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RELATIONSHIP OF ACCIDENT TYPE TO OCCUPANT INJURIES

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16. Abstract

This report describes an extension of previous work undertaken for the National Highway Traffic Safety Administration of the U.S. Department of Transportation. For that work, an Injury Priority Rating (IPR) model was developed to weight injuries in national accident files by their long-term societal consequences. The model calculated the estimated consequences of injury in dollars, with the main component of the cost being the predicted net loss of productivity as a result of injury or fatality. The new model, termed Multi-Injury Priority Rating (MIPR), further refines the original model by taking into account the cumulative effect of several injuries for a single person. The accident database has also been expanded to include National Accident Sampling System data from 1982 to 1983 in addition to 1980 and 1981. The study found that the combination of head, face, and neck injuries accounted for 62 percent of total MIPR to passenger car occupants. For left-front and right-front unrestrained occupants, over half of their total MIPR from frontal crashes resulted from crashes with a delta V of 30 mph or less.

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SUMMARY

STUDY DESIGN

The work reported here attempts to examine the relationship between occupant injury and crash environment, using a measure of injury severity that takes into account the long-term consequences of injury. This measure assigns to each injury an estimated dollar cost, based mainly on the costs of treatment and of lost production in the first year after the accident, and on lost production for the remainder of the victim's predicted lifetime.

The main data base used here is that provided by the National Accident Sampling System (NASS). NASS provides a statistical sample of all the police-reported traffic accidents in the United States. NASS uses the Occupant Injury Classification (OIC) scheme, which categorizes injuries by body region, aspect, lesion, system/organ, and severity, to describe each injury incurred. The severity of the injury is coded according to the Abbreviated Injury Scale (AIS), which uses a numeric scale ranging from 1 (minor) to 6 (unsurvivable). The dollar function used as an estimate of the societal cost of each injury was generated using the OIC and the AIS severity, together with the injured person's age and sex as reported by NASS.

The model used here to generate this cost function is an enhanced version of a model that was used for work under a contact with the National Highway Traffic Safety Administration (NHTSA).[1] This earlier work was intended to aid in the design of an Advanced Anthropomorphic Test Dummy by providing information on where, in the current accident population, the most severe injuries were incurred. The AIS scale did not provide sufficient detail on this problem and did not offer a convenient means of integrating the results by using some kind of continuous measure. The societal cost of injuries has obvious advantages here (and also some obvious disadvantages). Using dollar consequences as a weight, it would, for example, be possible to rank the injured body regions of passenger-car occupants and so to pay the greatest attention to the biofidelity and response of the dummy in those areas where the consequences of injury to accident victims were the greatest. It is hoped that the current work will be of similar utility.

The earlier model, called "Injury Priority Rating" or IPR, was deficient in that each injury to a person was treated separately in the calculation of the cost function. In theory this should lead to an over-estimation of the consequences of injury in terms of societal cost, since the sum of the costs of the various injuries might be greater than the person's total net worth to the community as estimated by the model. To put it another way, a person might be counted as 60 percent impaired from one injury and 50 percent impaired from a second injury, to give a total impairment of 110 percent. The model has been refined here so that the impairment is calculated in a cumulative manner across injuries to an individual and can never sum to more than 100 percent. The improved model is called "Multiple-Injury Priority Rating" or MIPR.

The reader is referred to the previous report for a detailed description of the methodology used in the creation of the IPR model. Here the older model formulation is

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[1]O. Carsten and J. O'Day, *Injury Priority Analysis*, Report No. UMTRI-84-24 (Ann Arbor: University of Michigan Transportation Research Institute, October 1984).

summarized and a detailed description is given of the refinements incorporated in the new model (MIPR). Some detail is also provided on the accident data used in the study. The earlier work used the 1980 and 1981 NASS files. For the new study, the 1982 and 1983 NASS data have been incorporated as well. In addition, individual NASS cases where contact point (injury source) had been coded missing were reviewed in their hard-copy form and a contact point coded where the evidence strongly indicated one.

That missing data in NASS presents some significant problems to the analyst deserves mention here. Not only is injury contact point coded unknown all too frequently, but the main measure of crash severity, delta V, is also missing in a large percentage of cases. These problems are compounded by the comparatively small number of serious accidents investigated by NASS, which makes it virtually impossible to examine the interaction of four or more factors in occupant injury causation. The combined 1980 through 1983 NASS files have only 5,811 injuries of severity AIS 2–6 to passenger-car occupants. This is insufficient to examine, for example, the interaction of seat position, principal direction of force, delta V, and body region, let alone take into account contact point. A further problem with the NASS data is the unknown size of the variances associated with the computations from NASS. There is at present no publicly available computer program for computing NASS variances, which may, because of the complex sample design, have large design effects.

PRINCIPAL FINDINGS

The MIPR model applies the estimated societal cost of injury to analysis of appropriate accident data. Here the model was used in analysis of a combined 1980 through 1983 NASS database. MIPR was used as a weighting factor and the shares of MIPR across various accident factors and within appropriate subsets were then ascertained. This enables the analyst to "prioritize" shares of MIPR and thus to indicate where countermeasures are, if effective, likely to produce the greatest societal benefit. Some of the salient results of performing the analysis are:

1. The MIPR model does not produce results that differ greatly from those obtained using the somewhat cruder single-injury IPR model. Slightly greater weight is given by the new model to the primary causes of occupant harm. Thus those body regions that are responsible for the greatest share of IPR are responsible for a slightly greater share of MIPR.

2. The combination of the head, face, and neck body regions accounts for 62 percent of MIPR to passenger car occupants. The same combination accounts for 87 percent of MIPR to *restrained* passenger car occupants.

3. The combination of the chest, back, and abdomen body regions accounts for 28 percent of MIPR to passenger car occupants.

4. Over one-third of driver MIPR occurs from collisions with a 12 o'clock direction of force. Seventeen percent results from collisions with non-horizontal directions of force.

5. Oblique side collisions account for more MIPR than direct side collisions. This applies both to drivers and to right-front passengers. Thus, 9 o'clock collisions account for 5.2 percent of driver MIPR, but 10 and 11 o'clock collisions account for 13.5 percent. Similarly, 3 o'clock collisions account

for 8.4 percent of MIPR to right-front passengers; 1 and 2 o'clock collisions account for 19.5 percent.

6. Using only known values of delta V, 56 percent of unrestrained driver MIPR for passenger cars in frontal crashes results from less severe crashes, i.e., those with a delta V less than 30 mph. For right-front passengers, the figure is 45 percent.

7. Again using only cases with known delta V, 60 percent of head, face, and neck MIPR for unrestrained drivers of passenger cars in frontal crashes results from less severe (30 mph or under) crashes. For injuries to the chest, back, and abdomen the comparable figure is 54 percent; for injuries to the upper extremities, 93 percent; and for injuries to the lower extremities, 31 percent. Thus one might conclude that, for drivers, serious injuries to the upper extremities are the easiest to prevent, because a higher proportion of them occur in less severe crashes. Next would come the combination of the head, face, and neck, followed by the combination of the chest, back, and abdomen, and last the lower extremities.

8. While 54 percent of chest, back, and abdomen MIPR to unbelted drivers of passenger cars in frontal crashes results from less severe crashes, for right-front passengers the proportion is 26 percent. This suggests that preventing serious injury to the trunk region is much more difficult for the right-front passenger than for the driver. There is some indication that the steering wheel is serving to protect drivers in severe crashes.

It seems appropriate at this point to raise some cautions about the results. The first is that, because of limitations in the data, it was not always possible to depict the crash environment to the extent that was desired. In particular, the high rates of missing delta V meant that analysis of crash severity was often not possible. Another concern is with the comparatively small number of occupants in the NASS files that sustain serious injuries. The combined 1980 through 1983 NASS files contain only 5,811 injuries of severity AIS-2 or greater to passenger car occupants. These injuries are sustained by the occupants of 3,033 vehicles. There are a total of 31,290 passenger cars in the combined 1980 through 1983 files. Thus, in 90 percent of the vehicles, the occupants sustain no injuries, injuries of AIS 1, or injuries of unknown severity.

One solution to the shortage of NASS cases at higher levels of crash severity would be to revise the threshold for the inclusion of cases in the NASS system or to sample at higher rates cases in which injuries greater than AIS 1 are sustained. Some revisions to the present sampling scheme are currently being considered and it is hoped that they will result in a file that contains fewer minor property-damage collisions and more cases relevant to injury prevention.

Finally, the reader should bear in mind that the size of the sampling errors from the NASS data are essentially unknown. No convenient computer program exists for their calculation, and they therefore constitute an unknown, but possibly large, quantity.

REPORT ORGANIZATION

The organization of the remainder of this report is as follows. "Methodology" describes the techniques used in developing the Multi-Injury Priority Model (MIPR). Both the calculation methods used and the main sources of data are outlined. The findings obtained by applying the model to the 1980–83 NASS data are presented in "Results." The appendices document the OSIRIS IV program used to calculate MIPR from the estimates of impairment and discuss some of the difficulties encountered in attempting to use another data source as a supplement to NASS.

METHODOLOGY

OVERVIEW

This section describes the methodology that was used to create a computerized system that would incorporate into the NASS data a means of calculating the societal cost of injury and of using that cost as a weighting factor in the analysis of occupant injuries. As in the previous version of the IPR model, these costs were calculated in terms of 1980 dollars. It was also decided to include in the economic model only those consequences that directly resulted from the injuries. Thus the costs of litigation or of property damage were excluded. Included in the model were the estimated cost to society of the net productivity lost as a result of an injury or fatality, the cost of work days lost immediately after the accident, and the cost of medical treatment. The model developed was a multi-injury model that takes into account, at least in simple terms, the cumulative effect of injuries beyond the first on a single person. This model is to be run at the injury level of an accident file, using every injury of severity AIS 2-6. AIS 1 injuries are excluded, in part because they are unlikely to have significant long-term consequences and therefore contribute little to the societal costs of accidents, and in part because data on their medical consequences were not available. A much more detailed description of the development of the basic IPR model is to be found in the earlier report.[1] Here the earlier work is summarized and only the modifications to the model are discussed in full.

The development of the refined injury priority model is depicted in Figure 1.

THE MEDICAL DATA

As before, the main body of information used on the long-term consequences of injury was that supplied by Chi Associates.[2] This was augmented with data supplied by UMTRI's own panel of physicians. The Chi data were produced under a NHTSA contract to code the anticipated consequences of all the injuries in the 1980 AIS manual[3] with an AIS of 2 through 5. Using a panel of four physicians, the consequences of 476 different injuries were coded. Each injury's consequences were coded for four age groups: ages less than 16, ages 16 through 45, ages 46 through 65, and ages over 65. The coding was for six different factors: mobility, cognitive/psychological, cosmetic, sensory, pain, and daily living. For each factor a four-point scale was used, ranging from slight (1) to maximum (4). The consequences of injury were assessed over three time frames after incurrence of the injury:

1. The first year: The codings were in terms of the duration of the specified level of the factor.

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[1]Carsten and O'Day, *Injury Priority Analysis*, pp. 7–14.

[2]A.E. Hirsch, T. Van Nguyen, R.H. Eppinger, R.S. Levine, J. Mackenzie, M. Marks, and A.K. Ommaya, *Impairment Scaling from the Abbreviated Injury Scale* (Arlington, Va.: Chi Associates, 1984).

[3]American Association for Automotive Medicine, *The Abbreviated Injury Scale: 1980 Revision* (Morton Grove, Ill.: American Association for Automotive Medicine, 1980).

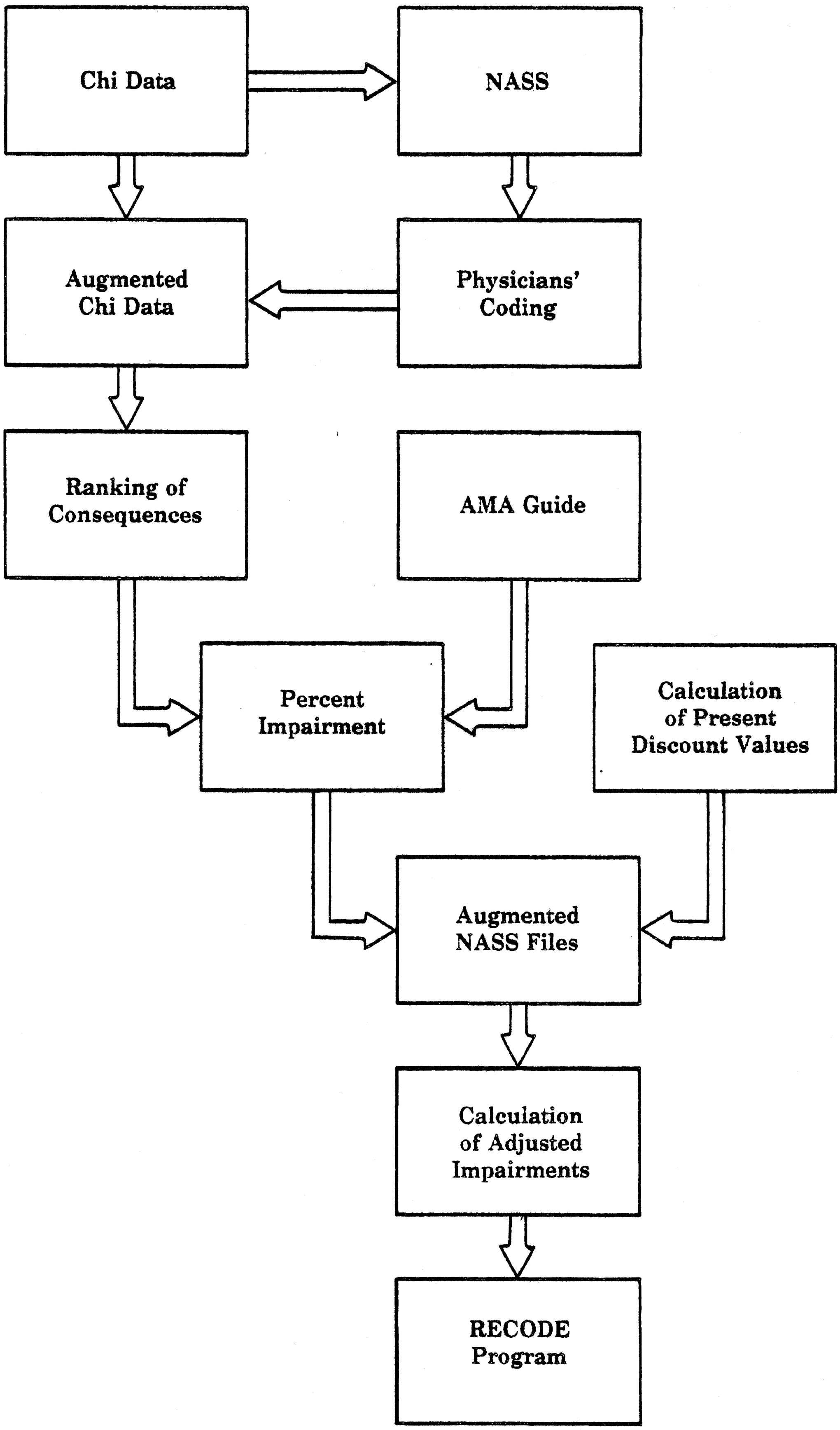

FIGURE 1. Development of Model.

2. Years two through five after the accident: The codings were in terms of the level of the factor, and it was assumed that there was no change during the interval in the severity of the consequences.

3. More than five years after the accident: The same coding scheme was used as for the two- through five-year period.

In addition, two other consequences were coded. The first was any long-term reduction in life expectancy as a result of the injury. This was coded in grouped years. The other was the need for surgery in order to repair the injury, coded as "yes" or "no."

However, the Chi data did not cover all the injury codes actually used by the NASS investigators. Some of the gaps could be explained by the somewhat different coding scheme in the NASS injury coding manual[4] as compared to the 1980 AIS manual. For such differences in coding convention, a notation was made of the NASS equivalent to the Chi code so that, when the final merges were made between the augmented Chi data and the NASS files, these cases would be matched. This still left another group of OICs from NASS for which there were no equivalents in the Chi data. Code sheets for these injuries, modeled on the code sheets used by Chi, were circulated to the physicians on the medical panel for Task A of the Dummy Contract with NHTSA. The results were computerized and combined with the data from Chi. There was now a dataset with the Chi consequences of injury coded for every OIC with a severity of AIS 2–5 in the NASS files, and the Chi data could be added to NASS by a match on OIC and severity.

However, an analysis of the consequences of injury, if performed on all the Chi variables, would be somewhat cumbersome. It was therefore decided to translate the Chi-style codings into a percentage of whole-body impairment for each time-period after the injury. These impairments could then be translated into a dollar value.

The most significant existing report on how to translate injury information into whole-body impairment was the AMA's *Guides to the Evaluation of Permanent Impairment.*[5] This presents the physician with the material for coding virtually any physical or mental injury in terms of impairment. Because the Chi data could not be directly matched with the AMA information in any convenient manner, an experiment was designed to obtain a single ranking of the Chi consequences. This ranking could then be translated into a whole body impairment using the AMA *Guides* for assistance. A computerized program was created to present respondents with pairs of Chi consequences in random order. The respondents had to decide whether one was more severe than the other or whether the two were of equal severity. To prevent bias, the level numbers were not given; instead a brief description of the consequences at the appropriate level was presented. The experiment was performed by physicians on the medical panel and by various members of the UMTRI staff.

Overall there was general agreement among the respondents on the rankings. A single rank ordering of the five types of impairment at each of their levels was obtained. (Daily living was omitted, as it seemed to be a combination of the other five.) The

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[4]E. Petrucelli, J.D. States, D.F. Huelke, and L.N. Hames, *Injury Coding Manual: Revised Edition, 1983* (Bloomington, Ind.: Institute for Research in Public Safety, 1983).

[5]American Medical Association, Committee on Rating of Mental and Physical Impairment, *Guides to the Evaluation of Permanent Impairment* (Chicago: American Medical Association, 1971).

respondents were asked to treat the sensory impairment as a visual one, because it was believed that different sensory impairments would have vastly different rankings.

The next step was to convert the rank ordering into a percentage of whole-body impairment for each of the four levels of the five types of impairment coded by the physicians. This was done by finding in the AMA *Guides* an injury that had the equivalent consequences in terms of level and type of impairment. The results obtained are shown in Table 1.

TABLE 1

PERCENTAGE OF WHOLE-BODY IMPAIRMENT FOR
THE CHI CONSEQUENCES OF INJURY

Level	Mobility	Cognitive	Cosmetic	Sensory (Vision)	Pain
Level 4	85	95	10	85	60
Level 3	65	90	0	24	10
Level 2	16–28	25	0	10–20	0
Level 1	5	5	0	5	0

The figures in Table 1 cover all the Chi consequences other than the non-vision sensory impairments. To arrive at numbers for these the AMA *Guides* was once again consulted. In the *Guides*, most of the codings for non-visual sensory impairments seemed to fall into three groups. These were injuries to the upper extremities, injuries to the lower extremities, and other injuries that were generally comparable to impairment of hearing. Thus the AMA panel coded injuries to the scrotum that caused sensory impairment at approximately the same level as injuries producing impaired hearing. Loss of taste and smell was coded as producing virtually no whole-body impairment, but examination of the augmented Chi data produced no injuries for which the physicians had coded impaired taste or smell. It was therefore decided to use the AMA levels for hearing for all non-vision sensory impairments, other than those to the extremities. This resulted in the percentage impairments shown in Table 2.

TABLE 2

PERCENTAGE OF WHOLE-BODY IMPAIRMENT FOR NON-VISION
SENSORY IMPAIRMENTS

Level	Upper Extremities	Lower Extremities	Other Non-Vision
Level 4	60	40	20
Level 3	45	30	12
Level 2	23	15	7
Level 1	10	7	3

Using these numbers it would now be possible to translate any single impairment coded by the physicians into a whole-body impairment for the time periods used by Chi. However, for most of the injuries, the physicians had coded not a single impairment but a combination of several. So it was necessary to combine the percentage impairments in such a way that no person was impaired more than 100 percent. As a first step in this, the physicians on the medical panel were asked to code percentage of "dependency" for some of the more common combinations of the impairments in the Chi scheme. To keep this simple, this was restricted to combinations of two impairments. The following combinations of impairments were coded as follows:

1. Mobility 1 and Cognitive 1
2. Mobility 1 and Cognitive 2
3. Mobility 2 and Cognitive 2
4. Mobility 4 and Cognitive 4
5. Cosmetic 2 and Sensory 1

The same group of respondents was also asked to code a percentage of dependency for all the twenty impairments in Table 1. Thus one could see how combinations of impairments affected the scoring. Examination of the results revealed that the physicians' coding essentially matched the scheme used by the AMA to combine impairments in their "Combined Values Chart."[6] This chart uses the formula:

$$A + B(1 - A)$$

where: *A* is the proportion impaired from the first impairment, and
B is the proportion from the second impairment.

This formula can be used cumulatively to add in third and subsequent impairments. It was decided to apply this formula to the augmented Chi data to obtain whole-body impairments from the various consequences coded. Thus the first step in translating the augmented Chi data into whole-body impairments was to convert each consequence using the numbers in Tables 1 and 2; the second step was to combine these impairments using the AMA formula. The resulting impairments could be added to the NASS data along with the raw Chi consequences by a match on grouped age, OIC, and AIS severity.

CALCULATING THE PRESENT DISCOUNT VALUES

The approach used to estimate the societal consequences of injury or fatality was that developed by Hartunian,[7] which treats such consequences in terms of lifetime costs. For a fatality the main cost is the estimated value of the person's lifetime net productivity. Similarly for a person who is 50 percent impaired for the rest of his or her life, a main factor in the lifetime cost is the loss of half of that person's net productivity. Net productivity for a given age and sex is assumed to be equivalent to average earnings for that sex and age, taking into account average pay and labor force participation. The value

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[6]AMA *Guides*, pp. 158–60.

[7]N.S. Hartunian, C.N. Smart, and M.S. Thompson, *The Incidence and Economic Costs of Major Health Impairments: A Comparative Analysis of Cancer, Motor Vehicle Injuries, Coronary Heart Disease, and Stroke* (Lexington, Mass.: D.C. Heath & Co., 1981).

assigned to work by homeworkers is the pay for such work in the marketplace. These values are discounted back to the present.

Following Hartunian[8], the present discounted value (PDV) of a person can be expressed as:

$$PDV = \sum_{n=a}^{85} P_{a,s}(n) \cdot Y_s(n) \cdot E_s(n) \cdot \left[\frac{1+\gamma}{1+r}\right]^{n-a} \qquad \text{for } a \geq 16$$

(NOTE: for $a < 16$, start summation at $n = 16$.)

where:
- a = the age at onset
- s = the sex of the individual
- γ = the average annual rate of growth in labor productivity
- $Y_s(n)$ = the mean annual earnings of employed people and homemakers in the general population of age n and sex s, measured at incidence-year (1980) levels
- $E_s(n)$ = the proportion of the general population of age n and sex s employed in the labor force or engaged in housekeeping tasks
- $P_{a,s}(n)$ = the probability of a person in the general population of age a and sex s surviving to a subsequent age n
- r = the discount rate

This model assumes that the net value of a worker to the economy is equal to that worker's earnings. The model uses average earnings by age and sex, because no figures are available on the actual earnings of the accident victims. It takes into account the probability of a person of a given age and sex surviving to a subsequent age. It also, by use of a discount rate, counts future earnings as of lesser value per dollar than current earnings. The assumption here is that the current net production of a worker will be reinvested in the economy and produce returns at the discount rate. An estimated growth rate for the economy is also included.

The probabilities of survival to each subsequent age up to 85 were calculated using the most recent series of U.S. life tables.[9] Probabilities of survival for each year from year 0 (age less than 1) through year 85 were calculated by sex, resulting in a 172-by-86 matrix.

The discount rate and predicted growth in labor productivity used were the same as in NHTSA's societal cost study,[10] i.e., 7 percent and 1.5 percent, respectively. The mean annual earnings of employed people and homemakers by age and sex in 1980 dollars were also obtained from the NHTSA study, as were the participation of each age and sex group in the labor force or in homemaking.

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[8]Ibid., p. 48.

[9]National Center for Health Statistics, "United States Life Tables for 1969–71," *U.S. Decennial Life Tables for 1969–71*, 1:1 (1975), pp. 8–11.

[10]National Highway Traffic Safety Administration, Report No. DOT-HS-806-342, *The Economic Cost to Society of Motor Vehicle Accidents* (Washington, D.C.: U.S. Department of Transportation, 1983).

Using these figures, the present discount value for each age and sex could then be calculated according to the above equation. The resulting figures were then incorporated, by a match on age and sex, in the fatal occupant records in the 1980 FARS file. Using this file, a mean for each age group, for both sexes, and for all the fatally injured occupants of known sex and age could be calculated. These means were transferred back into the file of present discount values to be used where age, sex, or both were unknown. Thus if a fatally injured person's age were coded as unknown, then the mean for that person's sex would be used. The present discounted value of a person's future earnings was also calculated for the three time periods used in the Chi study: within the first year after an accident, for two to five years after the accident, and for the rest of a person's life beyond five years.

The resulting discounted values were incorporated in the NASS data by a match on the injured person's age and sex.

THE SINGLE-INJURY MODEL AND THE MULTIPLE-INJURY MODEL

At this point all the information for the original, single-injury, IPR model could be added to a NASS injury-level file. It could also be added to an occupant-level file by a match with the first OIC only. The cost function in terms of lost production could be calculated by multiplying the estimated impairment by the discounted value for the appropriate time frame. The costs for the various time frames could be summed and combined with estimated costs of medical treatment. The total resulting cost could then be multiplied by the NASS sampling weight, to give a new weighting factor. Then, by using the newly created weights, any desired analysis could be performed. The method chosen was to write a program to generate the new weights for each record as it was passed to the analysis package. This was preferred to merely incorporating the new weighting factor in the modified NASS files, because the flexibility of modifying the model and some of the costs during analysis was retained. Another advantage was obtaining a program listing as part of each analysis run, so that the program was not just a "black box," generating results with no information as to the factors being incorporated. The program was written in OSIRIS IV's RECODE language but could easily be translated for other packages. The program listing is given in Appendix A.

The program sums the costs for each individual or each injury, depending on whether an occupant-level file or an injury-level file is being used. Only cases with an AIS between 2 and 6 were included. The final cost was then multiplied by the NASS weighting factor to create a new weighting factor for the analysis program.

The first factor calculated was the proportion of a person's stay spent in intensive care, and the converse, the proportion in non-intensive care. Here the figures from NHTSA's societal cost study, which infer the proportions from the AIS, were used. They are shown in Table 3. If a fatality occurred at an AIS of less than 6, the proportions for AIS 5 were used.

The number of days spent in the hospital was derived from the NASS variable that gives this information. Unfortunately, the NASS information stops at 31 days. The NASS number was used unless the case was an AIS-5 spinal-cord victim or unless the NASS information was missing. For the AIS-5 spinal-cord victims, a midpoint of 150 days was taken from the range in the NHTSA study. For the cases with the information missing in NASS, the values were taken from the NHTSA study: 10 days for an AIS 2, 11 days for an AIS 3, 17 days for an AIS 4, and 26 days for an AIS 5. NHTSA again

TABLE 3

PERCENTAGE OF HOSPITAL STAY IN INTENSIVE AND NON-INTENSIVE CARE

AIS Level	Percentage in Intensive Care	Percentage in Non-Intensive Care
AIS 2 .	0	100
AIS 3 .	10	90
AIS 4 .	30	70
AIS 5 .	60	40
AIS 6 .	100	0

provided the costs of a hospital stay in 1980 dollars at $515 a day for intensive care and $215 a day for non-intensive care.

The same methods were used to calculate the value of work days lost. The NASS variable indicating work days lost was used unless the value was unknown or the case was a spinal-cord victim. If work days lost was unknown, then the "fixed" number for days in the hospital was substituted. For spinal-cord victims, it was assumed that the whole of the first year after the accident would be lost. The cost of a single lost workday was calculated as the persons's productive value in the current year divided by 365. This cost was then multiplied by the "fixed" number of lost workdays. Fatal cases were assigned zero workdays lost, since these costs were already incorporated in their lifetime productive value.

For the period beyond the current (accident) year, the estimates of impairment derived from the augmented Chi data were used for all non-fatal cases. The impairment for the appropriate time span was multiplied by the present value of future earnings for the time span. For fatal cases, only the costs of hospital care and the present value of future earnings were summed and all injuries beyond the first were ignored. In other words, it was assumed that fatally injured persons had died from their most severe injury. This prevented the large cost factors for a fatality being attributed to relatively minor injuries and so distorting the analysis. Finally, all the costs were summed and multiplied by the NASS weighting factor.

The program for the multi-injury model is essentially the same. It merely uses a different set of impairment variables in calculating the costs of lost productivity beyond the current year. These new impairment variables were calculated in such a way that the total impairment for a given individual can never sum to more than 100 percent. The formula used here was an adaptation of that used in combining the impairments from the various categories in the augmented Chi data, namely:

$$AI = OI\,(1 - CI)$$

where: *AI* is the adjusted impairment,
OI is the original impairment calculated from the OIC, and
CI is the cumulative impairment defined as $\sum_{n=0}^{n-1} OI$
where *n* is the number of the injury to a given individual.

Using this formula, the adjusted impairment for a given injury is calculated as a percentage of the remaining "unimpaired" portion for a given individual. Thus if a person is estimated to be 60 percent impaired from his or her first injury, the "unimpaired" portion for that person is the remaining 40 percent. Then, if that person sustains a second injury that is estimated to result in 50 percent impairment, the adjusted impairment for the second injury is 50 percent of 40 percent, namely 20 percent.

While the total cumulative impairment for a given individual is not affected by the order in which the adjusted impairments are calculated, the adjusted impairments themselves are affected. The earlier a particular injury is passed to the routine that calculates the adjusted impairment, the larger that adjusted impairment will be. In the above two-injury example, if the adjusted impairment for the second injury were calculated first, the result would be the full 50 percent, while the adjusted impairment for the first injury (now calculated second) would be reduced to 30 percent. The total cumulative impairment would still be 80 percent.

It was thought reasonable, therefore, to pass the larger raw impairments to the program that calculated the adjusted impairments first, so that severe injuries would be counted at close to "full strength." The injuries for each individual were therefore sorted into order of decreasing impairment before being passed to the calculation program. This was done separately for each of the relevant Chi time periods, from two to five years after the accident and beyond five years after the accident.

The final data structure contains both the original, raw impairments and the new, adjusted impairments. The user can thus run an analysis with either the original IPR model or with the new model. To distinguish the new model from the old it will be called "Multi-Injury Priority Rating" or MIPR.

THE ACCIDENT DATA

The original work using the IPR model applied that model to 1980 and 1981 NASS data. However, the combination of those two years yielded only 2,262 injuries of severity AIS 2–6 to passenger-car occupants. It was therefore decided, for the current work, to build a four-year file combining NASS data from 1980 through 1983. The new file contains information on 8,379 injuries of AIS 2–6 to motor-vehicle occupants, of which 6,598 are to passenger-car occupants.[11] The elimination of injuries beyond the first to fatally injured occupants reduces these two numbers to 7,388 and 5,811, respectively. The final total of 5,811 injuries to occupants of passenger cars being used in analysis is somewhat disappointing. It points, once again, to the need for the emphasis in the NASS

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[11]Thirty-seven injuries, originally coded by NASS as AIS 2, ought to have been coded AIS 1 and have been deleted from the four-year file used for analysis. Before deletion of these cases, there were 8,416 injuries in the file.

system to be shifted to accidents involving injury, with data collection on minor accidents being eliminated or severely restricted. It is currently very difficult, because of inadequate sample size, to perform multivariate analysis of NASS injury cases.

When this project was started, it was hoped that two strategies would help solve some of the problems with NASS sample size. The first of these was to attempt to reduce the proportion of cases in NASS coded with unknown contact point. The second was to use alternative data sources where the information in NASS on a particular crash configuration or occupant injury was inadequate. Unfortunately, neither strategy was very successful.

One way to extract further information from NASS is to reduce the percentage of missing data. Problems with delta V will be discussed later, but there is also a significant amount of missing data in the coding of contact point in the occupant OIC set of variables. When the 1980 through 1983 NASS files are combined, the passenger-car subset has contact point missing for 34 percent of AIS 2–6 injuries. Contact point is missing for 38 percent of the AIS 2–6 head injuries and 46 percent of the neck injuries. Because of the sponsor's interest in head and neck injuries, and because of the large proportion of missing contact points for such injuries, it was thought beneficial to read through the hard-copy documentation of head and neck injury cases with unknown contact points in the hope of establishing a relatively certain source of injury. All such cases available (a few were missing) were studied, but this effort produced only a total of 121 additional contact points.[12] That reduced missing data for head and neck injuries with AIS 2–6 from 39 percent to 33 percent.

The second strategy, that of using alternative data sources where the information in NASS was too meager, met with a number of obstacles. The computer file of one promising data source, the National Electronic Injury Surveillance System (NEISS), arrived too late to be incorporated in the analysis. The NEISS data, collected by the Consumer Product Safety Commission from hospitals, are intended to provide a sample of all product-related injuries resulting in emergency room treatment. The National Highway Traffic Safety Administration (NHTSA) supported the data collection for several years, and the NEISS data from 1980 through 1982 contain cases where one of the products involved in the injury is a motor vehicle. The data collected on behalf of NHTSA have been built into a computerized database at UMTRI and await analysis.

It was also hoped to use the University of Michigan In-Depth Vehicle and Occupant Report (UMIVOR) data. Using the UMIVOR protocol, selected accidents are investigated in great detail. It was hoped that UMIVOR could be used to supplement NASS: by matching up appropriate subsets in the two data collection systems it would be possible to substitute analysis of the dataset with more cases in the subset (UMIVOR) for analysis of the dataset with insufficient cases (NASS). UMIVOR does indeed have a much better missing data rate than NASS. However, because of the small number of cases investigated each year, UMIVOR still tends to have many fewer cases with *known* values than NASS. The cumulative total of UMIVOR cases, through Update 3, is 1,073 vehicles, of which 904 are passenger cars. UMIVOR has data on only 447 occupants with AIS 2–6

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[12]The numbers for the respective accident years were 18 cases for 1980, 31 for 1981, 40 for 1982, and 32 for 1983.

injuries. In addition, UMIVOR lacks information on collision severity (delta V)[13] and, perhaps because of certain factors in the case selection, the distribution of clock direction in UMIVOR is very different from that in NASS.[14] A fuller discussion of these issues is to be found in Appendix B.

Because of these problems with the supplementary data sets, the analysis has been restricted to NASS. It is important therefore to emphasize once again some of the shortcomings of the NASS scheme. One of these has already been mentioned: NASS suffers from an inadequate number of investigations of accidents that result in serious injuries. This problem is compounded by a second: the unknown size of the variances associated with the estimates derived from NASS. Because of the complex sample design used in NASS, many of the estimates may have very large design effects. It is to be hoped that a more straightforward sampling scheme, one susceptible to some of the generally available sampling error programs, will be adopted. A third difficulty, also already alluded to, is the high rate of missing data, particularly for a number of the important variables in examining injury causation—clock direction, delta V, and contact point. In spite of all these problems, NASS still constitutes the best currently available source on issues of passenger-car occupant protection.

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[13]The codebook indicates that crash reconstruction was performed on 26 percent of the vehicles. However, the results of the reconstruction are not included in the computerized dataset.

[14]As in NASS, clock direction is based on the subjective opinion of the investigator. The CRASH2 program used to generate delta V uses clock direction in its internal calculations and would therefore require only a slight modification to list this information. This would almost certainly produce more reliable results than the current practice of relying on the judgment of the investigator.

RESULTS

OVERVIEW

This section presents the results of applying the new MIPR model to the combined 1980–83 NASS file. All the results are presented at the injury level; i.e., the MIPR value is calculated for each injury and then summed within each analysis stratum. Only the first injury to fatally injured occupants is counted, with the presumption that the fatality was due to this injury alone. Most tables present distributions of MIPR in terms of percentages, since the dollar amounts (estimated sums of MIPR in dollars resulting from four years of accidents) are not of themselves very enlightening.

IPR AND MIPR MODELS APPLIED TO OCCUPANTS OF ALL VEHICLES

The new, multi-injury model is clearly more satisfactory from a theoretical point of view, since the cost of lost production for any individual cannot be greater than that person's net lifetime value. It was not clear, however, that the results using MIPR would be radically different from the results obtained using the simpler IPR model. It was therefore thought enlightening to compare the overall distribution of consequences of injury across vehicle type and body region using both models. The results are presented in Tables 4 and 5. The first applies the old IPR model, the second the new MIPR model. The distributions are little different, and the overall percentages for each vehicle class are virtually identical. The share for on/off road vehicles is noticeably high at 5.1 percent, given their 1.1 percent share of the vehicle population in 1980.[1] The share of consequence of injury by body region is similar though not identical. Not unexpectedly, the single-injury model gives slightly less weight to injuries that are more likely to result in long-term impairment, such as those to the head and chest. This is because secondary injuries are given comparatively more weight by that model. This is reflected in the greater weights given by the single-injury model to injuries to the face, thigh, and knee. It should be noted that, while the percentage distributions are very similar, the dollar totals are also very similar but a little lower for the multi-injury model. The single-injury model overestimates the consequences of secondary injuries. This results in a grand total of $29.78 billion of IPR from all body regions and vehicle types, compared to $29.37 billion of MIPR.

PASSENGER CAR OCCUPANTS: THE GENERAL PICTURE

The remainder of this report will concentrate on passenger car occupants and, in particular, on front-seat occupants of passenger cars. Table 6 compares the distribution of MIPR for restrained and unrestrained passenger car occupants. The row percentages and sample sizes at the bottom of the table should be noted: there are very few cases of injury to restrained passenger car occupants in NASS (258 in four years), and restrained occupants account for only 2.4 percent of MIPR to passenger car occupants as a whole.

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[1]Federal Highway Administration, *Highway Statistics 1980* (Washington, D.C.: U.S. Department of Transportation), p. 160; S.R. Smith, *Analysis of Fatal Rollover Accidents in Utility Vehicles*, Report No. DOT-HS-806-357 (Washington, D.C.: U.S. Department of Transportation, 1982), p. 10.

TABLE 4

1980-83 NASS:
PERCENT IPR BY BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off-Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	32.3	0.0	3.1	7.5	1.0	43.9
Face	6.5	0.0	0.2	2.2	0.2	9.1
Neck	6.7	0.0	0.5	1.1	0.6	8.9
Shoulder ..	0.2	0.0	0.0	0.1	0.0	0.3
Chest	14.7	0.0	0.6	2.0	1.2	18.5
Back	0.9	0.0	0.0	0.0	0.0	1.0
Abdomen ..	4.8	0.0	0.0	0.5	0.4	5.8
Pelvis	0.6	0.0	0.0	0.1	0.0	0.7
Thigh	1.6	0.0	0.1	0.6	0.0	2.2
Knee	1.0	0.0	0.5	0.2	0.0	1.8
Lower leg ..	0.6	0.0	0.0	0.0	0.3	1.0
Ankle/foot .	0.8	0.0	0.0	0.4	0.0	1.2
Lower limb .	0.0	0.0	0.0	0.3	0.0	0.3
Upper arm .	0.6	0.0	0.0	0.3	0.0	0.9
Elbow	0.2	0.0	0.1	0.0	0.0	0.3
Forearm ..	0.9	0.0	0.0	0.2	0.0	1.2
Wrist/hand .	0.4	0.0	0.0	0.5	0.0	0.9
Upper limb .	0.2	0.0	0.0	0.2	0.0	0.4
Whole body	0.6	0.0	0.0	0.7	0.2	1.4
Unknown ..	0.2	0.0	0.0	0.0	0.0	0.2
Total	73.8	0.0	5.1	17.0	4.1	100.0
N	5,811	24	202	1,191	159	7,387

For restrained occupants, MIPR occurs overwhelmingly to the head and face. These two regions combined account for 85.0 percent of restrained MIPR. Interestingly, neck MIPR is lower as a percentage of overall MIPR than it is for unrestrained occupants. There is at least a hint here that current restraints (or rather current restraints as they are actually used) are not completely effective in preventing head and face injuries. On the other hand they seem to be very effective in preventing chest injuries.

Table 6 also demonstrates that the accident population in NASS is predominantly unbelted. Thus, while the remaining tables have not generally been filtered to exclude restrained occupants, the distributions shown are in reality ones for an unbelted population.

Table 7 shows the distribution of MIPR by seat position for passenger car occupants. The relative share of MIPR incurred by each seat position is shown in the "Row %" line at the bottom of the table. The combined front seat positions account for 91.7 percent of MIPR. The front center seat position incurs relatively more MIPR to the head than either the front left or front right positions. The front center position also stands out for the share of MIPR attributable to abdominal injury—almost four times as much, relatively, as for drivers. Chest MIPR is commensurately low for center-front occupants. Overall,

TABLE 5

1980-83 NASS:
PERCENT MIPR BY BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off-Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	32.5	0.0	3.1	7.5	1.0	44.1
Face	6.3	0.0	0.2	2.1	0.2	8.8
Neck	6.7	0.0	0.5	1.1	0.6	8.9
Shoulder ..	0.2	0.0	0.0	0.1	0.0	0.3
Chest	14.9	0.0	0.6	2.0	1.2	18.7
Back	0.9	0.0	0.0	0.0	0.0	1.0
Abdomen ..	4.8	0.0	0.0	0.5	0.4	5.8
Pelvis	0.6	0.0	0.0	0.1	0.0	0.7
Thigh	1.5	0.0	0.1	0.5	0.0	2.1
Knee	0.9	0.0	0.5	0.2	0.0	1.7
Lower leg ..	0.6	0.0	0.0	0.0	0.3	1.0
Ankle/foot .	0.8	0.0	0.0	0.4	0.0	1.2
Lower limb .	0.0	0.0	0.0	0.3	0.0	0.3
Upper arm .	0.6	0.0	0.0	0.3	0.0	0.9
Elbow	0.2	0.0	0.1	0.0	0.0	0.3
Forearm ..	0.9	0.0	0.0	0.2	0.0	1.2
Wrist/hand .	0.4	0.0	0.0	0.5	0.0	0.9
Upper limb .	0.2	0.0	0.0	0.2	0.0	0.4
Whole body	0.6	0.0	0.0	0.7	0.2	1.4
Unknown ..	0.2	0.0	0.0	0.0	0.0	0.2
Total	73.8	0.0	5.1	16.9	4.1	100.0
N	5,811	24	202	1,191	159	7,387

injuries to the head, face, and neck account for a preponderant share of MIPR, regardless of seat position. The three body regions combined are responsible for 60.9 percent of driver MIPR, 73 percent of center-front MIPR, and 58.2 percent of right-front MIPR. For left-front and right-front occupants, chest injuries are second to head, face, and neck injuries in share of MIPR.

The counterpart to the large weighting given by the model to injuries to the head and trunk areas is the small weighting assigned to injuries to the extremities. These are injuries that, on the whole, result in little or no long-term impairment and which therefore produce only small costs in a model whose large costs result from lost productivity.

The distribution of MIPR by direction of force for the first CDC is given in Table 8. The 12 o'clock direction is responsible for over one-third of MIPR overall, somewhat less for right-front passengers. Right-front passengers also incur a substantial amount of MIPR from 10 o'clock, 1 o'clock, 2 o'clock, and 3 o'clock collisions. They are thus incurring injuries with long-term consequences both from oblique left collisions and from right-side collisions. For drivers, on the other hand, MIPR results almost entirely from directions of force in the 9 o'clock through 2 o'clock arc. Non-horizontal directions of force, typically

TABLE 6

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR OCCUPANTS
BY BODY REGION AND RESTRAINT USE

Body Region	Restrained	Unrestrained	All
Head	73.1	43.2	44.0
Face	11.9	8.5	8.6
Neck	1.9	9.3	9.1
Shoulder ..	0.2	0.3	0.3
Chest	3.2	20.6	20.1
Back	0.7	1.2	1.2
Abdomen ..	1.7	6.6	6.5
Pelvis	0.1	0.9	0.8
Thigh	4.7	2.0	2.1
Knee	1.7	1.3	1.3
Lower leg ..	0.2	0.9	0.8
Ankle/foot .	0.1	1.1	1.1
Lower limb .	0.0	0.0	0.0
Upper arm .	0.0	0.8	0.8
Elbow	0.0	0.2	0.2
Forearm ..	0.2	1.3	1.3
Wrist/hand .	0.3	0.6	0.5
Upper limb .	0.0	0.3	0.3
Whole body	0.0	0.8	0.8
Unknown ..	0.0	0.3	0.3
Total	100.0	100.0	100.0
Row %	2.4	97.6	100.0
N	258	5,553	5,811

rollovers, account for a substantial proportion of MIPR for all seat positions, but particularly for drivers.

DELTA V AND DIRECTION OF FORCE FOR PASSENGER CAR OCCUPANTS

The ideal data file on automobile injury causation would perhaps permit analysis of injuries by seat position, crash severity, direction of force, and injury source (contact point). Even with a four-year NASS file, this level of detail proved impossible, and analysis had therefore to be limited to any three of these factors at one time. Results for crash severity (delta V) and direction of force, both without and with seat position, are presented first.

Table 9 provides the distribution of MIPR across delta V by direction of force for all passenger car occupants. The relative importance of each column, i.e., of each clock direction, can be obtained by reference to Table 8. It is particularly important here to note the large proportion of MIPR resulting from collisions with unknown delta V—62.3 percent. Even if rollovers were excluded, since by definition delta V is unknown for them,

TABLE 7

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR OCCUPANTS
BY BODY REGION AND SEAT POSITION

Body Region	Seat Position				
	Left Front	Center Front	Right Front	Other	All
Head	41.5	65.2	41.8	66.3	44.0
Face	9.4	2.4	7.3	4.8	8.6
Neck	10.0	5.4	9.1	1.8	9.1
Shoulder ..	0.3	0.4	0.2	0.2	0.3
Chest	22.1	0.7	19.2	8.0	20.1
Back	0.4	1.2	5.3	0.2	1.2
Abdomen ..	5.3	19.3	8.2	11.1	6.5
Pelvis	1.0	0.4	0.6	0.1	0.8
Thigh	2.1	1.9	2.1	1.7	2.1
Knee	1.4	1.5	0.7	0.6	1.3
Lower leg ..	1.0	0.6	0.3	0.1	0.8
Ankle/foot .	1.4	0.4	0.3	0.4	1.1
Lower limb .	0.0	0.0	0.0	0.0	0.0
Upper arm .	1.1	0.1	0.1	0.1	0.8
Elbow	0.3	0.1	0.2	0.0	0.2
Forearm ..	1.3	0.4	1.3	0.6	1.3
Wrist/hand .	0.4	0.1	1.2	0.3	0.5
Upper limb .	0.2	0.0	0.4	0.0	0.3
Whole body	0.4	0.0	1.2	3.6	0.8
Unknown ..	0.3	0.0	0.4	0.0	0.3
Total	100.0	100.0	100.0	100.0	100.0
Row %	73.3	1.5	16.9	8.3	100.0
N	3,757	120	1,348	586	5,811

the overall proportion of MIPR attributable to involvements with unknown delta V would be 55.3 percent. For clock directions 1, 2, 4, 9, and 10, collisions with unknown delta V account for more than half of MIPR. Equally, some of the distributions are based on an insufficient number of cases to be reliable. The distributions for clock directions 4, 5, and 7 should be discounted for this reason. For the more reliable distributions, what generally stands out is how little of the MIPR is incurred at high delta Vs. Only for the 10 o'clock, 11 o'clock, and 12 o'clock directions is a large proportion of MIPR caused by crashes with a delta V greater than 30 m.p.h.

Tables 10 and 11 examine the same relationship separately for drivers and right-front passengers. Once again the high proportion of MIPR attributable to unknown delta V should be noted. And once again certain distributions should be discounted because of inadequate sample sizes. The driver distributions for clock directions 4, 5, and 7 and the right-front passenger distributions for clock directions 4, 5, 6, 7, 8, and 9 fall into this category. The relative size of each column can be obtained from Table 8. For the drivers,

TABLE 8

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR OCCUPANTS
BY DIRECTION OF FORCE AND SEAT POSITION

Direction of Force	Seat Position			
	Left Front	Right Front	Other and Unknown	All
1 o'clock	4.9	10.1	1.8	5.5
2 o'clock	7.3	9.4	15.0	8.4
3 o'clock	2.0	8.4	4.9	3.3
4 o'clock	0.0	0.2	1.7	0.2
5 o'clock	0.1	0.6	0.3	0.2
6 o'clock	0.3	0.8	1.1	0.5
7 o'clock	0.6	0.3	0.0	0.5
8 o'clock	0.5	1.1	3.3	0.9
9 o'clock	5.2	2.0	1.0	4.3
10 o'clock	6.5	13.1	6.8	7.7
11 o'clock	7.0	1.8	7.4	6.1
12 o'clock	35.4	28.6	39.8	34.7
Non-horizontal	17.2	12.2	10.2	15.7
Unknown	13.0	11.4	6.7	12.1
Total	100.0	100.0	100.0	100.0
N	3,757	1,348	706	5,811

only clock directions 2, 3, 10, 11, and 12 have a large proportion of MIPR occurring from more-severe collisions, those with a delta V greater than 30 m.p.h. That drivers are incurring a significant amount of their long-term injuries in high-speed crashes with frontal or left-oblique force directions is no surprise. But that there are similar consequences to collisions with 2 o'clock and 3 o'clock force directions is perhaps more remarkable, particularly as the 2 o'clock direction accounts for as much as 7.3 percent of driver MIPR.

For the right-front occupants shown in Table 11, the only distributions with adequate sample size are those for clock directions 1, 2, 3, 10, 11, and 12. Of these only clock directions 2, 10, and 12 have a large proportion of MIPR occurring from collisions with a delta V greater than 30 m.p.h.

The next set of tables examines the relationship between seat position, delta V, direction of force, and body region. The first of these, Table 12, shows the distribution of driver MIPR by clock direction for a four-way grouping of body region. Head-on collisions at 12 o'clock lead in the share of MIPR for all groups of body region except the upper extremities. They account for a particularly large share of MIPR to the lower extremities. A particularly large share of MIPR to the trunk region (the combination of chest, back, and abdomen) and to the upper extremities is caused by crashes with a 2 o'clock direction of force. Turning to right-front passengers in Table 13, the head-on collisions at 12 o'clock consistently lead in share of MIPR, regardless of body region. Ten o'clock crashes are important contributors to head and trunk area MIPR, 11 o'clock crashes to MIPR to the

TABLE 9

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR OCCUPANTS
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force														
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.1	1.8	0.4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1
6-10 mph	1.6	7.0	1.9	0.0	0.2	0.0	0.1	2.1	0.9	1.5	3.3	0.2	0.0	0.1	1.2
11-15 mph	6.8	3.6	15.8	0.1	49.9	9.6	0.3	5.1	4.4	9.4	17.9	1.8	0.0	2.5	4.3
16-20 mph	3.0	8.2	15.6	14.4	33.7	18.9	1.0	0.7	2.2	4.7	13.0	5.0	0.0	0.1	4.6
21-25 mph	4.2	5.6	9.7	0.1	9.4	5.7	24.0	0.0	5.0	9.2	13.8	11.9	0.0	0.1	7.1
26-30 mph	15.7	5.5	8.5	2.7	0.0	26.6	0.0	57.0	4.1	2.9	8.1	6.5	0.0	0.1	5.4
31-35 mph	0.3	1.7	2.2	0.0	0.0	3.4	0.0	1.3	0.0	1.3	7.1	6.3	0.0	0.1	3.0
36-40 mph	0.1	1.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.6	10.9	0.0	0.0	4.1
41-45 mph	0.6	2.6	0.0	0.0	0.0	0.2	0.0	0.0	0.0	3.5	0.0	4.4	0.0	0.0	2.0
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	32.9	0.0	0.0	0.0	0.0	1.7	0.0	0.5	0.8
51-55 mph	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	3.1	0.0	4.9	0.0	0.0	1.9
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	11.2	0.0	6.7	0.0	0.0	3.2
Unknown .	67.7	63.9	43.2	82.3	6.8	34.0	41.8	33.8	83.1	52.5	36.2	39.7	100.0	96.4	62.3
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	382	442	166	29	26	82	33	69	180	393	560	1,884	679	886	5,811

TABLE 10

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR LEFT-FRONT OCCUPANTS
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force														
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.1	4.3	9.8	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.1
6-10 mph	2.2	3.4	2.7	0.0	0.5	0.0	0.1	4.2	0.9	2.3	2.8	0.3	0.0	0.2	0.9
11-15 mph	10.2	2.6	27.4	2.8	10.0	13.4	0.0	1.1	4.5	11.2	18.1	1.4	0.0	3.2	4.4
16-20 mph	3.8	4.7	3.9	32.4	76.0	1.9	1.1	1.3	1.5	2.9	14.2	5.5	0.0	0.1	3.9
21-25 mph	4.5	5.6	2.2	0.9	11.2	7.2	26.8	0.0	5.4	9.2	12.3	12.2	0.0	0.1	6.9
26-30 mph	15.2	2.5	0.0	0.0	0.0	4.6	0.0	11.1	4.6	1.1	9.4	6.9	0.0	0.1	4.4
31-35 mph	0.5	0.1	5.1	0.0	0.0	2.1	0.0	3.0	0.0	2.0	8.5	5.0	0.0	0.1	2.7
36-40 mph	0.1	3.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	11.7	0.0	0.0	4.5
41-45 mph	0.8	4.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	1.8
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	35.7	0.0	0.0	0.0	0.0	1.5	0.0	0.6	0.8
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	6.0	0.0	0.0	2.4
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	9.0	0.0	2.6	0.0	0.0	1.5
Unknown .	62.7	73.8	51.5	54.1	2.2	70.1	36.3	79.2	82.9	56.2	33.7	42.7	100.0	95.6	65.4
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	252	254	84	10	12	51	26	45	117	247	368	1,286	420	585	3,757

TABLE 11

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force														
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.2	4.9	1.6	0.0	0.0	0.0	0.0	1.3	0.2	0.1	1.7	0.1	0.0	0.0	0.7
11-15 mph	0.2	5.3	9.3	0.0	89.7	7.1	2.8	1.8	2.0	1.5	21.1	5.1	0.0	0.1	4.0
16-20 mph	1.2	26.9	31.1	99.5	0.8	0.4	0.0	0.0	10.6	10.0	9.5	5.5	0.0	0.0	8.7
21-25 mph	4.2	7.7	12.5	0.5	0.0	7.8	0.0	0.0	0.8	1.6	35.2	13.5	0.0	0.1	7.0
26-30 mph	18.3	0.4	20.1	0.0	0.0	78.4	0.0	94.9	0.0	0.5	4.4	6.7	0.0	0.0	7.3
31-35 mph	0.0	8.5	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.8	7.8	0.0	0.0	3.1
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	3.2
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	7.3	0.0	0.0	3.7
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0	4.4	0.0	0.0	1.3
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.7
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.2	0.0	17.9	0.0	0.0	7.6
Unknown .	75.8	46.3	25.4	0.0	9.5	5.9	88.0	1.9	86.4	55.1	27.3	18.1	100.0	99.8	52.8
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	86	132	54	6	10	22	6	13	33	89	120	399	170	208	1,348

extremities. Head-area, trunk-area, and lower-extremity MIPR is also occurring significantly at 1, 2, and 3 o'clock.

TABLE 12

1980–83 NASS:
PERCENT MIPR FOR PASSENGER CAR LEFT-FRONT OCCUPANTS
BY DIRECTION OF FORCE AND GROUPED BODY REGION

Direction of Force	Grouped Body Region					
	Head, Face, & Neck	Chest, Back, & Abdomen	Upper Extrem.	Lower Extrem.	Other & Unknown	All
1 o'clock	6.3	2.1	9.6	2.6	0.0	4.9
2 o'clock	2.6	17.9	11.5	2.4	18.4	7.3
3 o'clock	2.9	0.3	0.8	1.2	0.0	2.0
4 o'clock	0.0	0.0	0.0	0.0	0.0	0.0
5 o'clock	0.1	0.0	0.6	0.0	0.0	0.1
6 o'clock	0.4	0.0	0.1	0.1	0.2	0.3
7 o'clock	0.7	0.5	0.1	0.3	0.0	0.6
8 o'clock	0.6	0.3	0.2	0.5	0.0	0.5
9 o'clock	2.8	5.7	2.0	23.7	28.8	5.2
10 o'clock	5.5	9.7	1.0	5.7	0.0	6.5
11 o'clock	7.2	4.4	26.2	5.3	3.9	7.0
12 o'clock	35.3	35.1	20.9	45.9	32.4	35.4
Non-horizontal	22.3	9.5	20.2	3.7	0.4	17.2
Unknown	13.1	14.6	6.9	8.5	15.9	13.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
N	1,605	783	578	781	10	3,757

TABLE 13

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS BY DIRECTION OF FORCE AND GROUPED BODY REGION

Direction of Force	Grouped Body Region					
	Head, Face, & Neck	Chest, Back, & Abdomen	Upper Extrem.	Lower Extrem.	Other & Unknown	All
1 o'clock	10.3	11.0	1.4	10.2	0.0	10.1
2 o'clock	9.4	9.4	2.0	20.0	0.2	9.4
3 o'clock	4.5	16.5	3.4	6.7	0.0	8.4
4 o'clock	0.3	0.0	0.1	0.0	0.0	0.2
5 o'clock	0.1	0.0	14.5	0.0	0.0	0.6
6 o'clock	1.4	0.0	0.6	0.2	0.0	0.8
7 o'clock	0.5	0.0	0.0	0.0	0.0	0.3
8 o'clock	1.6	0.5	0.0	0.0	0.0	1.1
9 o'clock	3.3	0.1	0.5	0.3	0.0	2.0
10 o'clock	17.0	9.5	0.9	2.9	0.0	13.1
11 o'clock	1.4	0.1	18.8	7.5	0.0	1.8
12 o'clock	23.8	32.5	30.9	45.4	76.4	28.6
Non-horizontal	14.2	10.7	11.5	1.9	0.0	12.2
Unknown	12.3	9.9	15.1	4.8	23.4	11.4
Total	100.0	100.0	100.0	100.0	100.0	100.0
N	526	219	253	346	4	1,348

Tables 14 through 21 attempt to examine the relationship of delta V to direction of force by seat position and grouped body region. Unfortunately, they tend more to point to the limitations of the NASS data, even when using a four-year combined file, than to inform the analyst. Few of the distributions shown have sufficient sample size (a minimum of 30 cases with known delta V has been taken as a minimum requirement) to be valid. The shortage of cases is particularly troublesome for the tables on right-front passengers, Tables 18 to 21.

Table 14 shows the distribution of MIPR to the head, face, and neck for drivers. Only the columns showing the distributions for clock directions 1, 2, 10, 11, and 12 have an adequate number of cases. Of these, only the 10 through 12 quadrant shows a large proportion of MIPR occurring in crashes with a delta V greater than 30 m.p.h. In Table 15, on driver MIPR to the trunk area, only the 2 o'clock and 10 through 12 o'clock distributions have sufficient cases. At 2 o'clock, 10 o'clock, and 12 o'clock more MIPR is incurred as a result of high-severity collisions than from low-severity collisions. The 10 o'clock distribution is particularly skewed towards very-high-speed collisions and should be contrasted with the 10 o'clock distribution for head, face, and neck injuries in the previous table. In Table 16, on upper-extremity injuries to drivers, only the distributions for clock directions 1, 2, 11, and 12 have an adequate number of cases. They show that upper-extremity MIPR is predominantly caused by low-severity crashes. This is generally true too of MIPR to driver lower extremities, shown in Table 17. Here only the 1, 10, 11, and 12 o'clock distributions have sufficient cases. Only at 12 o'clock is there much lower-extremity MIPR from more-severe crashes.

The final four tables in this subsection, for right-front occupants, have even sparser data than the previous set on grouped body region for drivers. In Table 18, on MIPR to the head, face, and neck, only two columns, those showing the distributions for 2 o'clock and 12 o'clock directions of force, have an adequate number of cases. At 12 o'clock, MIPR to the head area is split almost equally between the less-severe and the more-severe crashes. At 2 o'clock, there is a substantial contribution from crashes with a 31–35 m.p.h. delta V, but none from even more severe crashes. Table 19, on MIPR to the trunk area, only one column, that for 12 o'clock, has adequate data. Here MIPR is caused at all levels of crash severity except the least severe. In Tables 20 and 21, on MIPR to the extremities, the 12 o'clock distributions are once again the only ones with sufficient cases. They show that, in direct frontal crashes, both upper- and lower-extremity MIPR occurs to a somewhat greater extent as a result of the less-severe crashes.

One solution to the problem of inadequate sample size is to combine levels on the variables being analyzed. This strategy has been adopted to produce Figure 2, which summarizes the data displayed in Tables 14 through 21 but ignores the dimension of clock direction and, in addition, groups body region and delta V. The MIPR for each grouped body region and seat position is shown with a split between the less-severe crashes (delta V of 30 mph or less) and the more-severe crashes (delta V over 30 mph). The contrast between driver and right-front passenger in MIPR to the lower extremities is particularly striking. The same strategy of combining across some variables to increase the degree to which other variables can be analyzed is used in the next subsection.

TABLE 14

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR LEFT-FRONT OCCUPANTS WITH HEAD, FACE, AND NECK INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force														
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	4.7	10.3	0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.1	0.0	0.1	0.2
6-10 mph	2.7	13.6	0.7	0.0	0.0	0.0	0.1	5.0	2.5	2.7	2.4	0.4	0.0	0.1	1.1
11-15 mph	3.9	9.9	30.5	0.0	14.2	9.8	0.0	1.0	11.7	4.6	24.6	1.8	0.0	0.7	4.5
16-20 mph	3.7	19.3	2.5	32.9	68.8	2.0	1.0	0.0	1.0	4.4	16.2	5.0	0.0	0.2	4.1
21-25 mph	2.6	21.9	1.7	0.0	15.5	6.3	3.0	0.0	0.0	10.3	12.0	13.0	0.0	0.1	6.9
26-30 mph	7.3	0.7	0.0	0.0	0.0	5.0	0.0	0.0	0.0	2.0	3.5	6.0	0.0	0.0	3.0
31-35 mph	0.5	0.3	5.7	0.0	0.0	1.8	0.0	0.0	0.0	3.5	13.1	2.1	0.0	0.0	2.1
36-40 mph	0.1	0.1	3.1	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.2	14.3	0.0	0.0	5.3
41-45 mph	1.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	1.2
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	50.3	0.0	0.0	0.0	0.0	0.1	0.0	1.0	0.5
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	1.4
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.4
Unknown .	78.1	34.3	51.1	56.8	1.6	74.8	45.6	93.9	84.3	70.7	27.9	49.0	100.0	97.9	69.3
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	113	114	37	6	8	31	11	8	30	99	146	550	199	253	1,605

TABLE 15

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR LEFT-FRONT OCCUPANTS WITH CHEST, BACK, AND ABDOMEN INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force												
	1 o'clock	2 o'clock	3 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.4	0.2	8.0	0.0	0.0	1.0	0.3	2.2	7.4	0.1	0.0	0.0	0.7
11-15 mph	7.2	0.2	1.1	65.5	0.0	1.6	1.8	16.1	11.0	0.6	0.0	8.9	3.9
16-20 mph	0.5	0.1	19.8	0.0	0.0	4.0	0.3	0.4	0.3	8.2	0.0	0.1	3.1
21-25 mph	0.2	1.2	0.5	22.9	100.0	0.0	16.2	3.2	16.3	13.5	0.0	0.0	7.4
26-30 mph	78.5	1.0	0.0	0.0	0.0	67.9	15.0	0.1	39.8	5.9	0.0	0.0	6.7
31-35 mph	0.0	0.0	0.2	9.8	0.0	19.4	0.0	0.5	1.3	9.4	0.0	0.2	3.5
36-40 mph	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	8.2	0.0	0.1	3.7
41-45 mph	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	3.9
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	6.3	0.0	0.0	3.4
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.8	0.0	4.3	0.0	0.0	3.6
Unknown .	13.2	87.1	70.5	1.8	0.0	6.1	66.4	43.7	23.2	35.4	100.0	90.7	60.2
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	38	65	21	9	1	18	30	73	74	256	98	100	783

TABLE 16

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR LEFT-FRONT OCCUPANTS WITH UPPER EXTREMITY INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force														
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.1	0.0	0.0	0.1
6-10 mph	0.1	4.7	0.0	0.0	0.0	0.0	5.5	9.2	1.0	2.2	0.2	0.1	0.0	0.0	0.7
11-15 mph	88.1	4.9	0.6	58.1	0.0	68.2	0.0	0.0	2.1	8.9	0.5	1.5	0.0	0.1	9.7
16-20 mph	2.6	6.7	0.1	22.9	95.5	0.0	51.2	47.3	4.1	4.6	25.1	10.0	0.0	0.0	10.5
21-25 mph	4.2	0.7	5.5	19.0	0.9	22.9	43.3	0.0	3.8	72.4	2.2	4.2	0.0	0.0	2.8
26-30 mph	3.6	0.1	0.0	0.0	0.0	0.0	0.0	12.6	0.0	0.0	0.0	35.7	0.0	0.0	7.8
31-35 mph	0.0	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.9	0.0	0.0	0.2
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0	1.7
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1
Unknown .	1.4	82.7	90.8	0.0	3.7	8.8	0.0	31.0	86.8	11.9	71.8	38.6	100.0	99.9	66.2
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	41	49	14	4	3	4	4	11	16	24	50	170	87	101	578

TABLE 17

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR LEFT-FRONT OCCUPANTS WITH LOWER EXTREMITY INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force													
	1 o'clock	2 o'clock	3 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.2	1.8	39.8	100.0	0.0	0.0	2.0	0.0	0.2	0.2	0.1	0.0	1.8	0.8
11-15 mph	0.4	1.8	0.4	0.0	51.6	0.0	0.8	0.1	33.8	11.8	1.2	0.0	0.1	3.2
16-20 mph	19.6	0.6	17.7	0.0	0.0	4.9	0.0	3.1	7.6	10.4	0.4	0.0	0.0	2.7
21-25 mph	57.7	0.2	14.0	0.0	8.8	0.0	0.0	1.4	35.2	29.1	5.7	0.0	0.9	8.3
26-30 mph	3.4	1.3	0.0	0.0	0.0	0.0	4.3	0.0	0.4	3.6	10.2	0.0	2.1	5.2
31-35 mph	3.4	0.0	0.2	0.0	0.0	0.9	0.0	0.0	0.4	0.7	12.8	0.0	0.4	6.1
36-40 mph	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	6.3	0.0	0.0	3.2
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.0	0.0	7.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	0.0	0.0	9.3
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8.0	0.0	0.0	3.7
Unknown .	15.3	88.5	27.9	0.0	39.5	94.2	92.9	95.3	22.4	40.9	19.6	100.0	94.8	50.5
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	60	25	12	1	6	10	8	40	51	97	309	35	127	781

TABLE 18

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS WITH HEAD, FACE, AND NECK INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force														
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.3	6.8	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.1	0.0	0.0	0.7
11-15 mph	0.2	6.4	29.9	0.0	0.0	6.2	2.6	1.6	2.0	0.7	43.0	9.4	0.0	0.1	5.2
16-20 mph	1.7	34.8	0.0	100.0	0.0	0.0	0.0	0.0	10.9	12.0	19.6	10.4	0.0	0.0	8.8
21-25 mph	2.2	11.1	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.6	8.6	9.7	0.0	0.1	3.9
26-30 mph	30.5	0.6	0.0	0.0	0.0	81.4	0.0	94.8	0.0	0.5	5.4	7.9	0.0	0.0	7.9
31-35 mph	0.0	14.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.5
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.7	0.0	0.0	4.9
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	5.5	0.0	0.0	4.0
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	1.1
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	2.0
Unknown .	65.1	25.6	70.1	0.0	100.0	4.2	88.4	2.1	87.1	70.2	23.5	22.7	100.0	99.7	59.9
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	34	44	9	1	3	10	4	7	17	22	39	176	77	83	526

TABLE 19

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS WITH CHEST, BACK, AND ABDOMEN INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force													
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	8 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.9	0.0	0.0	0.0	0.0
11-15 mph	0.0	1.0	0.0	0.0	0.0	0.0	3.5	0.0	3.6	21.1	0.9	0.0	0.0	0.8
16-20 mph	0.0	8.9	48.3	100.0	0.0	0.0	0.0	0.0	2.9	0.0	0.1	0.0	0.0	9.1
21-25 mph	0.8	3.8	19.0	0.0	0.0	100.0	0.0	93.7	4.9	10.4	22.7	0.0	0.0	11.5
26-30 mph	0.0	0.0	31.2	0.0	0.0	0.0	95.6	0.0	0.4	31.4	0.0	0.0	0.0	5.6
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	18.6	0.0	0.0	6.1
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	0.0	0.0	3.9
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.1	0.0	37.0	0.0	0.0	19.8
Unknown .	99.2	86.1	1.4	0.0	100.0	0.0	0.9	6.3	7.0	6.5	8.5	100.0	99.9	43.2
All . . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	15	26	10	1	1	1	6	4	29	10	43	36	37	219

TABLE 20

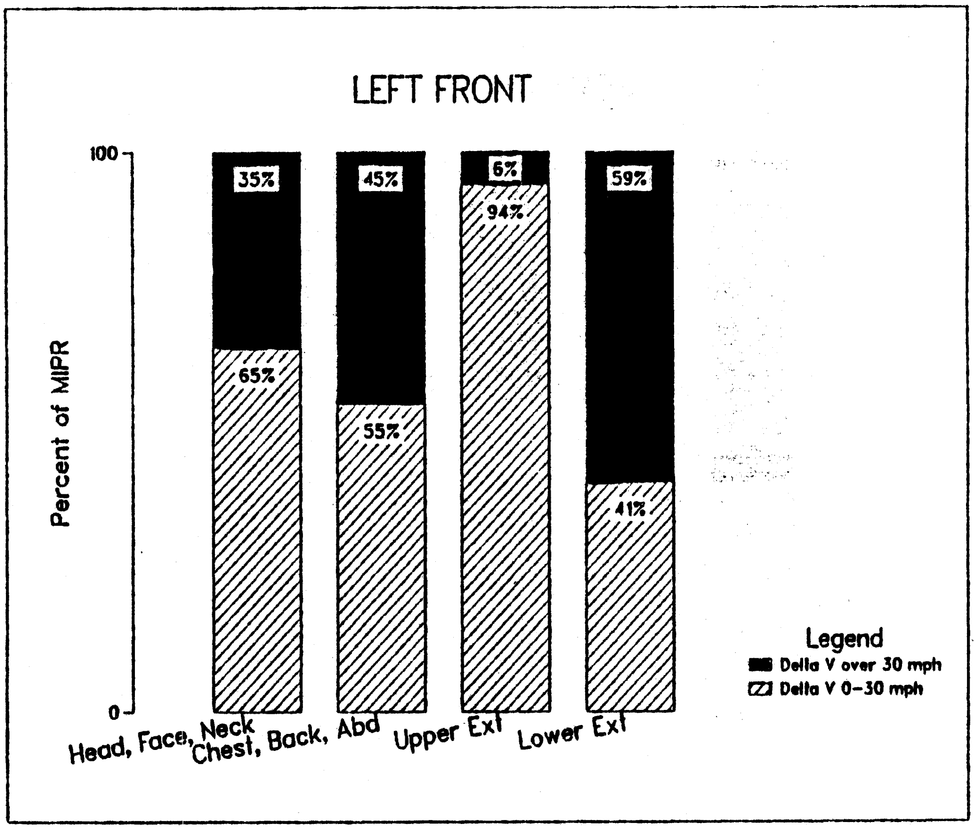
1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS WITH UPPER EXTREMITY INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force													
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.0	0.0	2.3	0.0	0.0	0.0	0.0	18.8	11.5	0.0	0.8	0.0	0.0	0.5
11-15 mph	8.5	32.5	1.4	0.0	99.1	42.3	100.0	0.0	17.5	2.9	0.6	0.0	0.0	16.4
16-20 mph	44.6	3.7	0.0	52.7	0.9	0.0	0.0	0.0	6.2	0.5	9.2	0.0	0.0	3.9
21-25 mph	14.6	7.9	5.6	47.3	0.0	0.0	0.0	0.0	3.2	82.7	1.0	0.0	0.4	16.6
26-30 mph	15.2	3.8	0.9	0.0	0.0	0.0	0.0	0.0	0.9	4.0	7.4	0.0	0.0	3.4
31-35 mph	0.0	0.0	1.0	0.0	0.0	7.2	0.0	0.0	0.0	1.8	0.3	0.0	0.0	0.5
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	1.6
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	2.5
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown .	17.1	52.1	88.8	0.0	0.0	50.5	0.0	81.2	60.6	8.0	67.5	100.0	99.6	54.7
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	18	26	16	2	6	7	1	7	19	24	58	30	39	253

TABLE 21

1980-83 NASS:
PERCENT MIPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS WITH LOWER EXTREMITY INJURIES
BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force												
	1 o'clock	2 o'clock	3 o'clock	4 o'clock	6 o'clock	7 o'clock	9 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.2	10.3	47.0	0.0	0.0	0.0	0.0	3.4	8.7	0.4	0.0	0.0	6.1
11-15 mph	1.0	11.3	0.0	0.0	0.0	0.0	0.0	2.9	1.2	2.3	0.0	0.0	3.6
16-20 mph	0.3	43.8	2.9	100.0	40.8	0.0	0.0	32.9	2.2	1.7	0.0	0.4	11.1
21-25 mph	61.0	0.3	5.8	0.0	0.0	0.0	0.0	1.3	7.5	5.7	0.0	0.4	9.9
26-30 mph	2.3	0.1	0.4	0.0	0.0	0.0	0.0	0.2	0.8	39.7	0.0	0.0	18.4
31-35 mph	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	9.9	0.0	0.0	4.5
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0	6.0
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	1.8
46-50 mph	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.6
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown .	35.1	34.2	43.0	0.0	59.2	0.0	100.0	59.2	79.6	21.9	100.0	99.3	38.0
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	19	35	19	2	4	1	5	19	47	121	27	47	346



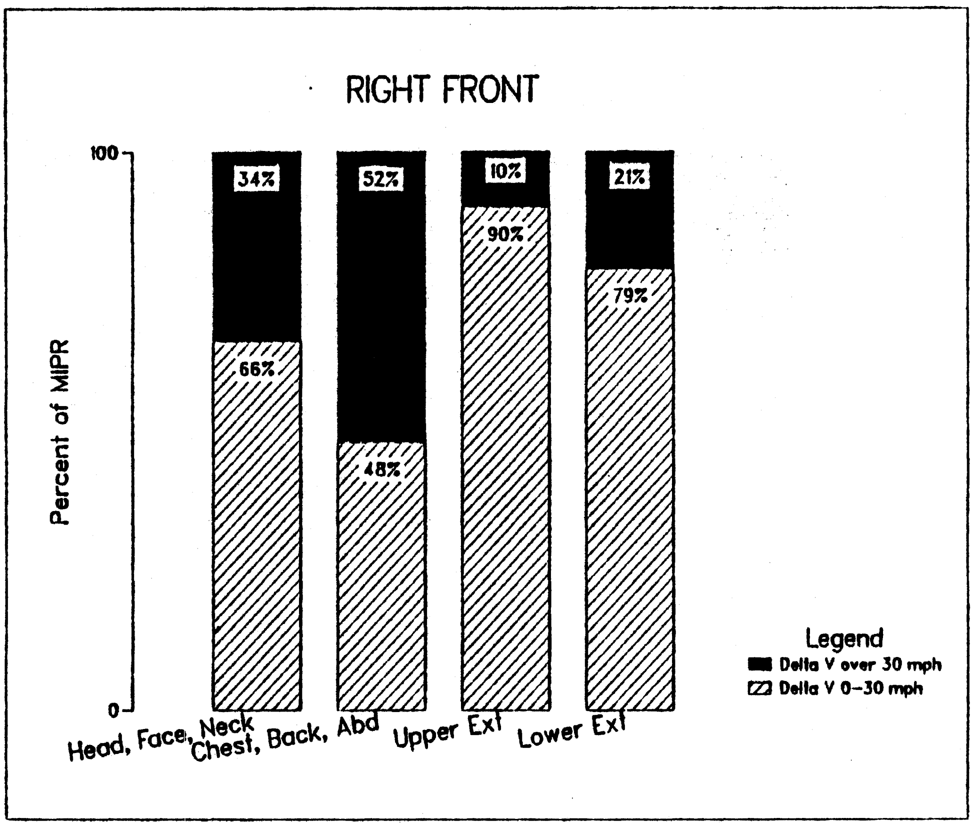


FIGURE 2. 1980-83 NASS: Percent MIPR for Passenger Car Occupants with Known Delta V by Seat Position, Grouped Body Region, and Delta V.

SAFETY PRIORITIES IN LOW-SEVERITY CRASHES

Because of the current interest in developing a passenger car interior that would protect an unbelted occupant in a 30 m.p.h. frontal collision, it seems reasonable to apply the MIPR model to that problem and to ascertain the priorities in designing the "friendly" interior. The previous sections have shown the difficulties in using NASS data at the most desirable level of detail. So here, many of the variables will of necessity have to be bracketed to increase cell size in the tables. Delta V will be split into 30 m.p.h. and less on the one hand and over 30 m.p.h on the other. Body region will be grouped into the four categories used previously. Clock direction will be similarly grouped into four quadrants, with special concentration on the frontal (11 through 1) quadrant. It will then be possible to focus on the less-severe (under 31 m.p.h.) crash environments that are causing the greatest MIPR and to identify for those environments which are the most harmful contact points. Although right-front passengers account for only 16.9 percent of passenger car MIPR, seat position will be included as a factor, since a passenger car that protected only the driver and left the right-front passenger vulnerable would be unacceptable. Belted occupants will be excluded from the runs, since they are well protected by current hardware in less-severe crashes. At each stage in the analysis, the proportion of *total* passenger car MIPR being addressed will be ascertained.

The first task here is to examine clock direction and seat position for unrestrained passenger car occupants. This is done in Table 22 which shows distributions for 97.6 percent of total passenger car MIPR. The remaining 2.4 percent is incurred by restrained occupants.[2] Overall, collisions with frontal directions of force account for 46.2 percent of MIPR to these unrestrained occupants, of which almost all (41.3 percent) is to left-front and right-front passengers. This 41.3 percent is what would be addressed by a "friendly" interior that protected occupants in these two seat positions at all levels of crash severity. Non-horizontal directions of force, principally rollovers, rank as the next most important grouping, but account for only 16.0 percent overall, 15.0 percent to left-front and right-front occupants. Because the frontal crashes constitute the most important component of the overall MIPR to unrestrained passenger car occupants, and because they are the crashes of interest in developing the "friendly" interior, the remaining tables in this section will concentrate on them.

Table 23 shows the distribution of MIPR to unrestrained left-front and right-front passenger car occupants by crash severity. Crash severity has been split into 30 m.p.h. or less delta V and over 30 m.p.h. delta V. The whole table represents 40.3 percent of total passenger car MIPR (41.3 percent of the 97.6 percent represented in the previous table). In Table 23, the less-severe crashes account for 31.7 percent of the subgroup MIPR and the more-severe crashes for 27.1 percent. The problem here is the large proportion of MIPR accounted for by crashes with unknown delta V: 41.2 percent. This requires some kind of imputation to replace these unknown values of delta V. Since these are crashes that resulted in at least one injury of severity AIS 2 or greater and since crashes with no-horizontal directions of force are excluded, it seems reasonable to impute values to the unknown cases in the same proportion as the known cases. This imputation can be achieved by simply omitting the unknown cases in calculating the distribution of delta V and yet assuming that the resulting values are representative of all cases, known and unknown. This has been done in Table 24, which represents 23.7 percent of total passenger car MIPR when counting only cases with known delta V, but 40.3 percent (as in Table 23) when cases with unknown delta V are included. From Table 24, the less-severe

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[2]See Table 6 for the split between restrained and unrestrained passenger car occupants.

TABLE 22

1980-83 NASS:
PERCENT MIPR FOR UNRESTRAINED PASSENGER CAR OCCUPANTS
BY GROUPED DIRECTION OF FORCE AND SEAT POSITION

Grouped Direction of Force	Seat Position						
	Left Front		Right Front		Other and Unknown		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	
11, 12, 1 o'clock	47.0	34.4	40.7	6.9	49.9	4.9	46.2
2, 3, 4 o'clock . .	9.4	6.9	17.2	2.9	22.0	2.2	12.0
5, 6, 7 o'clock . .	0.5	0.4	1.6	0.3	1.4	0.1	0.8
8, 9, 10 o'clock .	12.4	9.1	16.5	2.8	9.6	0.9	12.8
Non-horizontal .	17.6	12.9	12.4	2.1	10.3	1.0	16.0
Unknown	13.1	9.6	11.6	2.0	6.8	0.7	12.2
Total	100.0	73.2	100.0	17.0	100.0	9.8	100.0
N	3,576		1,290		687		5,553

NOTE: This table represents 97.6 percent of total passenger car MIPR.

crashes are responsible for 53.9 percent of MIPR to unrestrained left-front and right-front passenger car occupants in frontal crashes. Interestingly, the right-front occupants incur over half of their MIPR in over 30 m.p.h. collisions. This implies either that crashes in vehicles with more than one occupant tend to be more severe, which runs counter to current knowledge, or that an unbelted driver is better protected in a frontal collision than an unbelted right-front occupant.

Tables 25 through 28 add the dimension of body region to this split on delta V. The first two tables show distributions without any missing data imputation. The second two apply the same procedure for replacing missing data as used in Table 24. Tables 27 and 28 provide some interesting contrasts, and shed some light on the observed difference in the distribution of MIPR by crash severity for left-front and right-front occupants. From Table 27 it can be observed that for drivers the proportion of MIPR resulting from the less-severe crashes is, except for the lower extremities, consistently greater than the proportion from the more-severe crashes. And lower-extremity MIPR accounts for only 11.1 percent of the total, although that in itself is considerably more than upper-extremity MIPR. Turning to Table 28, the explanation for the greater susceptibility of right-front passengers to MIPR from the more-severe crashes lies wholly in MIPR to the trunk region. Trunk MIPR from crashes with a delta V greater than 30 m.p.h. constitutes 27.3 percent of overall MIPR to unrestrained right-front passenger car occupants in frontal crashes. The comparable figure for drivers is 13.6 percent. This suggests that the steering assembly, while being a principal cause of trunk-region injury for drivers,[3] may to some extent protect them against more-severe injury. This protection is not available to the unbelted

[3]See Table 29.

TABLE 23

1980-83 NASS:
PERCENT MIPR FOR UNRESTRAINED LEFT-FRONT AND RIGHT-FRONT PASSENGER CAR OCCUPANTS IN FRONTAL CRASHES BY DELTA V AND SEAT POSITION

Delta V	Seat Position				
	Left Front		Right Front		Both
	Col%	Tot%	Col%	Tot%	
0-30 mph ..	32.0	26.7	30.0	5.0	31.7
Over 30 mph	25.2	21.0	36.7	6.1	27.1
Unknown ...	42.8	35.6	33.3	5.6	41.2
Total	100.0	83.3	100.0	16.7	100.0
N	1,822		593		2,415

NOTE: This table represents 40.3 percent of total passenger car MIPR.

TABLE 24

1980-83 NASS:
PERCENT MIPR FOR UNRESTRAINED LEFT-FRONT AND RIGHT-FRONT PASSENGER CAR OCCUPANTS IN FRONTAL CRASHES WITH KNOWN DELTA V BY DELTA V AND SEAT POSITION

Delta V	Seat Position				
	Left Front		Right Front		Both
	Col%	Tot%	Col%	Tot%	
0-30 mph ..	56.0	45.4	45.0	8.5	53.9
Over 30 mph	44.0	35.7	55.0	10.4	46.1
Total	100.0	81.0	100.0	19.0	100.0
N	1,149		392		1,541

NOTE: This table represents 23.7 percent of total passenger car MIPR, 40.3 percent when adjusted for missing data on delta V.

right-front occupant. It should not be forgotten, however, that injuries to the head, face, and neck account for the largest share of MIPR to both drivers and right-front occupants.

TABLE 25

1980–83 NASS:
PERCENT MIPR FOR UNRESTRAINED LEFT-FRONT PASSENGER CAR OCCUPANTS
IN FRONTAL CRASHES BY DELTA V AND GROUPED BODY REGION

Delta V	Grouped Body Region										
	Head, Face, & Neck		Chest, Back, & Abdomen		Upper Extremities		Lower Extremities		Other & Unknown		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	
0–30 mph . .	30.5	18.8	36.0	9.0	48.7	2.2	24.3	2.0	0.0	0.0	32.0
Over 30 mph	20.7	12.8	31.0	7.8	3.7	0.2	54.2	4.4	10.7	0.1	25.2
Unknown . . .	48.8	30.1	33.0	8.3	47.6	2.2	21.4	1.7	89.3	0.5	42.8
Total	100.0	61.8	100.0	25.1	100.0	4.5	100.0	8.1	100.0	0.5	100.0
N	778		350		248		444		2		1,822

NOTE: This table represents 33.6 percent of total passenger car MIPR.

TABLE 26

1980–83 NASS:
PERCENT MIPR FOR UNRESTRAINED RIGHT-FRONT PASSENGER CAR OCCUPANTS
IN FRONTAL CRASHES BY DELTA V AND GROUPED BODY REGION

Delta V	Grouped Body Region										
	Head, Face, & Neck		Chest, Back, & Abdomen		Upper Extremities		Lower Extremities		Other & Unknown		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	
0–30 mph ..	38.4	19.9	18.0	6.4	46.9	2.1	32.5	1.6	0.0	0.0	30.0
Over 30 mph	26.7	13.8	50.7	18.2	8.9	0.4	27.3	1.3	100.0	2.9	36.7
Unknown ...	34.9	18.1	31.3	11.2	44.2	2.0	40.2	2.0	0.0	0.0	33.3
Total	100.0	51.8	100.0	35.9	100.0	4.5	100.0	4.9	100.0	2.9	100.0
N	246		64		100		182		1		593

NOTE: This table represents 6.7 percent of total passenger car MIPR.

TABLE 27

1980–83 NASS:
PERCENT MIPR FOR UNRESTRAINED LEFT-FRONT PASSENGER CAR OCCUPANTS
IN FRONTAL CRASHES WITH KNOWN DELTA V BY DELTA V AND GROUPED BODY REGION

Delta V	Grouped Body Region										
	Head, Face, & Neck		Chest, Back, & Abdomen		Upper Extremities		Lower Extremities		Other & Unknown		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	
0–30 mph . .	59.6	32.9	53.7	15.8	93.0	3.9	31.0	3.5	0.0	0.0	56.0
Over 30 mph	40.4	22.3	46.3	13.6	7.0	0.3	69.0	7.7	100.0	0.1	44.0
Total	100.0	55.3	100.0	29.4	100.0	4.1	100.0	11.1	100.0	0.1	100.0
N	458		221		161		308		1		1,149

NOTE: This table represents 19.2 percent of total passenger car MIPR, 33.6 percent when adjusted for missing data on delta V.

TABLE 28

1980–83 NASS:
PERCENT MIPR FOR UNRESTRAINED RIGHT-FRONT PASSENGER CAR OCCUPANTS
IN FRONTAL CRASHES WITH KNOWN DELTA V BY DELTA V AND GROUPED BODY REGION

Delta V	Grouped Body Region										
	Head, Face, & Neck		Chest, Back, & Abdomen		Upper Extremities		Lower Extremities		Other & Unknown		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	
0–30 mph . .	59.0	29.8	26.2	9.7	84.1	3.2	54.4	2.4	0.0	0.0	45.0
Over 30 mph	41.0	20.7	73.8	27.3	15.9	0.6	45.6	2.0	100.0	4.4	55.0
Total	100.0	50.6	100.0	36.9	100.0	3.8	100.0	4.4	100.0	4.4	100.0
N	166		37		73		115		1		392

NOTE: This table represents 4.5 percent of total passenger car MIPR, 6.7 percent when adjusted for missing data on delta V.

The final step here is to examine contact point (source of injury) in the less-severe frontal crashes. Distributions of contact point by grouped body region are shown in Tables 29 and 30. From Table 29 it can be observed that the steering assembly is the prime cause of MIPR to unrestrained drivers in less-severe frontal crashes. The steering assembly alone is responsible for 83.7 percent of MIPR to the trunk region. and 11.4 percent of MIPR to the head area. The other principal causes of MIPR are the windshield (which is the leading contributor of MIPR to the head area), the instrument panel (which generates MIPR by causing injuries to the upper and lower extremities), and the A-pillar (which again causes injuries to the head area). Injuries from external objects, presumably mainly to ejected occupants, account for 6.7 percent of driver MIPR. In these frontal low-severity crashes ejection does not appear to be a major cause of MIPR. The proportion of driver MIPR attributable to unknown contact points is disturbingly high at 19.2 percent.

The distribution of MIPR by contact point for right-front passengers is naturally quite different from the distribution for drivers. For these occupants the windshield is the principal cause of MIPR in the low-severity frontal crashes, accounting for 43.3 percent of the total. Almost all of this windshield MIPR occurs through the medium of injury to the head area, although the windshield also accounts for over half of MIPR to the upper extremities. Following the windshield are the instrument panel, the A-pillar, and the transmission lever. Unknown contact point is less of a problem here than for drivers. MIPR to the head area is generated almost entirely through contact with the windshield and A-pillar. MIPR to the trunk, which has already been discussed in some detail, is caused by contact with the transmission lever and the instrument panel. MIPR to the extremities is attributable almost entirely to the instrument panel.

These last two tables show some of the priorities in designing the "friendly" interior. They point in particular to a need to reduce steering-assembly-related injuries to the trunk area for drivers, windshield-related injuries to the head area for drivers *and* right-front passengers, and A-pillar-related injuries to the head area and instrument-panel-related injuries to the trunk area for right-front passengers.

TABLE 29

1980-83 NASS:
PERCENT MIPR FOR UNRESTRAINED LEFT-FRONT
PASSENGER CAR OCCUPANTS IN FRONTAL CRASHES WITH 0-30 MPH
DELTA V BY CONTACT POINT AND GROUPED BODY REGION

Contact Point	Grouped Body Region								
	Head, Face, & Neck		Chest, Back, & Abdomen		Upper Extremities		Lower Extremities		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	
Windshield	35.1	20.6	0.0	0.0	0.0	0.0	0.0	0.0	20.6
Mirror	3.9	2.3	0.0	0.0	0.0	0.0	0.0	0.0	2.3
Steering assem	11.4	6.7	83.7	23.6	4.5	0.3	18.2	1.1	31.7
Add-on	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Instr panel	0.5	0.3	1.1	0.3	53.6	3.7	68.0	4.2	8.5
Sunvisor	2.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Oth front obj . .	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Side interior . . .	0.1	0.0	0.4	0.1	0.4	0.0	1.2	0.1	0.2
Side hardware .	0.0	0.0	0.1	0.0	0.0	0.0	0.9	0.1	0.1
A-pillar	9.2	5.4	0.0	0.0	0.0	0.0	0.0	0.0	5.4
B-pillar	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Unk. pillar	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Side window . .	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Seat	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Other occupant	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Oth int object . .	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Front header . .	1.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Rear header . . .	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Roof rail	0.0	0.0	0.0	0.0	1.1	0.1	0.0	0.0	0.1
Roof	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Floor	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1	0.1
Trans lever . . .	0.0	0.0	0.8	0.2	0.0	0.0	0.2	0.0	0.3
Foot control . . .	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.2	0.2
Hood	3.1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Oth ext of veh .	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.1	0.1
Oth ext object .	8.2	4.8	0.3	0.1	0.0	0.0	0.0	0.0	4.9
Non-contact . . .	0.1	0.1	2.5	0.7	0.3	0.0	0.1	0.0	0.8
Unknown	22.1	13.0	11.0	3.1	39.9	2.7	5.5	0.3	19.2
Total	100.0	58.8	100.0	28.2	100.0	6.9	100.0	6.2	100.0
N	378		166		134		196		874

NOTE: This table represents 10.8 percent of total passenger car MIPR, 18.3 percent when adjusted for missing data on delta V.

TABLE 30

1980-83 NASS:
PERCENT MIPR FOR UNRESTRAINED RIGHT-FRONT
PASSENGER CAR OCCUPANTS IN FRONTAL CRASHES WITH 0-30 MPH
DELTA V BY CONTACT POINT AND GROUPED BODY REGION

Contact Point	Grouped Body Region								
	Head, Face, & Neck		Chest, Back, & Abdomen		Upper Extremities		Lower Extremities		All
	Col%	Tot%	Col%	Tot%	Col%	Tot%	Col%	Tot%	
Windshield	60.0	39.7	0.0	0.0	50.7	3.6	0.0	0.0	43.3
Mirror	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Steering assem	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Add-on	0.0	0.0	0.0	0.0	3.1	0.2	0.0	0.0	0.2
Instr panel	3.6	2.4	45.7	9.8	41.6	2.9	25.3	1.3	16.4
Sunvisor	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Side interior ...	0.0	0.0	1.1	0.2	1.3	0.1	1.6	0.1	0.4
A-pillar	23.0	15.2	0.0	0.0	0.0	0.0	0.0	0.0	15.2
Side window ..	0.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Seat	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Other occupant	0.4	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.3
Front header ..	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Roof rail	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Roof	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Floor	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.4	0.4
Trans lever ...	0.0	0.0	49.0	10.5	0.0	0.0	0.0	0.0	10.5
Ground	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Non-contact ...	0.3	0.2	0.0	0.0	0.6	0.0	9.7	0.5	0.8
Unknown	9.2	6.1	3.9	0.8	2.2	0.2	55.9	3.0	10.0
Total	100.0	66.2	100.0	21.5	100.0	7.0	100.0	5.3	100.0
N	138		23		60		94		315

NOTE: This table represents 2.0 percent of total passenger car MIPR, 3.4 percent when adjusted for missing data on delta V.

APPENDICES

APPENDIX A

LISTING OF RECODE PROGRAM

A listing of the source code for the OSIRIS IV RECODE program used to calculate MIPR is provided below. The program uses variable numbers from the combined NASS file rather than variable names. The variable numbers correspond to variable names as follows:

- V7: Year of Accident
- V54: Inflation Factor—Nation
- V413: Occupant Treatment/Mortality
- V414: Occupant Hospital Stay
- V415: Occupant Working Days Lost
- V601: OIC Number
- V602: OIC—Body Region
- V607: OIC—AIS Severity
- V1103: Adjusted Impairment for Years 2-5 After Accident
- V1104: Adjusted Impairment for Years 6+ After Accident
- V1750: Lifetime Present Discounted Value
- V1751: Present Discounted Value for Year 1 After Accident
- V1752: Present Discounted Value for Years 2-5 After Accident
- V1753: Present Discounted Value for Years 6+ After Accident

OSIRIS IV RECODE PROGRAM

```
&RECODE
 RECODE=1
& Pass only first injury for each fatal occupant
 IF V413 IN(3-6) OR V413 EQ 9 AND V607 NE 6 THEN GO TO NONF
 IF V601 NE 1 THEN REJECT
NONF CONTINUE
& Calculate proportion of hospital stay in intensive
& care (R1)
 IF V607 EQ 2 THEN R11=0 AND R12=10
 IF V607 EQ 3 THEN R11=1 AND R12=9
 IF V607 EQ 4 THEN R11=3 AND R12=7
 IF V607 EQ 5 OR V413 EQ 1 THEN R11=6 AND R12=4
 IF V607 EQ 6 THEN R11=10 AND R12=0
 R1=R11/10
 R2=R12/10
& Calculate days in hospital
 IF V414 EQ 99 AND V607 EQ 2 THEN R414=10 ELSE R414=V414
 IF V414 EQ 99 AND V607 EQ 3 THEN R414=11
 IF V414 EQ 99 AND V607 EQ 4 THEN R414=17
 IF V414 EQ 99 AND V607 EQ 5 THEN R414=26
 IF V602 IN('BIE','BIL','BIN','BSE','BSL','BSN') AND V607 EQ 5 -
    THEN R414=150 AND R1000=1
```

```
& Calculate cost of intensive care
 R3=R1*515
& Calculate cost of non-intensive care
 R4=R2*215
& Calculate cost of days lost
 IF V7 IN(82,83) AND V415 LT 61 THEN R415=V415 ELSE R415=R414
 IF V7 IN(80,81) AND V415 LT 31 THEN R415=V415
 IF R1000 EQ 1 THEN R415=365
 IF MDATA(V1751) THEN R1751=0 ELSE R1751=V1751/365
 R5=R1751*R415
& Calculate costs for years 2 through 5
 IF MDATA(V1752,V1103) THEN R6=0 ELSE R6=V1752*V1103
& Calculate costs for year 6 on
 IF MDATA(V1753,V1104) THEN R7=0 ELSE R7=V1753*V1104
& Calculate costs for fatals
 IF V413 IN(1,2) OR V413 EQ 9 AND V607 EQ 6 -
    THEN R5=0 AND R6=0 AND R7=0 AND R8=V1750 ELSE R8=0
& Sum costs
 R101=R3+R4
 R102=R101+R5
 R103=R102+R6
 R104=R103+R7
 R105=R104+R8
& Create WTVAR
 R54=V54*R105
 END
&END
```

APPENDIX B

PROBLEMS WITH THE UMIVOR DATA

The University of Michigan In-Depth Vehicle and Occupant Report (UMIVOR) protocol is used for investigating selected accidents, occurring mainly in the Detroit area. Accidents are chosen for investigation because they are of interest to the investigator rather than through some statistical sampling scheme. Through Update 3, the UMIVOR database contains information on 1073 vehicles, of which 904 are passenger cars. These 904 vehicles contained 447 occupants who sustained injuries of AIS 2–6. The number of AIS 2–6 injuries incurred was 779. The percentage of these injuries coded with contact point unknown was 9.5, which compares favorably with NASS.

Difficulties arise, however, when trying to analyze the UMIVOR data. The main problem is the inadequate number of cases. Table B.1 compares the number of head, face, and neck injuries from UMIVOR and NASS. While UMIVOR has a very low rate of missing data on contact point, it still has fewer cases with *known* contact points than NASS. It is also interesting to note that UMIVOR has the highest rate of missing data just where NASS does, namely for the head cases.

TABLE B.1

COMPARISON OF UMIVOR WITH 1980–83 NASS:
CONTACT POINT UNKNOWN FOR AIS 2–6 INJURIES BY BODY REGION

Body Region	UMIVOR			NASS		
	Number of Cases	Contact Point Unknown		Number of Cases	Contact Point Unknown	
		N	%		N	%
Head	194	23	11.9	604	220	36.6
Face	75	1	1.3	206	28	13.6
Neck	25	1	4.0	104	39	37.5

These problems are compounded when attempting to add such dimensions as seat position to the analysis. Table B.2 shows the comparison between UMIVOR and NASS for head injuries by seat position, with the cases restricted to the left-front and right-front positions. UMIVOR simply does not provide sufficient cases for it to serve as an alternative source to NASS, providing information where NASS is deficient.

TABLE B.2

COMPARISON OF UMIVOR WITH 1980-83 NASS:
CONTACT POINT UNKNOWN FOR AIS 2-6 HEAD INJURIES BY SEAT POSITION

Seat Position	UMIVOR			NASS		
	Number of Cases	Contact Point Unknown		Number of Cases	Contact Point Unknown	
		N	%		N	%
Left front	148	21	14.2	396	128	32.3
Right front	31	1	3.2	117	48	41.0

Finally, it should be mentioned that information on collision severity in the form of delta V is not provided in the UMIVOR data and that the distribution of clock direction is somewhat different from that in NASS. As shown in Table B.3, both the 11 o'clock and 1 o'clock directions seem to be over-represented in UMIVOR as compared to NASS. This raises some concern about the selection of cases for UMIVOR or about differences in investigation methods from those used in NASS.

TABLE B.3

COMPARISON OF UMIVOR WITH 1983 NASS:
CLOCK DIRECTION FOR PASSENGER CARS WITH
MAXIMUM AIS OF 2-6 AND KNOWN CLOCK DIRECTION

Direction of Force	UMIVOR	NASS
1 o'clock	12.6	9.1
2 o'clock	7.5	8.6
3 o'clock	5.1	2.6
3 o'clock	2.0	0.6
5 o'clock	0.0	0.8
6 o'clock	1.4	3.3
7 o'clock	0.7	0.6
8 o'clock	2.0	1.3
9 o'clock	5.1	5.2
10 o'clock	5.8	7.9
11 o'clock	15.0	12.5
12 o'clock	32.4	35.7
Non-horizontal	9.9	11.7
Total	100.0	100.0
N	293	871