include only two measures of accident severity, namely, driver injury and extent of vehicle damage. Here again, towaway accidents were associated with more serious levels of each of the two variables when the other was being controlled for. It was also observed that the proportion of vehicles towed was higher for each level of vehicle damage when the driver was injured. In all likelihood, this is due to the width of the five damage categories: none, slight, moderate, severe, demolished. Given a particular category, towing would be more likely to occur at the upper end of that damage category where the relatively more severe crashes occur.

The relative odds representing the chance of a vehicle being towed give an indication of the magnitude of the differences introduced by using a towaway reporting threshold rather than using all accidents. Thus, for example, if one were focusing on side impacts in single vehicle accidents, then from Table 3.7 there would be fewer than expected such crashes at low speeds in a data set based on a towaway reporting threshold. In addition, for single vehicle accidents, such data sets will have an underrepresentation of accidents when the object struck is not very rigid such as fence, sign or guardrail. Similarly for multi-vehicle accidents, if a particular study required a representative sample of vehicle sizes in accidents -- not just of those involved in serious accidents -- then, from Table 3.8, it is apparent that a NASS-type data set would not be suitable.

In Chapter 4 the effect of towaway crashes as a sampling criterion on accident and injury characteristics as well as on effectiveness investigations was studied. The results showed that there were overall differences in accident characteristics under the two sampling schemes. However, for accidents with severe occupant injuries, there were not apparent differences in accident characteristics such as rural-urban area, highway class, accident type under the two sampling schemes (i.e., the towaway subset constitutes virtually all of the sampling frame of serious injury-producing accidents).

The results in Chapter 4 indicate that, compared with all accidents, injury rates are overestimated, while restraint usage and belt effectiveness are underestimated in towaway accidents and provide estimates of these differences. However, each of these measures showed similar trends across vehicle size and model year under the two sampling criteria.

The study shows that most of the effects introduced by using a towaway reporting threshold agree with intuition. Thus for instance, it was shown that the odds for high speed, single vehicle accidents being included in towaway samples are about four times the odds for low speed, single vehicle accidents being included. As high speed accidents generally have a more severe consequence, such an effect would in many analyses not be too restrictive.

In summary, the results of the investigation indicate that there are differences between accident data based on a towaway criterion and accident data based on a typical statewide reporting threshold (e.g., personal injury and/or property damage exceeding $200). Most configurations such as high speed, front-end impacts, which result in more severe accidents would be overrepresented in such data bases, and consequently this should be accounted for when non-injury or minor injury accidents are the focus of a given study. However, when the injury criterion is relatively serious, the towaway sample will not exclude many injuries of interest. For example, the towaway sample will exclude only approximately 1.5 percent of the fatalities (K) and only 4.6 percent of the serious (A+K) injuries. Thus, the injuries generally of most interest will by-and-large be included in the towaway sample.

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APPENDIX A

Variables of Interest from 1976 North Carolina Accident Data

1. Day of Week

1 Monday
2 Tuesday
3 Wednesday
4 Thursday
5 Friday
6 Saturday
7 Sunday
8 Not stated

2. Time of Day

(24 hour clock including minutes)

0000 Midnight
1200 Noon
2460 Not stated
example: 1630 = 4:30 PM

3. Investigating Agency

1 Municipal police
2 Sheriff
3 Rural or county police
4 Highway patrol
5 Other traffic investigating agency
6 Not stated

4. Highway Class

1 Interstate
2 U.S.
3 N.C.
4 Rural paved road
5 Rural unpaved road
6 City street
7 Private property
8 Not stated

5. Light Condition

1 Daylight
2 Dusk
3 Dawn
4 Darkness (street lighted)
5 Darkness (street not lighted)
6 Not stated

6. Object Struck

1 Tree
2 Utility pole
3 Fence or fence post
4 Guardrail or guardpost in median
5 Guardrail or guardpost on shoulder
6 Bridge
7 Underpass
8 Traffic island, curb or median
9 Sign or sign post
10 Animal
11 Ditch bank
12 Parked vehicle
13 Pedestrian
14 Other object
15 No object struck
16 Not stated

7. Accident Severity

(Most severe injury in accident using the definition given in the "Classification of Motor Vehicle Traffic Accidents" (1976) published by the National Safety Council)

1 Fatal
2 A or B class injury
3 C class injury
4 Property damage only
5 Not stated

---

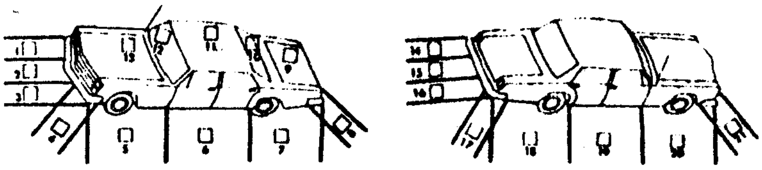
8. Accident Type

1 Ran off road - right
2 Ran off road - left
3 Ran off road - straight ahead
4 Non-collision in road - overturn
5 Non-collision in road - other
6 Collision of motor vehicle with pedestrian
7 Collision of motor vehicle with parked vehicle
8 Collision of motor vehicle with train
9 Collision of motor vehicle with bicycle
10 Collision of motor vehicle with animal
11 Collision of motor vehicle with fixed object
12 Collision of motor vehicle with other object
13 Collision of MV with another MVs rear end - stopping or slowing
14 Collision of MV with another MVs rear end - turning
15 Collision of MV with another MV turning left from same roadway
16 Collision of MV with another MV turning left across traffic
17 Collision of MV with another MV turning right from same roadway
18 Collision of MV with another MV turning right across traffic
19 Collision of MV with another MV head on
20 Collision of MV with another MV sideswipe
21 Collision of MV with another MV at an angle
22 Collision of MV with another MV backing
23 Not stated

---

9. Initial Point of Contact

(The 1st of 3 points possibly marked)
1-24 as diagrammed



25 Front end - distributed impact
26 Left side - distributed impact
27 Rear end - distributed impact
28 Right side - distributed impact
29 Roll-over only
30 No contact
31 Not stated

NOTE: To be distributed, at least 2 of the 3 impact sites were marked.

---

10. Roll-over

1 Yes
2 No

---

11. Vehicle Maneuver**

1 Stopped in travel lane
2 Parked out of travel lanes
3 Parked in travel lane
4 Going straight ahead
5 Changing lanes or merging
6 Passing
7 Making right turn
8 Making left turn
9 Making U turn
10 Backing
11 Slowing or stopping
12 Starting in roadway
13 Parking
14 Leaving parked position
15 Other
16 Not stated

---

12. Vehicle Defect

1 Defective brakes
2 Defective headlights
3 Defective rear lights
4 Defective steering
5 Defective tires
6 Other defect
7 No defect detected
8 Not stated

---

13. Estimated Speed Prior to Impact

Actual speed (0 is valid)
999 Not stated

---

14. TAD Rating #1

(NOTE: TAD is all blank if n.s.)
Impact site & type of impact
Possible codes are alphabetic
(See "Vehicle Damage Scale for Traffic Accident Investigators" (1971)
published by the National Safety Council)

---

15. Damage Severity Rating

1-7 possible

---

16. Amount of Damage to Vehicle

In tens of dollars
9999 Not stated
example: 0050 = $500-509

---

17. Vehicle Model Year

(As noted by investigating officer)

---

18. Vehicle Size (derived from the VIN)

1 Luxury car
2 Medium car
3 Standard car
4 Intermediate car
5 Compact car
6 Subcompact car
7 Mini car
8 Specialty car
9 Imported car
10 Small Truck (van, pickup, etc.)
11 Large Truck or Tractor-Trailer
12 Unknown

**See the Vehicle Maneuver Recodes at the end of this Appendix.

---

19. Body Style (derived from the VIN)

1 2 door sedan
2 2 door hardtop
3 2 door convertible
4 2 door stationwagon
5 4 door sedan
6 4 door hardtop
7 4 door convertible
8 4 door stationwagon (2 seat)
9 4 door stationwagon (3-4 seat)
10 Van body (hood size unknown)
41 Truck body - long hood
42 Truck body - short hood
43 Truck body - cab-over-engine
99 Unknown

---

20. Model Year (derived from the VIN)

NOTE: may differ by 1 year from the year recorded by the officer

---

21. Total Number of Occupants

0-8
9 More than 8 occupants
\- Not stated

---

22. Physical Condition of Driver

1 Ill
2 Fatigued
3 Asleep
4 Other physical impairment
5 Restriction not complied with
6 Normal
7 Not stated

---

23. Sobriety of Driver

1 Had not been drinking
2 Drinking--ability impaired
3 Drinking--unable to determine impairment
4 Not stated

---

24. Driver Charged with Violation

1 Yes
2 No
3 Not stated

---

25. Vehicle Drivability (beginning 1/76)

1 Drivable
2 Not drivable
0 Not stated

---

26. Vehicle Severity
(Most severe injury in vehicle)

1 Fatal
2 A class injury
3 B class injury
4 C class injury
5 Property damage only
6 Not stated

---

27. Injury Class of Driver

1 Not injured
2 Class C injury
3 Class B injury
4 Class A injury
5 Killed
6 Driver not present
7 Not stated

28. Restraint of Driver

1 No belt
2 Lap belt
3 Shoulder & lap
4 Shoulder belt
5 Child restraint
6 Driver not present
7 Not stated

29. Race of Driver

1 White
2 Negro
3 Indian
4 Other
5 Driver not present
6 Not stated

30. Sex of Driver

1 Male
2 Female
3 Driver not present
4 Not stated

31. Age of Driver

(Actual age on day of accident)
01-96
97 Older than 96
98 Driver not present
99 Not stated

32. Means of Involvement

Single Vehicle Accident

1 Ran-off-road
(1 veh. with acc. type = 1,2,3)
2 Hit fixed object
(1 veh. with acc. type = 11)
3 Hit non-fixed object
(1 veh. with acc. type = 4,5,12)

Multi-vehicle Accident

4 Car vs car
(2 cars of veh. type - 1,4,14,19)
5 Car vs truck or bus
(car with above veh. type &
truck of veh. type = 5 thru 13)
6 More than two vehicles involved

Other Accidents

7 Any 1 or 2 veh. accident not categorized above
(e.g. acc. type = 6,8,9,10 & 2 vehicle accidents involving
2 trucks or any motorcycles)

33. Region of Impact

1 Frontal collision
(pt. of contact - 1,2,3,4,21,25)
2 Right side collision
(p.o.c. = 18,19,20,28)
3 Left side collision
(p.o.c. = 5,6,7,26)
4 Rear end collision
(p.o.c. = 8,14,15,16,17,27)
5 Unspecified
(p.o.c. = 9 thru 13 &
22,23,24,29,30,31)

---

34. Speed of Accident (created from vehicle speed(s) and accident configuration)

1 00-29 mph
2 30-49 mph
3 50-79 mph
4 Not stated

Vehicle Maneuver Recodes (Variable #7, Appendix A)

1 Stopped in travel lane (01)
Making right turn (07)

2 Parked out of travel lanes (02)
Parked in travel lane (03)
Other (15)

3 Going straight ahead (04)

4 Changing lanes or merging (05)
Leaving parked position (14)

5 Passing (06)
Making left turn (08)
Making U turn (09)

6 Slowing or stopping (11)
Starting in roadway (12)

7 Backing (10)
Parking (13)

APPENDIX B

Variables of Interest from 1975 New York Accident Data

1. Hour

01-24	(Military clock)
24	Unknown

2. Land Usage

0	Unknown
1	School/playground
2	One/two family residential
3	Apartment residential
4	Business/shopping
5	Industrial/manufacturing
6	Agricultural/undeveloped
7	Recreational/Park/Camping

3. Weather

0	Unknown
1	Clear
2	Cloudy
3	Rain
4	Snow
5	Sleet/Hail/Freezing Rain
6	Fog/Smog/Smoke
7	Other

4. Road Character

0	Unknown
1	Straight and Level
2	Straight/Grade
3	Straight at Hillcrest
4	Curve and Level
5	Curve and Grade
6	Curve at Hillcrest

5. Road Surface Condition

0	Unknown
1	Dry
2	Wet
3	Muddy
4	Snow/Ice
5	Slush
6	Other

6. First Event

0	Unknown

Collision With

1	Motor vehicle
2	Pedestrian
3	Bicyclist
4	Animal
5	Railroad train
10	Other

Collision With Fixed Object

11	Light support/Utility pole
12	Guide rail
13	Crash cushion
14	Sign post
15	Tree
16	Building/Wall
17	Curbing
18	Fence
19	Bridge structure
20	Culvert/Headwall
21	Median/Barrier
22	Snow embankment
23	Earth element/Rock/Ditch
24	Fire hydrant
30	Other fixed object

Non-Collision

31	Overturned
32	Fire/Explosion
33	Submersion
34	Ran off road only
40	Other

7. Manner of Collision

0	Unknown
1	Rear End
2	Overtaking
3	Left Turn
4	Intersection
5	Right Turn
6	Right Turn
7	Head On
8	Sideswipe
9	Other

8. Type of Road System

0	Unknown
1	State Highway
2	County Roads
3	Town Roads
4	Municipal Streets
5	Parkway
6	Thruway
7	Northway
8	Other Limited Access Highway
9	Unknown Roadway
10	Non-Traffic
11	Interstate

9. Age of Driver

00-76	Years
99	Unknown

10. Model Year

0 Unknown

21-76

11. Apparent Contributing Factors

0	Unknown
1	None

Human

2	Alcohol Involvement
3	Backing Unsafely
4	Driver Inattention
5	Driver Inexperience
6	Drugs (Illegal)
7	Failure to Yield Right of Way
8	Fell Asleep
9	Following Too Close
10	Illness
11	Lost Consciousness
12	Passenger Distraction
13	Passing or Lane Usage Improper
14	Pedestrian's Error/Confusion
15	Physical Disability
16	Prescription Medication
17	Traffic Control Device Disregarded
18	Turning Improper
19	Unsafe Speed
40	Other (Human)

Vehicular

41	Accelerator Defective
42	Brakes Defective
43	Headlights Defective
44	Other Lighting Defects
45	Oversized Vehicle
46	Steering Failure
47	Tire Failure/Inadequate
48	Tow Hitch Defective
49	Windshield Inadequate
60	Other (Vehicle)

Environmental

61	Animal's Action
62	Glare
63	Lane Marking Improper/Inadequate
64	Obstruction/Debris
65	Pavement Defective
66	Pavement Slippery
67	Shoulders Defective/Improper
68	Traffic Control Device Improper/ Non-Working
69	View Obstructed/Limited
80	Other (Environmental)

12. Pre-Accident Vehicle Action

0	Unknown
1	Going Straight Ahead
2	Making Right Turn
3	Making Left Turn
4	Making U-Turn
5	Starting from Parking
6	Starting in Traffic
7	Slowed or Stopping
8	Stopped in Traffic
9	Entering Parked Position
10	Parked
11	Avoiding Object in Roadway
12	Changing Lanes
13	Overtaking
14	Merging
15	Backing
20	Other

13. Area of Impact

0	Unknown
1	Undercarriage
10	Hood and Front
20	Right Front Fender
30	Right Door(s)
40	Right Rear Fender
50	Rear and Trunk
60	Left Rear Fender
70	Left Door(s)
80	Left Front Fender
90	Roof

14. No. of Occupants

00-98
99 Unknown

15. Restraint Use of Driver

0 Unknown
1 No Restraint Used
2 Lap Belt
3 Harness
4 Lap Belt and Harness
5 Child Restraint
6 Other

16. Total of Injuries

00 No injuries or no injury information
01-99

17. Second Event

0 Unknown

Collision With

1 Motor vehicle
2 Pedestrian
3 Bicyclist
4 Animal
5 Railroad Train
10 Other

Collision With Fixed Object

11 Light Support/Utility Pole
12 Guide Rail
13 Crash Cushion
14 Sign Post
15 Tree
16 Building/Wall
17 Curbing
18 Fence
19 Bridge Structure
20 Culvert/Headwall
21 Median/Barrier
22 Snow Embankment
23 Earth Element/Rock Cut/Ditch
24 Fire Hydrant
30 Other Fixed Object

Non-Collision

31 Overturned
32 Fire/Explosion
33 Submersion
34 Ran Off Road Only
40 Other

13. Extent of Damage

0 Unknown
1 (N) None
2 (L) Light
3 (M) Moderate
4 (S) Severe
5 (D) Demolished

19. Vehicle Towed

0 No
1 Yes

20. Driver's Type of Physical Complaint

0 Unknown
1 Amputation
2 Concussion
3 Internal
4 Minor Bleeding
5 Severe Bleeding
6 Minor Burn
7 Moderate Burn
8 Severe Burn
9 Fracture Dislocation
10 Contusion-Bruise
11 Abrasion
12 Complaint of Pain
13 None Visible

21. Driver's Status

0 Not Applicable or Unknown
1 K or Apparently Dead
2 A or Unconscious
3 Semiconscious
4 B Injury
5 C Injury
6 Incoherent
7 Shock
8 Conscious
9 No Injury

22. Location of Driver's Physical Complaint

0 Unknown
1 Head
2 Face
3 Eye
4 Neck
5 Chest
6 Back
7 Shoulder-Upper Arm
8 Elbow-Lower Arm-Hand
9 Abdomen-Pelvis
10 Hip-Upper Leg
11 Knee-Lower Leg-Foot
12 Entire Body

APPENDIX C

Fitted Frequencies for Multi-Vehicle Accidents
(20% 1976 North Carolina)

Table C.1 Fitted frequencies and odds ratios of non-drivable vs. drivable accidents by vehicle maneuver, vehicle size, impact size, and accident speed. (Source: 20% 1976 North Carolina data)

Speed	Impact Site	Vehicle Size**	Vehicle Drivable	Vehicle Maneuver*						
				1	2	3	4	5	6	7
Low	Front	LM	No	16.5	2.4	140.0	3.7	19.3	19.4	0.4
			Yes	102.7	7.1	397.0	33.7	85.8	96.5	4.0
			(Odds Ratio)	(0.2)	(0.3)	(0.4)	(0.1)	(0.2)	(0.2)	(0.1)
		SI	No	46.9	5.2	440.2	9.8	60.8	57.9	1.2
			Yes	258.3	13.5	1100.6	77.5	237.9	254.1	11.3
			(Odds Ratio)	(0.2)	(0.4)	(0.4)	(0.1)	(0.3)	(0.2)	(0.1)
		Co	No	18.6	2.3	177.9	3.6	26.6	24.0	0.4
			Yes	77.5	4.6	336.2	21.7	78.8	79.6	3.1
			(Odds Ratio)	(0.2)	(0.5)	(0.5)	(0.2)	(0.3)	(0.3)	(0.1)
		S	No	35.9	2.9	266.1	7.1	37.4	36.4	0.4
			Yes	115.1	4.4	387.5	32.8	85.4	93.1	2.2
			(Odds Ratio)	(0.3)	(0.7)	(0.7)	(0.2)	(0.4)	(0.4)	(0.2)
		Tr	No	8.1	1.4	95.9	2.7	11.7	11.8	0.5
			Yes	65.3	5.2	351.6	31.4	67.4	76.3	6.4
			(Odds Ratio)	(0.1)	(0.3)	(0.3)	(0.1)	(0.2)	(0.2)	(0.1)
	Side	LM	No	5.0	2.1	33.4	1.6	14.4	3.4	0.5
			Yes	55.0	12.8	227.2	26.2	93.0	16.4	10.9
			(Odds Ratio)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)	(0.2)	(0.1)
		SI	No	14.1	4.5	104.6	4.1	45.0	10.2	1.5
			Yes	137.7	24.4	626.9	60.1	256.8	43.0	30.4
			(Odds Ratio)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)	(0.2)	(0.1)
		Co	No	5.4	1.9	40.3	1.5	18.8	4.0	0.5
			Yes	39.4	7.9	182.7	16.1	81.2	12.9	7.9
			(Odds Ratio)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)	(0.3)	(0.1)
		S	No	10.3	2.4	60.1	2.8	26.4	6.1	0.5
			Yes	58.4	7.5	209.8	24.2	87.6	15.0	5.7
			(Odds Ratio)	(0.2)	(0.3)	(0.3)	(0.1)	(0.3)	(0.4)	(0.1)
		Tr	No	1.9	1.0	18.2	0.9	6.9	1.7	0.5
			Yes	27.8	7.5	159.7	19.4	58.0	10.3	13.7
			(Odds Ratio)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)
	Rear	LM	No	18.3	2.4	9.8	1.2	5.6	12.5	1.1
			Yes	207.4	10.7	88.6	9.3	43.5	107.7	71.6
			(Odds Ratio)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)
		SI	No	53.2	5.3	31.3	5.2	18.0	38.1	3.4
			Yes	532.0	20.9	250.5	21.8	123.0	289.4	204.4
			(Odds Ratio)	(0.1)	(0.3)	(0.1)	(0.2)	(0.1)	(0.1)	(0.0)
		Co	No	22.1	2.5	13.2	1.2	8.3	16.6	1.3
			Yes	167.2	7.5	80.1	6.4	42.7	94.9	58.5
			(Odds Ratio)	(0.1)	(0.3)	(0.2)	(0.2)	(0.2)	(0.2)	(0.0)
		S	No	40.3	2.9	18.7	2.3	11.0	23.8	1.1
			Yes	234.9	6.7	87.3	9.2	43.7	105.0	39.7
			(Odds Ratio)	(0.0)	(0.4)	(0.2)	(0.3)	(0.3)	(0.2)	(0.0)
		Tr	No	8.9	1.3	6.6	0.9	3.4	7.6	1.3
			Yes	130.7	7.9	77.8	8.6	33.9	84.4	112.7
			(Odds Ratio)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)

*For recoded values see page A-7

**LM = Luxury, Medium; SI = Standard, Intermediate; Co = Compact; S = Subcompact, Imported; Tr = Trucks.

Table C.1 (Con't)

Speed	Impact Site	Vehicle Size**	Vehicle Drivable	Vehicle Maneuver* 1	2	3	4	5	6	7
Medium	Front	LM	No	8.8	2.3	302.0	5.5	35.6	17.2	0.7
			Yes	25.5	2.2	335.5	19.1	71.7	39.0	1.5
			(Odds Ratio)	(0.3)	(1.0)	(0.9)	(0.3)	(0.5)	(0.4)	(0.5)
		SI	No	25.1	4.0	956.7	14.4	112.7	51.9	2.1
			Yes	64.6	4.2	937.0	44.3	200.5	103.3	4.1
			(Odds Ratio)	(0.4)	(1.0)	(1.0)	(0.3)	(0.6)	(0.5)	(0.5)
		Co	No	10.1	2.2	389.3	5.4	49.7	21.6	0.8
			Yes	19.5	1.4	288.2	12.5	66.9	32.6	1.1
			(Odds Ratio)	(0.5)	(1.6)	(1.4)	(0.4)	(0.7)	(0.7)	(0.7)
		S	No	16.3	2.3	491.3	8.9	59.0	27.7	0.6
			Yes	24.5	1.2	280.2	16.0	61.1	32.2	0.7
			(Odds Ratio)	(0.7)	(1.9)	(1.8)	(0.6)	(1.0)	(0.9)	(0.9)
		Tr	No	4.7	1.4	227.7	4.3	23.8	11.6	0.9
			Yes	17.9	1.8	327.2	19.7	62.1	33.9	2.5
			(Odds Ratio)	(0.3)	(0.8)	(0.7)	(0.2)	(0.4)	(0.3)	(0.4)
	Side	LM	No	5.0	1.7	106.1	4.7	37.6	9.0	0.8
			Yes	27.1	3.5	298.2	32.1	116.6	20.6	4.1
			(Odds Ratio)	(0.2)	(0.5)	(0.4)	(0.1)	(0.3)	(0.4)	(0.2)
		SI	No	14.2	3.6	334.5	12.3	118.5	27.0	2.6
			Yes	68.2	6.8	828.9	74.0	324.3	54.5	11.5
			(Odds Ratio)	(0.2)	(0.5)	(0.4)	(0.2)	(0.4)	(0.5)	(0.2)
		Co	No	5.4	1.6	129.9	4.4	49.9	10.7	0.9
			Yes	19.7	2.2	243.3	19.9	103.2	16.4	3.0
			(Odds Ratio)	(0.3)	(0.7)	(0.5)	(0.2)	(0.5)	(0.7)	(0.3)
		S	No	8.8	1.5	163.3	7.2	59.0	13.7	0.7
			Yes	24.6	1.8	235.6	25.3	94.0	16.1	1.8
			(Odds Ratio)	(0.4)	(0.9)	(0.7)	(0.3)	(0.6)	(0.9)	(0.4)
		Tr	No	2.1	0.8	63.5	3.0	20.0	4.8	0.9
			Yes	15.0	2.3	230.8	26.1	80.1	14.2	5.7
			(Odds Ratio)	(0.1)	(0.3)	(0.3)	(0.1)	(0.2)	(0.3)	(0.2)
	Rear	LM	No	10.8	2.7	6.9	0.6	8.7	6.0	0.7
			Yes	78.3	5.4	33.6	2.6	41.7	32.0	13.4
			(Odds Ratio)	(0.1)	(0.5)	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)
		SI	No	31.7	6.0	22.3	1.7	28.0	18.4	2.3
			Yes	202.4	10.6	95.6	6.2	119.0	86.7	38.5
			(Odds Ratio)	(0.2)	(0.6)	(0.2)	(0.3)	(0.2)	(0.2)	(0.1)
		Co	No	13.3	2.8	9.5	0.7	13.0	8.1	0.9
			Yes	64.1	3.8	30.8	1.8	41.6	28.6	11.1
			(Odds Ratio)	(0.2)	(0.7)	(0.3)	(0.4)	(0.3)	(0.3)	(0.1)
		S	No	20.4	2.8	11.4	1.0	14.6	9.8	0.7
			Yes	75.9	2.9	28.3	2.2	36.0	26.7	6.3
			(Odds Ratio)	(0.3)	(1.0)	(0.4)	(0.5)	(0.4)	(0.4)	(0.1)
		Tr	No	5.8	1.7	5.2	0.5	5.8	4.0	0.9
			Yes	54.3	4.4	32.4	2.7	35.8	27.6	23.2
			(Odds Ratio)	(0.1)	(0.4)	(0.2)	(0.2)	(0.2)	(0.1)	(0.0)

*For recoded values see page A-7

**LM = Luxury, Medium; SI = Standard, Intermediate; Co = Compact; S = Subcompact, Imported; Tr = Trucks.

Table C.1 (Con't)

Speed	Impact Site	Vehicle Size**	Vehicle Drivable	Vehicle Maneuver*						
				1	2	3	4	5	6	7
High	Front	LM	No	2.2	1.4	106.0	2.0	15.5	5.7	0.5
			Yes	3.7	0.8	57.9	3.6	16.7	8.0	0.3
			(Odds Ratio)	(0.6)	(1.8)	(1.8)	(0.6)	(0.9)	(0.7)	(1.7)
		SI	No	6.3	3.1	332.8	5.1	48.8	17.0	1.5
			Yes	9.3	1.5	160.2	8.2	46.2	21.1	1.0
			(Odds Ratio)	(0.7)	(2.1)	(2.1)	(0.6)	(1.1)	(0.8)	(1.5)
		Co	No	2.5	1.4	132.6	1.9	21.1	6.9	0.5
			Yes	2.8	0.5	48.3	2.3	15.1	6.5	0.3
			(Odds Ratio)	(0.9)	(2.8)	(2.8)	(0.8)	(1.4)	(1.1)	(1.7)
		S	No	2.9	1.0	122.6	2.3	18.3	6.5	0.3
			Yes	2.5	0.3	34.4	2.1	11.0	4.7	0.1
			(Odds Ratio)	(1.1)	(3.3)	(3.6)	(1.1)	(1.7)	(1.4)	(3.0)
		Tr	No	1.5	1.1	100.4	2.0	13.1	4.8	0.8
			Yes	3.3	0.8	70.9	4.6	18.1	8.8	0.8
			(Odds Ratio)	(0.5)	(1.4)	(1.4)	(0.4)	(0.7)	(0.6)	(1.0)
	Side	LM	No	1.4	1.2	45.1	1.9	18.8	2.9	1.0
			Yes	5.2	1.7	72.9	7.8	36.3	4.8	2.0
			(Odds Ratio)	(0.3)	(0.7)	(0.6)	(0.2)	(0.5)	(0.6)	(0.5)
		SI	No	4.0	2.5	140.8	4.9	58.8	8.6	3.1
			Yes	12.9	3.2	200.9	17.9	100.1	12.7	5.5
			(Odds Ratio)	(0.3)	(0.8)	(0.7)	(0.3)	(0.6)	(0.7)	(0.7)
		Co	No	1.5	1.1	53.5	1.7	24.2	3.3	1.1
			Yes	3.6	1.0	57.7	4.7	31.2	3.7	1.4
			(Odds Ratio)	(0.4)	(1.1)	(0.9)	(0.4)	(0.9)	(0.9)	(0.8)
		S	No	1.8	0.8	49.3	2.1	21.0	3.1	0.6
			Yes	3.3	0.6	41.0	4.4	20.8	2.7	0.6
			(Odds Ratio)	(0.6)	(1.3)	(1.2)	(0.5)	(1.0)	(1.2)	(1.0)
		Tr	No	0.8	0.7	33.8	1.5	12.5	1.9	1.3
			Yes	3.6	1.3	70.9	8.0	31.3	4.2	3.4
			(Odds Ratio)	(0.2)	(0.5)	(0.5)	(0.2)	(0.4)	(0.5)	(0.4)
	Rear	LM	No	4.7	1.8	4.0	0.5	4.5	2.1	0.4
			Yes	18.5	1.9	9.0	1.0	10.7	6.6	2.3
			(Odds Ratio)	(0.3)	(1.0)	(0.4)	(0.5)	(0.4)	(0.3)	(0.2)
		SI	No	13.8	3.9	12.8	1.3	14.3	6.5	1.2
			Yes	47.3	3.8	25.3	2.3	30.4	17.8	6.4
			(Odds Ratio)	(0.3)	(1.0)	(0.5)	(0.6)	(0.5)	(0.4)	(0.2)
		Co	No	5.6	1.8	5.3	0.5	6.5	2.8	0.4
			Yes	14.7	1.3	8.0	0.7	10.4	5.8	1.8
			(Odds Ratio)	(0.4)	(1.4)	(0.7)	(0.7)	(0.6)	(0.5)	(0.2)
		S	No	6.4	1.3	4.7	0.6	5.3	2.5	0.2
			Yes	12.7	0.7	5.4	0.6	6.6	3.9	0.8
			(Odds Ratio)	(0.5)	(1.9)	(0.9)	(1.0)	(0.8)	(0.6)	(0.3)
		Tr	No	3.2	1.4	3.7	0.5	3.7	1.8	0.6
			Yes	16.1	2.0	10.9	1.2	11.6	7.2	4.9
			(Odds Ratio)	(0.2)	(0.7)	(0.3)	(0.4)	(0.3)	(0.3)	(0.1)

*For recoded values see page A-7

**LM = Luxury, Medium; SI = Standard, Intermediate; Co = Compact; S = Subcompact, Imported; Tr = Trucks.

Appendix D. HSRC vehicle make and size groups.

Size Group		Make-Model (Example)
Luxury		Big Buick (Electra)
		Cadillac (Fleetwood)
		Big Pontiac (Bonneville)
Medium		Medium Buick (LeSabre)
		Medium Oldsmobile (Delta 88)
		Medium Pontiac (Catalina)
Standard		Standard Chevrolet (Impala)
		Standard Ford (Galaxie)
		Standard Plymouth (Fury)
Intermediate		Chevrolet Chevelle (Chevelle Malibu)
		Intermediate Ford (Fairlane)
		Intermediate Oldsmobile (Cutlass)
		Intermediate Pontiac (LeMans)
Compact		Chevrolet Nova
		Ford Maverick
		Ford Mustang
		Plymouth Valiant
Subcompact	Domestic	Chevrolet Vega
		Ford Pinto
	Foreign	Datsun
		Toyota
		VW Beetle
		VW Fastback

highway
Safety
Research
Center