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INJURY PRIORITY ANALYSIS

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The Engineering Design, Development, Testing, and Evaluation
of an Advanced Anthropomorphic Test Device

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16. Abstract The work reported here is intended to aid in the design of an advanced anthropomorphic test device by indicating the body regions in which the most serious occupant injuries are incurred. For this purpose, an analysis was carried out on the 1980 and 1981 data files from the National Accident Sampling System (NASS). It was decided that a more sensitive and convenient scale than the Abbreviated Injury Scale (AIS) alone was required to weight the various injuries. A new weighting factor, termed Injury Priority Rating (IPR), was therefore calculated and applied. This factor took into account both the expected net production (i.e., earnings) of a person over his or her lifetime and that person's expectation of survival to each subsequent age had he or she not been injured in an accident. The resulting dollar amounts were combined with a percent impairment that was derived from the likely consequences of injury as coded by two panels of physicians. The analysis using IPR found that injuries to the combination of the head, face, and neck stood out as having the most serious consequences for the front occupants of passenger cars. Direct frontal collisions at a 12 o'clock $\pm 15^\circ$ direction of force accounted for over a third of IPR to front occupants, while just over a sixth was accounted for by collisions with non-horizontal directions of force.

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INTRODUCTION

The effort under Task A was designed to generate information for the designers of the Advanced Anthropomorphic Test Dummy on what kinds of serious injuries were incurred by the occupants of passenger cars and how those injuries were incurred. For this analysis, it was decided to use the data provided by the National Accident Sampling System (NASS). NASS provides a statistical sample of all the police-reported traffic accidents in the United States, and was, at the time the injury analysis was carried out, available for 1980 and 1981. 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). In addition to this information on the injury, NASS provides detailed information on the circumstances producing the injury, including the severity of the crash in the form of change in velocity or delta V.

The NASS files on their own, however, do not provide a direct means of ranking injuries by body region and injury causation in terms of their consequences to the community. It was believed that it would be reasonable to design the dummy in terms of just such societal consequences, so that greatest attention could be paid to the biofidelity and response of the dummy in those areas where the consequences of injury to humans were greatest. It was also decided that, while not perfect, the best measure of the societal consequences of injury would be an estimate of the cost in economic terms. This cost would consist largely of the lost production resulting from injury and of the expense of medical care. The function generated from the application of an economic cost model has been termed "Injury Priority Rating" or IPR.

The other ingredient required in the analysis that is missing from NASS is a finer estimation of the severity of the injury and its medical consequences than the AIS scale provides. Thus the AIS scale makes no distinction based on the age of the individual incurring the injury. It also provides no information on the lingering effects of a particular injury or on the possibility of increasing impairment as the victim becomes older. Fortunately for this work, NHTSA had recently funded a study by Chi Associates in this area (Hirsch et al. 1984), and the Chi data were made available to UMTRI.

The reader should be aware of some significant problems with the analysis presented here. The most important is perhaps the 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. A further major problem with the NASS data is the high proportion of missing information, particularly on delta V. Other potential problems are addressed in the text.

In spite of these possible limitations, we believe that the methods and the results are reasonable for the purpose at hand. The methods have been carefully documented, and, in general, it will be possible to recompute the results using different assumptions. In addition, the biases that resulted from the use of aggregate estimates of the consequences of injury in earlier studies have been eliminated or at least reduced through the use of a methodology that calculates the consequences of injury at the individual level before summing. The age of the injured person is taken into account in the estimation of the likely impairment, both in the short term and in the long term. Both the age and the sex of the injured person are taken into consideration in computing the societal costs of that impairment.

The organization of the remainder of this report is as follows. "Previous Work" summarizes and reviews the recent work in this area. "Methodology" describes in some detail the technique that was developed to compute the IPR. The consequences of applying that technique to the 1980 and 1981 NASS data are presented in "Results." A number of appendices are attached that provide further documentation of the methodology and some supplementary results.

PREVIOUS WORK

OVERVIEW

This section will summarize the principal previous studies whose work was incorporated in the development of a model to prioritize injuries in terms of their share of the economic consequences as a whole. The approach to these studies was generally utilitarian rather than critical. In other words, the studies were reviewed or data from them were incorporated more with a view to speeding up the development of a workable model than with a view to applying a rigorous critique of their underlying assumptions. However, the methodology and data were subjected to a review for proper method of calculation and general accuracy.

No attempt was made to review all the literature in the field of calculating societal costs. Instead, the review concentrated on those studies which were most immediately relevant to the development of the UMTRI model. Here, the principal works were those of Hartunian et al. (1981), NHTSA (1983), Malliaris et al. (1982), Hirsch et al. (1984), and the AMA Committee on Rating of Mental and Physical Impairment (1971).

THE ECONOMIC COSTS OF INJURIES

Hartunian et al. (1981) developed a methodology to compare the economic consequences of cancer, motor vehicle injuries, coronary heart disease, and stroke. They adopted the <u>incidence</u> rather then the <u>prevalence</u> approach to the calculation of these economic consequences. The former approach uses the number of cases of a particular disability occurring during a specified time period (usually one year) and calculates for those cases the lifetime costs of the disability. The lifetime costs are expressed in terms of a present value. Thus the main lifetime cost of a fatality is the estimated value of that person's lifetime net productivity. Net productivity is assumed to be equal to earnings. These anticipated earnings are discounted to the present to take into account the multiplier effect of the reinvestment of a person's net productivity.

The prevalence approach, on the other hand, uses the number of cases of people suffering from a particular disability in any one period of time to estimate the <u>current</u> costs stemming from that disability. The authors argue that the incidence approach is generally superior for policy makers concerned with preventive programs, since this approach reveals the benefits to be gained by eliminating or reducing the incidence of a particular disability.

The authors endeavored, as far as possible, to base their conclusions on disaggregated rather than aggregated data. Thus they used lifetime net productivity estimates based on the individual age and sex of each injured or sick person, instead of using some kind of average figure for the whole injured population. They also attempted to disaggregate the particular type and level of the disability in question. However they did not disaggregate the information on motor-vehicle injuries to the level of distinguishing between specific injuries and their particular consequences. Instead, they were obliged to distinguish injuries merely by their general severity. They derived their estimates of the incidence of fatality from the Fatal Accident Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA). The estimates of injury from motor-vehicle accidents were derived mainly from NHTSA's National Crash Severity Study (NCSS). NCSS used the six-level Abbreviated Injury Scale (AIS) to code the severity of a particular injury. The authors used a person's maximum AIS (MAIS) in estimating the consequences of injury. For example, if a person suffered multiple injuries, only the injury with the highest AIS score (the most severe) was used. In estimating the societal costs from reduced life expectancy of critically (MAIS 5) injured victims, the authors derived estimates based on whether the person incurred spinal-cord injury or not. The persons who did not incur spinal-cord injury were assigned a single constant relative mortality rate,[1] while for spinal-cord victims estimates of relative mortality were based on four levels of impairment. The occurrence of these four levels of impairment by sex and by eight age groups was obtained not from NCSS but from an earlier study (Smart and Sanders 1976) of spinal-cord injuries.

In estimating foregone earnings, the authors assumed that all persons with a MAIS of 1 through 4 incurred no long-term disability. The MAIS-5 group were again separated into spinal-cord victims and non-spinal-cord victims. The same method was then used as for estimating relative mortality. Employment (i.e., labor-force participation) rates were applied that were constant for all non-spinal-cord victims and for each of the four levels of spinal-cord impairment.

Thus the authors were prevented, by limitations in the then current data, from pursuing disaggregation to perhaps its ultimate extent—the estimation of consequences of injury based on the particular injury or combination of injuries incurred, and on the victim's age and sex.

THE NHTSA SOCIETAL COST STUDY

The National Highway Traffic Safety Administration (1983) produced its own analysis of the economic cost of motor-vehicle accidents. This report, like that of Hartunian et al. (1981), adopted the incidence approach and, in the calculation of foregone earnings from fatalities, also used the disaggregated approach. However, in making this calculation, a shortcut was taken: the average age of death for the specified sex was used in place of the life expectancy given the particular age of the victim. This method assumes that accident victims have the same age distribution as the population as a whole and assumes that all individuals have a one hundred percent chance of survival until their average age of death. Thus, anticipated net production before the mean age of death is overestimated, and anticipated net production after the mean age of death is ignored.

In most of the other calculations for this study, an aggregated rather than disaggregated approach was used. Here too, errors sometimes crept in. For example, in calculating remaining life span for those incurring severe head injuries and spinal-cord injuries, the report used the average age of the victims and subtracted that average age from the life expectancy at birth of the U.S. population. Even if the life expectancy at the average age of injury had been used, there is no reason to believe that the mean life expectancy of a population is equal to the life expectancy for the mean age within that population.

For NHTSA's immediate purpose—to estimate the total economic consequences of motor-vehicle accidents—the aggregated technique should, if properly applied, produce the

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[1]The relative mortality rate is the ratio of the mortality of the group of interest to the mortality of the general population.

same answers as the disaggregated technique. The results cannot, however, be applied to subgroups within the population without potential error. The disaggregated technique takes into account the differing distributions of age, sex, etc., within each subgroup and is thus far better suited to such tasks as comparing the consequences of different kinds of injuries.

The NHTSA study did contain one significant advance over previous estimations of societal cost. For the first time a nationally representative sample of motor vehicle accidents was used in the calculations. The study drew on data from the National Accident Sampling System (NASS) for the years 1979 and 1980. NASS, which is managed by NHTSA, is a system to collect detailed information on a statistical sample of all the police-reported motor-vehicle accidents occurring in the United States. Included in NASS, as earlier in NCSS, is a coding of injuries using the Occupant Injury Classification (OIC) scheme. This allows national estimates of injuries to be made using all the detail of the OIC codings.

THE HARM MODEL

Malliaris et al. (1982) applied an earlier NHTSA (1976) societal cost study, which used 1975 dollars, to develop priorities in crash protection. They termed the economic consequences of injury "Harm" and sought to find, using data from NHTSA's National Crash Severity Study (NCSS), where the greatest Harm lay and what the potential of reducing that Harm was. Results were presented by contact point, body region, seat position, general area of damage, vehicle type, etc. The paper marked a major advance over previous studies, in that it used the first large (though not nationally representative) file of accident data with information on <u>all</u> injury levels and it applied sophisticated estimates of the societal consequences of injury. The main problem with the methodology is that the costs resulting from injury were calculated at the aggregate level and were constant within each AIS level. In addition, the probability of a fatality was assumed to be constant within each AIS level regardless of age or of the body region injured. Thus an AIS–3 injury to the head was assumed to have the same consequences in terms of cost as an AIS–3 injury to the leg, and those costs were constant across all age groups and both sexes. The societal cost of a fatality was also constant regardless of the age or sex of the victim. This would have no effect in looking at the aggregate population of victims of motor-vehicle accidents but could potentially cause significant bias in, for example, comparing motorcycle riders who are generally young to the occupants of heavy trucks who are generally older.

THE CONSEQUENCES OF INJURY

Hirsch et al. (1984) (referred to in this report as the Chi study) worked under contract with NHTSA to code the anticipated consequences of all the injuries in the 1980 AIS manual (AAAM 1980) 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 the incurrence of the injury:

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

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."

The Chi data mark a major advance over previous efforts in the field. For the first time, it is theoretically possible by matching on age group and OIC code to estimate, for any injury in a file using the OIC scheme, what the likely consequences are for the rest of the injured person's life. A few reservations should be made about this data, however. First, only a single physician was used to code the consequences of each injury. The data may therefore be biased by that particular physician's experience or preconceptions. Second, the OIC scheme does not code each injury in the AIS manual uniquely. For codings that represented multiple injuries, Hirsch et al. calculated a scoring that was the average of the injuries represented by that OIC. And third, not all the injuries in the coding manual (Petrucelli et al. 1983) used by the NASS investigators were covered.

THE AMA GUIDES TO PERMANENT IMPAIRMENT

The American Medical Association (1971) published a guide to assist physicians in rating permanent impairment resulting from mental or physical illness. The AMA defined permanent impairment as being "any anatomic or functional abnormality or loss after maximal medical rehabilitation has been achieved, which abnormality or loss the physician considers stable or nonprogressive at the time evaluation is made." This, the AMA held, was a medical condition, whereas permanent disability was not a purely medical condition, since it combined medical factors with other factors in evaluating a person's ability to engage in gainful activity.

The *Guides* were intended to provide examining physicians with the criteria to rate permanent impairment. It consists of a series of chapters, each covering an individual body system, such as the central nervous system and the skin. The guide for each body system was prepared by a separate committee or group of consultants. For each impairment, a value is provided both for percent impairment to the system or organ, and for "whole-man" impairment. Thus, restricted motion to the elbow could be sufficient to be coded as 39 percent impairment to the upper extremity, which translates into 23 percent impairment of the whole man. The *Guides* provide a table for combining two or more impairments to the whole man into a single value.

METHODOLOGY

OVERVIEW

This section describes the methodology that was used in the creation of a computerized system to generate information on how to prioritize injuries for the dummy design. A system was required that would provide a way of rating injuries according to their consequences using the existing accident files. In line with previous work, it was decided to define these consequences in economic terms, specifically in 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 as being irrelevant to the design of a test dummy. 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 single-injury model, i.e., it did not take into account the interaction of two or more injuries to a single person. The development of a multi-injury model is being reserved for further work. Thus, as presently constituted, the model can either be run at the occupant level of an accident file, using the first or most severe injury in the estimation, or it can be run at the injury level so that every injury is treated as a separate case.

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

FILLING IN THE GAPS IN THE CHI DATA

A comparison of the consequence-of-injury data received from Chi Associates with the injury codes used in the 1980 and 1981 NASS files revealed that not all the injury codes in NASS had been covered by the physicians working for Chi. A computer match was therefore made between the Chi file and the two NASS files. The matching algorithm first attempted to find matches using all five characters of the OIC and subsequently attempted to find matches ignoring the second character (aspect). From these matches a listing was obtained of all the NASS OICs that had failed to be matched with a Chi OIC. A number of these could be explained by the somewhat different coding scheme in the NASS injury coding manual (Petrucelli 1983) as compared to the AIS manual (AAAM 1980). 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.

There was, however, 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 Task A medical panel. Each injury was given to two physicians for coding, and, as far as was possible, the physicians were asked to code injuries in their areas of expertise. Conflicts between the codings by each pair of physicians were raised at a subsequent meeting of the medical panel.

The result of this work to augment the Chi data and to make the coding of the OICs compatible with NASS was a dataset that permitted all the Chi information to be incorporated in every NASS injury record with an AIS between 2 and 5. Thus analysis could be performed on all the Chi variables, once the Chi data had been transferred across

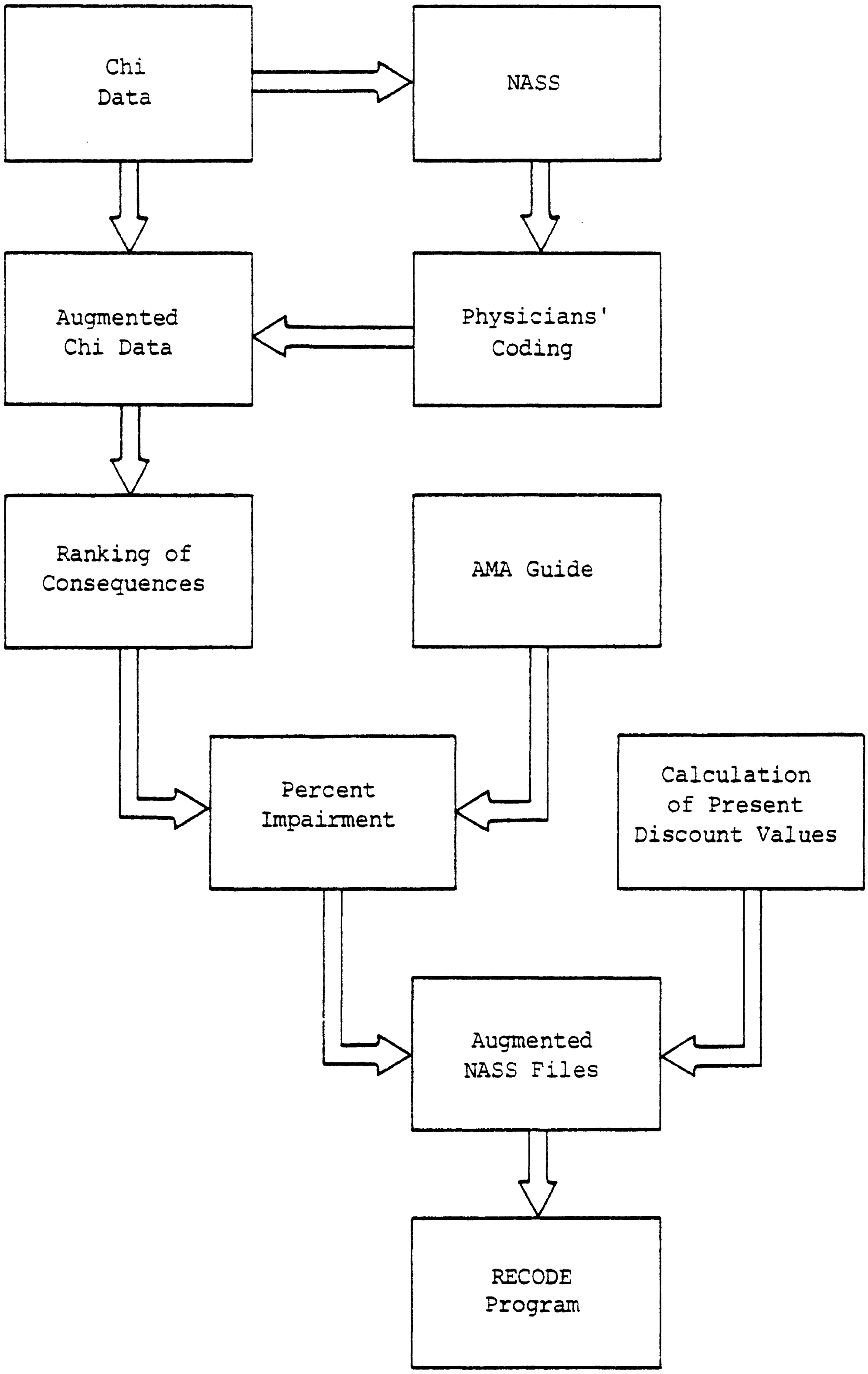

FIGURE 1. Development of Model.

by a match on OIC and age group. However, such an analysis, 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 using the Hartunian et al. methodology, i.e., using the present value of future earnings. Finally, after incorporating some other costs, the injuries in NASS could be ranked by their economic consequences. The model would not include all the economic consequences of motor-vehicle accidents but only those resulting directly from the injuries. Thus property damage, legal costs, and other such factors would be omitted.

TRANSLATING THE CHI CODINGS INTO IMPAIRMENT

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* (1971). This presents the physician with the material for coding virtually any physical or mental injury in terms of impairment. There were at least two major problems with using the AMA *Guides* directly and matching each OIC to an AMA injury to obtain impairment:

1. This would have been an extremely time-consuming task and would have essentially meant reproducing the Chi effort. Much effort would have been expended on translating the OICs into the AMA descriptions of injury.

2. The Chi detail, differentiating the consequences by four different age groups and separating the effects of injury into three time periods, would have been lost.

It was therefore decided to create an experiment to obtain a single ranking of the Chi consequences and to translate this ranking into a whole-body impairment using the AMA *Guides* for assistance. This process is described more fully in Appendix B. A computerized program was created to present respondents with pairs of the Chi consequences in random order. The respondents were asked to rank the second consequence as more severe than, the same severity as, or less severe than the first consequence. Thus the respondent might be asked to rank a level−4 cosmetic against a level−1 cognitive. To prevent bias the level numbers were not given; instead a brief description of the consequence at the appropriate level was presented. The experiment was performed by the 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 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.

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

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

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 were 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" (AMA 1971, pp. 158–60). 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.

CALCULATING THE PRESENT DISCOUNT VALUES

As has been discussed in the previous section, the NHTSA societal cost study used an inappropriate shortcut to calculate the lifetime values of victims of automobile accidents. Furthermore, the NHTSA study did not calculate these values for the periods used in the Chi study, i.e., for the current year (the year of the accident), the period from two to five years after the accident, and the rest of the victim's life. It was therefore necessary to recalculate the overall value of a person and to calculate the values for the three time periods.

The methodology here was that of Hartunian et al. (1981, p. 48). It applied the formula that calculates the present discounted value (PDV) of a person as:

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

(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 (NCHS 1975). 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, 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.

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 the all 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.

Finally, to incorporate these numbers in NASS, a series of matches were carried out with the 1980 and 1981 NASS files. First, a set of matches were made on the age and sex of the person to add the various discounted values to the 1980 and 1981 NASS occupant files and to the 1980 and 1981 NASS injury files. Second, a set of matches were made on OIC and grouped age to incorporate the Chi and impairment information in the same four files. The match to the occupant level files was made on the first injury coded for each victim, because NASS has a convention that stipulates that injuries be coded in order of descending severity. The result was a set of files incorporating all the NASS and Chi information and with the capability of generating estimates of the economic consequences of injury.

GENERATING INJURY PRIORITIZATION FROM NASS

The final step in the creation of an operating system to prioritize the injuries from 1980 and 1981 NASS in terms of body region, direction of force, delta V, etc., was to create a means of incorporating the cost function in the 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 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 fatalities and cases with an AIS between 2 and 6 were included. (A few cases with an AIS of 7 were also included, because they were really miscodings that should have an AIS of 2.) 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.

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

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 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.

Virtually identical programs were used in processing the NASS occupant-level and injury-level files. The only difference was that, in the analysis of the injury-level file, only the first injury was passed to the analysis program if the case was a fatality. 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.

RESULTS OF THE INJURY PRIORITY ANALYSIS

OVERVIEW

This section summarizes the results obtained in applying the injury prioritization model to the 1980 and 1981 NASS data sets. The task was to explore the data to find out which injuries should be accorded high priorities and then to explore the crash environment in which these injuries occurred, looking at such factors as direction of force, delta−V, and contact point.

Although analysis was carried out at both the occupant level (looking at the first injury) and at the injury level (looking at all injuries), this section will report mainly on the injury-level results. This has been done in the interest of readability and to prevent clutter. For the most part, there was little difference in the results obtained for the two modes of analysis. The development of a multi-injury model that would compute impairment by combining a person's various injuries has for now been deferred.

A further step taken in the interest of ease of analysis was to produce data files combining 1980 and 1981 NASS. These combined files eliminate some of the problems of year-to-year fluctuations in a sampling system such as NASS and also significantly increase the sample sizes from which conclusions are drawn. Most of the results are therefore given in terms of the average of the two years.

THE GLOBAL PICTURE

The first analysis looked at the global picture to see how injuries were distributed by vehicle type and body region. The distribution of the injury priority rating is shown as a percentage of the total IPR. Table 4 shows the results of analyzing the 1980 NASS file in this way at the occupant level. The first injury for each occupant, which according to the NASS coding convention is the most severe, was used. Only vehicles that can contain occupants were included in the analysis; thus motorcycles and bicycles were excluded. The car occupants accounted for 74.1 percent of the injury rating, with light truck occupants coming in second among the vehicle classes at 14.3 percent. The share of on/off-road vehicles is somewhat high at 5.7 percent, given their share of the vehicle population which was 1.1 percent in 1980 (FHWA 1980; Smith 1982). It is also notable that for these vehicles head, neck, and knee injuries stand out. Among the body regions,[2] the head leads at 49.3 percent overall, followed by the chest at 16.6 percent. Car occupants with head injuries account for 37.0 percent of the total. If the head, face, and neck are grouped together, they account for 66.3 percent of the total as compared to 23.5 percent for the chest, back, and abdomen grouped together.

Table 5 shows the same analysis carried out without the consequences-of-injury function. In other words, it shows the nationally estimated distribution of occupants receiving AIS-2 through 6 injuries. The share of the various vehicle types is somewhat different. That of heavy truck occupants is much lower than in the previous table,

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[2]Table 4 and several subsequent tables provide distributions of IPR by the NASS body regions. The NASS coding scheme for body region is shown in Appendix D.

TABLE 4

1980 NASS (OCCUPANT LEVEL):
PERCENT INJURY PRIORITY RATING (IPR) BY
BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	37.0	0.0	2.7	7.8	1.8	49.3
Face	8.2	0.0	0.0	1.5	0.0	9.7
Neck	5.5	0.0	1.0	0.7	0.0	7.3
Shoulder .	0.1	0.0	0.0	0.0	0.0	0.1
Chest	11.8	0.0	0.0	1.8	3.0	16.6
Back	0.1	0.0	0.0	0.0	0.0	0.1
Abdomen .	5.8	0.0	0.0	0.2	0.8	6.8
Pelvis	1.5	0.0	0.0	0.0	0.0	1.5
Thigh	1.0	0.0	0.0	0.2	0.0	1.1
Knee	0.7	0.0	2.0	0.0	0.0	2.7
Lower leg .	0.2	0.0	0.0	0.0	0.2	0.5
Ankle/foot	0.1	0.0	0.0	0.0	0.0	0.1
Upper arm	0.7	0.0	0.0	0.9	0.0	1.6
Elbow ...	0.0	0.0	0.0	0.0	0.0	0.0
Forearm ..	1.5	0.0	0.0	0.2	0.0	1.7
Wrist/hand	0.1	0.0	0.0	0.1	0.0	0.2
Upper limb	0.0	0.0	0.0	0.7	0.0	0.7
Total	74.1	0.0	5.7	14.3	5.9	100.0

suggesting that, when injured, they tend to receive more severe injuries. The share of on/off-road vehicle occupants is also lower, apparently because of the heavy weighting given in the injury priority model to head and neck injuries. This is confirmed by the share of head-injured occupants, who now account for 24.7 percent of the total, compared to the 49.3 percent of Table 4. The head, face, and neck group accounts for 40.3 percent of the total without the consequence function, and the chest, back, and abdomen group for 20.9 percent.

Tables 6 and 7 present the same pair of tables generated from 1981 NASS. The distribution in Table 6 is generally the same as that in Table 4, although the overall share of head injuries is somewhat lower and that of chest injuries somewhat higher. The head, face, and neck group accounts for 57.7 percent of the total, and the chest, back, and abdomen group for 31.6 percent. Once again, in Table 7, the distribution for injured occupants without using the consequences-of-injury function is presented. As in 1980, the share of head-injured occupants is lower with than without using the function. Once again too, use of the function elevates the share for occupants of on/off-road vehicles and heavy trucks, while lowering the share for occupants of passenger cars. In 1981, in contrast to 1980, use of the function also raises the share for occupants of light trucks. This difference seems to be attributable to the head, face, and neck injuries of the light truck occupants.

TABLE 5

1980 NASS (OCCUPANT LEVEL):
ESTIMATED PERSONS INJURED BY BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off-Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	18.0	0.0	0.4	5.7	0.7	24.7
Face	10.7	0.0	0.0	1.9	0.0	12.7
Neck	2.6	0.0	0.1	0.2	0.0	2.9
Shoulder .	7.8	0.2	0.5	1.4	0.0	9.9
Chest	8.0	0.0	0.1	2.0	0.4	10.4
Back	4.8	0.0	0.5	0.2	0.0	5.5
Abdomen .	4.2	0.0	0.1	0.7	0.1	5.0
Pelvis	2.5	0.0	0.1	0.5	0.0	3.1
Thigh	2.5	0.0	0.0	0.4	0.0	2.9
Knee	3.3	0.0	0.2	0.1	0.0	3.6
Lower leg .	3.3	0.2	0.0	0.3	0.1	3.8
Ankle/foot	4.5	0.0	0.0	1.1	0.2	5.8
Upper arm	0.7	0.0	0.0	0.2	0.0	0.9
Elbow ...	0.0	0.0	0.0	0.2	0.0	0.2
Forearm ..	2.7	0.0	0.1	0.5	0.0	3.2
Wrist/hand	4.1	0.0	0.0	1.1	0.1	5.3
Upper limb	0.0	0.0	0.0	0.1	0.0	0.1
Total	79.6	0.3	2.0	16.6	1.4	100.0

Tables 8 and 9 present the same analysis as in Tables 4 and 6, this time run at the injury level. In other words, instead of analyzing the first injury for each occupant, these tables analyze every AIS-2 through 6 injury for each occupant. However, no account is taken of the interaction of multiple injuries on an occupant: each injury is treated separately. As might be expected, the inclusion of injuries beyond the first injury increases the share of the body regions where a life-threatening injury is less likely. Thus in both years the shares for the head and chest fall, while those for the knee and lower leg rise. It seems likely that, if a multiple injury model were applied, the picture would fall somewhere between the first injury results, which ignore some of the lesser injuries, and the every-injury results, which may give undue importance to these lesser injuries. For the sake of convenience, subsequent results will be presented only at the injury level. This should present a more complete picture than the runs at the occupant level. The comparable results at the occupant level can be found in Appendix C.

Part of the analysis shown in Tables 8 and 9 is displayed in Figure 2. The two pies illustrate the relative share of each vehicle type in the incurrence of IPR, using the 1980 and 1981 NASS files.

TABLE 6

1981 NASS (OCCUPANT LEVEL):
PERCENT INJURY PRIORITY RATING (IPR) 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	5.0	7.3	0.4	45.2
Face	3.8	0.0	0.2	1.8	0.3	6.1
Neck	2.8	0.0	0.0	2.8	0.9	6.4
Shoulder ..	0.3	0.0	0.0	0.0	0.0	0.3
Chest	19.4	0.0	2.0	1.5	0.1	22.9
Back	2.5	0.0	0.0	0.0	0.2	2.6
Abdomen ..	5.9	0.0	0.0	0.2	0.0	6.1
Pelvis	0.1	0.0	0.0	0.0	0.0	0.1
Thigh	1.5	0.0	0.1	0.2	0.0	1.7
Knee	0.4	0.0	0.0	0.1	0.0	0.5
Lower leg ..	0.1	0.0	0.0	0.0	0.0	0.1
Ankle/foot .	0.1	0.0	0.0	0.0	0.0	0.2
Lower limb .	0.0	0.0	0.0	1.0	0.0	1.0
Upper arm .	1.6	0.0	0.0	0.0	0.0	1.6
Elbow	0.0	0.0	0.0	0.0	0.0	0.1
Forearm ..	0.1	0.0	0.0	0.4	0.0	0.5
Wrist/hand .	0.0	0.0	0.0	1.8	0.0	1.9
Upper limb .	0.4	0.0	0.0	0.0	0.0	0.4
Whole body	1.6	0.0	0.0	0.0	0.1	1.8
Unknown ..	0.4	0.0	0.0	0.0	0.0	0.4
Total	73.5	0.0	7.2	17.2	2.1	100.0

TABLE 7

1981 NASS (OCCUPANT LEVEL):
ESTIMATED PERSONS INJURED BY BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off-Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	30.7	0.0	0.8	3.4	0.5	35.3
Face	6.8	0.0	0.1	1.8	0.2	9.0
Neck	2.0	0.0	0.0	0.9	0.1	3.0
Shoulder . .	9.7	0.2	0.1	1.0	0.0	11.0
Chest	8.5	0.0	0.3	1.3	0.4	10.5
Back	2.3	0.0	0.0	0.1	0.1	2.6
Abdomen . .	3.1	0.0	0.0	0.7	0.0	3.8
Pelvis	1.4	0.0	0.2	0.4	0.0	2.1
Thigh	2.2	0.0	0.1	0.3	0.0	2.7
Knee	4.1	0.2	0.0	0.5	0.0	4.8
Lower leg . .	1.3	0.0	0.0	0.6	0.2	2.1
Ankle/foot .	2.6	0.0	0.0	0.9	0.0	3.5
Lower limb .	0.1	0.0	0.0	0.1	0.0	0.1
Upper arm .	1.5	0.1	0.1	0.0	0.0	1.6
Elbow	0.6	0.0	0.0	0.1	0.0	0.7
Forearm . .	2.1	0.1	0.7	0.5	0.0	3.3
Wrist/hand .	2.9	0.0	0.0	0.4	0.1	3.4
Upper limb .	0.1	0.0	0.0	0.0	0.0	0.1
Whole body	0.3	0.0	0.0	0.0	0.0	0.3
Unknown . .	0.1	0.0	0.0	0.0	0.0	0.1
Total	82.4	0.6	2.3	13.0	1.7	100.0

TABLE 8

1980 NASS (INJURY LEVEL):
PERCENT INJURY PRIORITY RATING (IPR) BY
BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off-Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	34.1	0.0	2.3	7.8	1.5	45.8
Face	10.5	0.0	0.0	3.0	0.0	13.5
Neck	4.7	0.0	0.9	0.6	0.0	6.2
Shoulder .	0.2	0.0	0.0	0.0	0.0	0.2
Chest	10.1	0.0	0.0	1.6	2.5	14.3
Back	0.1	0.0	0.0	0.0	0.0	0.1
Abdomen .	5.3	0.0	0.0	0.2	0.7	6.2
Pelvis	1.4	0.0	0.0	0.0	0.0	1.4
Thigh	1.4	0.0	0.0	0.4	0.0	1.9
Knee	1.5	0.0	1.7	0.0	0.0	3.3
Lower leg .	1.2	0.0	0.0	0.0	0.4	1.6
Ankle/foot	0.6	0.0	0.0	0.0	0.0	0.7
Lower limb	0.0	0.0	0.0	0.0	0.0	0.0
Upper arm	0.6	0.0	0.0	0.8	0.0	1.3
Elbow ...	0.7	0.0	0.0	0.0	0.0	0.7
Forearm . .	1.4	0.0	0.0	0.2	0.0	1.6
Wrist/hand	0.5	0.0	0.0	0.1	0.0	0.6
Upper limb	0.0	0.0	0.0	0.6	0.0	0.6
Total	74.4	0.0	5.0	15.5	5.1	100.0

TABLE 9

1981 NASS (INJURY LEVEL):
PERCENT INJURY PRIORITY RATING (IPR) BY
BODY REGION AND VEHICLE TYPE

Body Region	Passenger Car	Bus	On/Off-Road Vehicle	Light Truck	Heavy Truck	All Vehicles
Head	31.6	0.0	4.9	7.4	0.4	44.3
Face	4.6	0.0	0.2	2.3	0.3	7.4
Neck	2.7	0.0	0.0	2.5	0.8	6.0
Shoulder . .	0.3	0.0	0.0	0.0	0.0	0.4
Chest	18.3	0.0	1.8	1.4	0.1	21.6
Back	2.4	0.0	0.0	0.0	0.2	2.7
Abdomen . .	5.8	0.0	0.0	0.2	0.0	6.1
Pelvis	0.2	0.0	0.0	0.0	0.0	0.2
Thigh	1.7	0.0	0.1	0.2	0.0	2.0
Knee	0.8	0.0	0.0	0.1	0.0	0.8
Lower leg . .	0.3	0.0	0.0	0.0	0.0	0.3
Ankle/foot .	0.2	0.0	0.0	0.0	0.0	0.3
Lower limb .	0.0	0.0	0.0	0.9	0.0	1.0
Upper arm .	1.4	0.0	0.0	0.0	0.0	1.5
Elbow	0.0	0.0	0.4	0.0	0.0	0.5
Forearm . .	0.5	0.0	0.0	0.4	0.0	0.9
Wrist/hand .	0.1	0.0	0.0	1.7	0.0	1.8
Upper limb .	0.4	0.0	0.0	0.0	0.0	0.4
Whole body	1.5	0.0	0.0	0.0	0.1	1.6
Unknown . .	0.4	0.0	0.0	0.0	0.0	0.4
Total	73.3	0.1	7.4	17.3	2.0	100.0

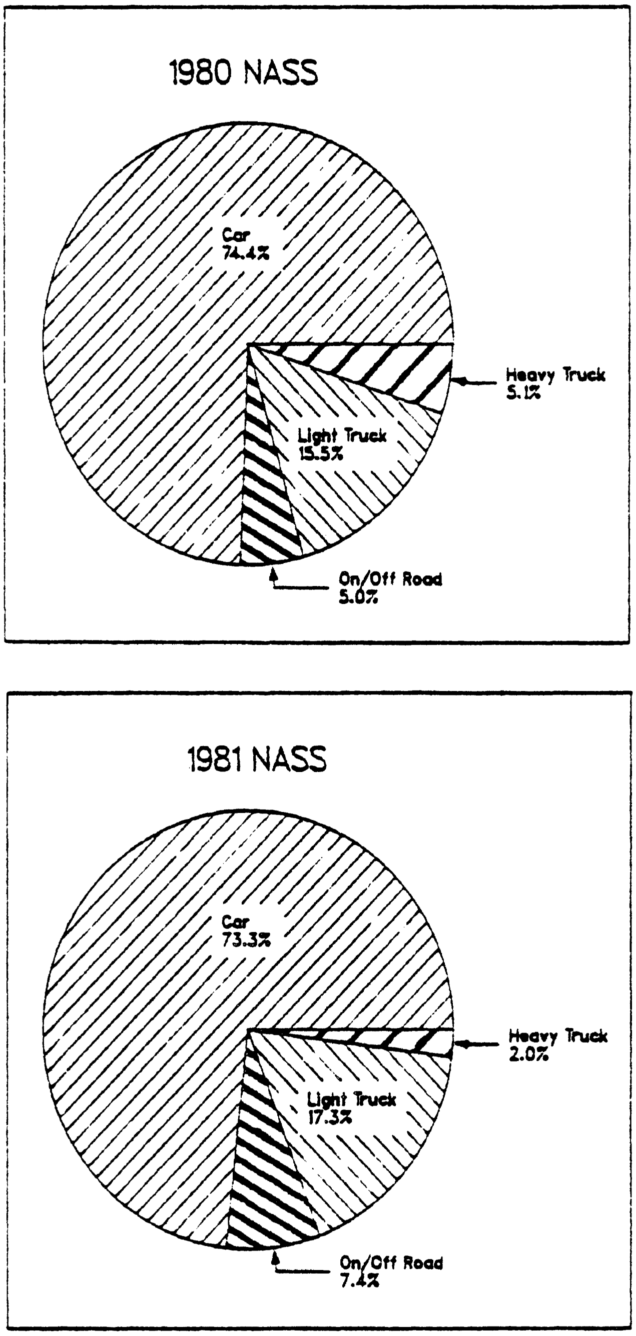


FIGURE 2. 1980 and 1981 NASS (Injury Level): Percent IPR by Vehicle Type.

PASSENGER CAR OCCUPANTS

The remainder of this section will concentrate on passenger car occupants and especially on front-seat occupants. Table 10 shows the distribution of the injury consequence function by body region for restrained and unrestrained passenger car occupants. The unrestrained group account for over 98 percent of total IPR to passenger car occupants, and as a consequence there is virtually no difference between the distribution for this group and that for all passenger car occupants. It is interesting to note the predominant share of head injuries in the IPR to the restrained occupants. The restraints are apparently unable to prevent a small number of serious head injuries, although they virtually eliminate serious injuries to most other body regions.

TABLE 10

1980 AND 1981 NASS (INJURY LEVEL): PERCENT IPR FOR PASSENGER CAR OCCUPANTS BY BODY REGION AND RESTRAINT USE

Body Region	Restrained[a]	Unrestrained[b]	All
Head	89.3	43.7	44.6
Face	4.6	10.6	10.5
Neck	3.2	5.1	5.1
Shoulder ..	0.1	0.3	0.3
Chest	0.7	19.3	18.9
Back	0.9	1.6	1.6
Abdomen ..	0.3	7.7	7.5
Pelvis	0.0	1.1	1.1
Thigh	0.3	2.1	2.1
Knee	0.0	1.6	1.6
Lower leg ..	0.0	1.1	1.0
Ankle/foot .	0.0	0.6	0.6
Lower limb .	0.0	0.0	0.0
Upper arm .	0.0	1.4	1.3
Elbow	0.0	0.5	0.5
Forearm ..	0.0	1.3	1.3
Wrist/hand .	0.4	0.4	0.4
Upper limb .	0.0	0.3	0.3
Whole body	0.0	1.0	0.9
Unknown ..	0.0	0.2	0.2
Total	100.0	100.0	100.0

[a]The restrained group accounts for 1.9 percent of the total IPR for passenger car occupants.

[b]The unrestrained group accounts for 98.1 percent of the total IPR for passenger car occupants.

Table 11 shows the distribution of the injury consequence function by seat position for passenger car occupants. As might be expected, the front positions account for over 90 percent of the total, with the major portion going to the left-front seat position. This is not necessarily any reflection of greater risk in that position, but more likely of a higher occupancy rate.

TABLE 11

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR FOR PASSENGER CARS BY SEAT POSITION

Seat Position	Proportion of IPR
Front left . .	72.7
Front center	1.4
Front right .	16.2
All other . .	9.7
Total	100.0

Table 12 shows the distribution of the injury consequence function by body region for front occupants of passenger cars only. The distribution for each seat position is shown. For the drivers, the head, chest, and face are the most important body regions with almost every other region falling out of the picture. But what is perhaps most remarkable is the role of abdominal injury for the center and right positions. Even if the front-center figure of a 34.1 percent share for abdominal injuries is discounted because of small sample size (69 injuries), the share for the right-front position at 14.0 percent is almost three times that for the driver (4.9 percent). Unfortunately an examination of the contact points for these abdominal injuries to right-front passengers found that, by IPR share, 74 percent of them were unknown. Of the known group, virtually all were from contact with "side hardware or armrest."

This run on the contact points for each body region was made separately for drivers and right-front passengers. For the drivers, 37.8 percent of the IPR was attributable to unknown contact points, with almost half of this (16.3 percent overall) being for head injuries. Among the known combinations of body region and contact point for drivers, the highest ranking was head into some exterior object at 11.6 percent overall. (All the exterior contact points were grouped together for this analysis.) Presumably these injuries resulted from ejection. The other major combinations were chest into steering wheel at 9.7 percent overall, head into windshield at 5.5 percent, face into windshield at 4.9 percent, head into A-pillar at 2.9 percent, head into front header at 2.2 percent. Any other individual combination accounted for less than 2 percent of the driver IPR.

For the right-front passengers, the proportion of IPR attributable to unknown contact points was even higher at 52.1 percent overall. This indicates a significant problem with the 1980 and 1981 NASS files. This time the leading combination was chest into instrument panel at 6.6 percent of the overall IPR. The other leading combinations (those with over 2 percent of the IPR) were head into A-pillar at 5.9 percent, head into

TABLE 12

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR FOR PASSENGER CAR FRONT OCCUPANTS
BY BODY REGION AND SEAT POSITION

Body Region	Seat Position			
	Front Left	Front Center	Front Right	All Front
Head	42.6	52.8	42.7	42.8
Face	11.7	4.4	8.3	11.0
Neck	6.2	0.0	3.5	5.6
Shoulder ..	0.4	0.6	0.2	0.4
Chest	20.5	0.9	18.4	19.8
Back	0.5	0.0	7.3	1.7
Abdomen ..	4.9	34.1	14.0	7.0
Pelvis	1.4	0.7	0.5	1.2
Thigh	2.3	1.4	1.5	2.1
Knee	1.9	2.8	0.9	1.7
Lower leg ..	1.3	1.2	0.5	1.1
Ankle/foot .	0.7	0.7	0.3	0.6
Lower limb .	0.0	0.0	0.0	0.0
Upper arm .	1.8	0.1	0.1	1.5
Elbow	0.7	0.0	0.0	0.6
Forearm ..	1.5	0.4	0.9	1.4
Wrist/hand .	0.4	0.1	0.9	0.5
Upper limb .	0.3	0.0	0.0	0.3
Whole body	0.6	0.0	0.0	0.5
Unknown ..	0.3	0.0	0.0	0.3
Total	100.0	100.0	100.0	100.0

windshield at 4.6 percent, chest into some exterior object at 4.3 percent, head into an exterior object at 3.9 percent, face into roof top at 3.6 percent, abdomen into side hardware or armrest at 3.5 percent, face into windshield at 3.0 percent, and head into roof top at 2.5 percent.

DELTA V AND CLOCK DIRECTION

The remainder of this section will expand the analysis already presented to include the direction of force (from the first CDC) and the crash severity shown by the change in velocity (delta V). Table 13 shows the distribution of the injury consequence function by direction of force for four groups of seat position. The same data, for the left-front and right-front seat positions, are displayed in Figure 3.

It should be noted that, from Table 11, the left-front occupants account for 72.7 percent of the IPR and the right-front occupants for 16.2 percent. The "other" group accounts for 25.9 percent. The non-horizontal directions, presumably rollovers, were

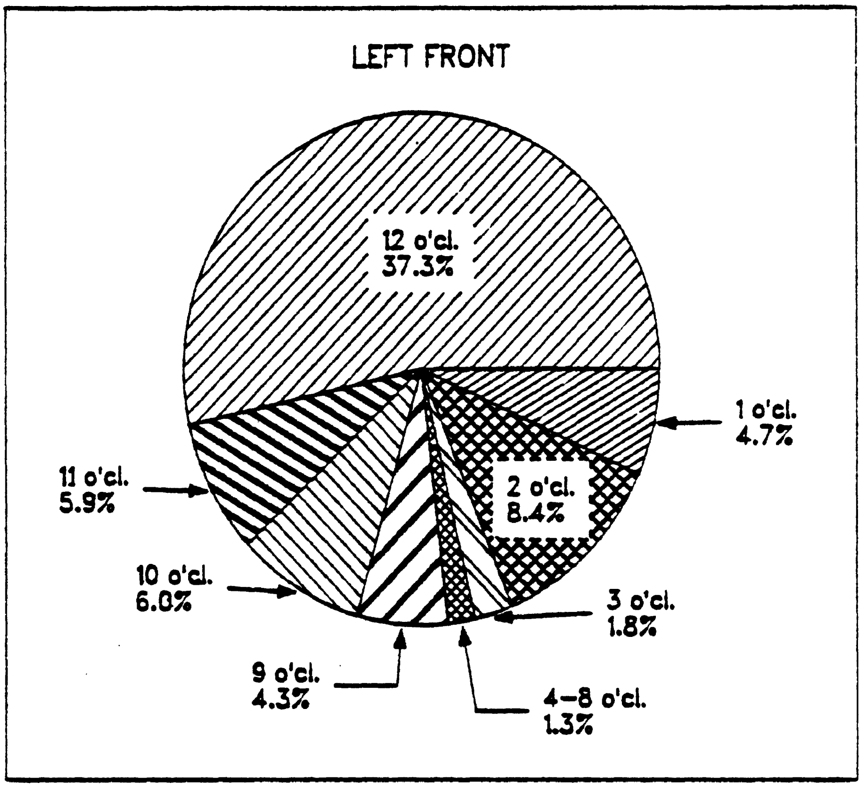
TABLE 13

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	4.7	7.9	0.3	4.8
2 o'clock	8.4	11.3	17.0	9.8
3 o'clock	1.8	9.4	6.1	3.5
4 o'clock	0.0	0.0	0.0	0.0
5 o'clock	0.1	0.0	0.0	0.1
6 o'clock	0.4	1.3	1.5	0.7
7 o'clock	0.4	0.0	0.0	0.3
8 o'clock	0.4	2.1	5.0	1.2
9 o'clock	4.3	0.4	1.2	3.3
10 o'clock	6.0	18.3	5.3	7.9
11 o'clock	5.9	0.5	5.7	5.0
12 o'clock	37.3	28.4	47.0	36.9
Non-horizontal	19.7	8.4	4.0	16.1
Unknown	10.6	11.9	6.9	10.4
Total	100.0	100.0	100.0	100.0
N	1445	509	308	2262

responsible for about a sixth of the injury consequences as measured by IPR. For the drivers, by far the most important direction of force was 12 o'clock, i.e., head-on. The right-front passengers, on the other hand, while they incurred the largest amount of their IPR at 12 o'clock, also incurred a substantial amount at 10 o'clock. In other words, left-oblique force direction represents a significant problem for right-front passengers. This will be further discussed below. Right-front passengers also incurred proportionally more IPR at 3 o'clock than did drivers at 9 o'clock. Overall, the 9 o'clock through 3 o'clock sector accounts for virtually all of the IPR.

Table 14 shows the overall distribution of the injury consequence function across delta V for each direction of force. Note that the relative size of the IPR for each direction must be obtained from the previous table, where it is shown in the "All" column. The first thing to note here is the high proportion of unknown delta Vs, representing 68.9 percent of the IPR for passenger cars. Only for the 6, 8, 11, and 12 o'clock distributions does unknown delta V account for less than half of the IPR. The distributions for clock directions 4, 5, and 7 can probably be ignored because of the small number of cases on which they are based (1, 5, and 7, respectively). For clock directions 1, 3, 9, and 11, over half the IPR for known delta V was incurred at a delta V of 20 mph or less. By contrast, for the 12 o'clock direction, only 12 percent of the IPR for known delta V is attributable to



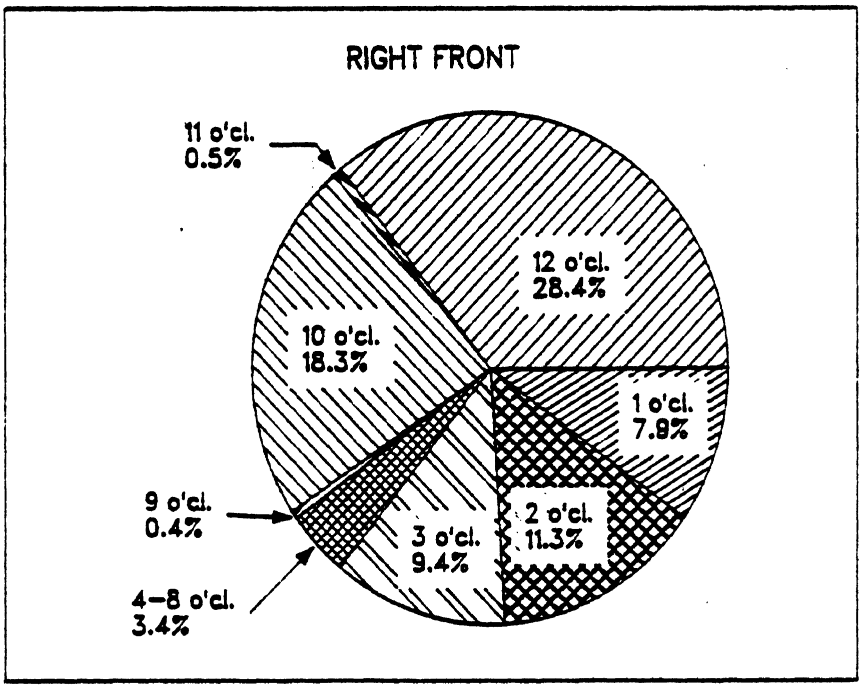


FIGURE 3. 1980 and 1981 NASS (Injury Level): Percent IPR by Seat Position and Horizontal Direction of Force.

these less severe crashes. Thus it would appear that side collisions are more dangerous to occupants than straight frontal collisions of equivalent force.

Tables 15 and 16 show the same distribution separately for left-front and right-front occupants. The relative size of the distributions shown in the columns may be obtained from Tables 11 and 13. The total IPR depicted in Table 15 is four and a half times as great as that depicted in Table 16. In Table 15, the distributions for the 4, 5, and 7 o'clock directions may be ignored because of small sample size (1, 4, and 6 cases, respectively). Similarly in Table 16, those for the 5, 6, 7, 8, and 9 o'clock directions, with their sample sizes of 1, 12, 1, 12, and 9, may also be ignored. What stands out in Table 15, other than the high proportion accounted for by unknown delta V (73.1 percent of the overall driver IPR), is the tendency in the distribution for the 12 o'clock direction to be of high delta Vs. For this direction, using only the cases with known delta V, 16 percent of the IPR was incurred at delta Vs of 20 mph or less, 84 percent at higher delta Vs. Of the other directions, only 2, 6, 8, and 10 o'clock and the non-horizontal crashes had over half their IPR for known delta V resulting from the more severe crashes. Looking at Table 16, this tendency towards high delta Vs in the distribution for 12 o'clock is even more pronounced. For the right-front passengers subjected to a force at 12 o'clock, 3 percent of the IPR for known delta V was incurred at a delta V of 20 mph or less, and 97 percent at a delta V of over 20 mph. At 1 o'clock, 98 percent of the IPR for known delta V was incurred in crashes with a delta V of over 20 mph. There is a paler reflection of this tendency towards IPR attributable to higher delta Vs in the distributions for 10 and 11 o'clock. But the tendency toward high delta Vs should not be over-emphasized. Of driver IPR for known delta V, 81 percent was incurred in crashes with a delta V of 45 mph or less. For right-front passengers the comparable figure is 77 percent.

Figure 4 shows some of this data on IPR by delta V in graphical form. Two curves of cumulative IPR are given, one for front collisions (11, 12, and 1 o'clock) and one for side collisions (2 through 4 o'clock and 8 through 10 o'clock). The curves show that, for side collisions as compared to front collisions, a greater proportion of IPR is attributable to less severe crashes. Thus, for side collisions, one third of all IPR results from crashes with a delta V of 20 mph or less. For front collisions, one third of all IPR results from crashes of 24 mph or less.

The next series of tables break down the analysis shown in the last two tables even further. They show the distribution of IPR by delta V and direction of force, split on body region for both left-front and right-front passenger car occupants. There is one table for each combination of body region and seat position. Rather than showing each NASS body region separately and running out of cases at once, the body regions have been grouped. The first body area is a combination of head, face, and neck. The second is a grouping of chest, back, and abdomen. The upper extremities from the shoulder out provide the third grouping, while the fourth consists of the lower extremities from the pelvis down. In theory, by comparing these tables, one should be able to get a picture of the interaction of seat position, body region, direction of force, and delta V. The tables for each of the two seat positions are introduced by a table showing the relative magnitude of the IPR for each body region, i.e., the relative sizes of the columns in the subsequent four tables. Tables 17 and 22 show these relative magnitudes.

Table 17 shows that, for drivers with head, face, or neck injuries, the IPR from 12 o'clock collisions is almost ten times as great as that from 11 o'clock collisions. This should be remembered when comparing the distributions shown in the columns of Table 18. More substantively, Table 17 shows that, while the serious consequences of injuries to the head region result mainly from direct frontal forces and from non-horizontal forces, a significant share of the consequences of injury to the trunk region is attributable to right oblique

TABLE 14

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
6-10 mph	1.1	0.5	0.0	0.0	0.0	0.1	0.0	0.1	2.3	1.4	5.9	0.2	0.0	0.0	0.6
11-15 mph	10.4	2.9	7.8	100.0	0.0	1.6	0.0	6.3	0.4	1.0	6.6	1.1	0.0	0.0	2.0
16-20 mph	4.0	3.8	7.6	0.0	76.2	22.8	0.0	0.2	3.1	5.8	19.4	4.8	0.0	0.0	4.3
21-25 mph	6.4	2.8	1.8	0.0	21.8	4.8	67.5	0.0	1.7	11.4	9.8	12.7	0.0	0.0	7.0
26-30 mph	3.9	7.8	14.1	0.0	0.0	28.7	0.0	72.2	0.0	4.4	12.3	3.8	0.0	0.0	4.9
31-35 mph	0.2	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.4	6.9	0.0	0.0	2.6
36-40 mph	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.9	0.0	0.0	1.5
41-45 mph	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	1.9	0.0	0.0	1.5
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	0.1	0.0	0.0	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	7.2	0.0	0.0	2.7
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	0.0	0.0	3.8
Unknown .	74.0	78.2	65.4	0.0	2.0	37.8	32.5	21.2	92.5	70.3	45.3	47.0	100.0	100.0	68.9
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	155	162	66	1	5	36	7	46	72	132	234	797	276	273	2262

TABLE 15

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	0.2	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2
6-10 mph	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.2	2.5	2.2	4.7	0.2	0.0	0.0	0.7
11-15 mph	14.4	2.6	3.4	100.0	0.0	2.9	0.0	2.0	0.4	1.1	3.5	1.1	0.0	0.0	1.7
16-20 mph	5.2	2.8	1.4	0.0	75.5	1.8	0.0	0.0	2.2	2.2	21.2	6.4	0.0	0.0	4.5
21-25 mph	5.0	1.8	0.0	0.0	22.4	5.6	69.3	0.0	1.8	13.7	10.4	12.9	0.0	0.0	7.0
26-30 mph	5.4	3.5	0.0	0.0	0.0	2.3	0.0	21.5	0.0	1.4	14.3	4.6	0.0	0.0	3.3
31-35 mph	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	5.1	0.0	0.0	2.0
36-40 mph	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.0	0.0	0.0	1.1
41-45 mph	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	1.4
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	0.1	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	9.6	0.0	0.0	3.6
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	1.4
Unknown .	68.2	82.2	86.3	0.0	2.1	87.4	30.7	76.3	93.2	79.4	45.2	50.8	100.0	100.0	73.1
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	112	89	21	1	4	20	6	23	48	84	167	518	166	186	1445

TABLE 16

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	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	0.0	0.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
11-15 mph	0.1	1.8	14.9	0.0	1.3	0.0	1.7	0.0	0.6	3.6	2.1	0.0	0.0	2.4
16-20 mph	0.1	9.7	14.2	100.0	0.5	0.0	0.0	54.8	12.2	22.8	0.5	0.0	0.0	5.2
21-25 mph	10.1	8.8	0.4	0.0	7.7	0.0	0.0	0.0	0.1	22.9	14.6	0.0	0.0	6.2
26-30 mph	0.0	0.5	32.2	0.0	87.3	0.0	96.5	0.0	0.6	2.3	2.6	0.0	0.0	7.1
31-35 mph	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	5.0	14.1	0.0	0.0	4.0
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	3.5
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.7	0.0	0.9	0.0	0.0	3.1
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	0.0	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	0.5	0.0	0.0	0.1
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.6	0.0	0.0	9.2
Unknown .	89.7	79.1	38.1	0.0	2.4	100.0	1.8	45.2	70.8	43.4	19.8	100.0	100.0	59.1
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	21	49	28	1	12	1	12	9	33	38	181	73	51	509

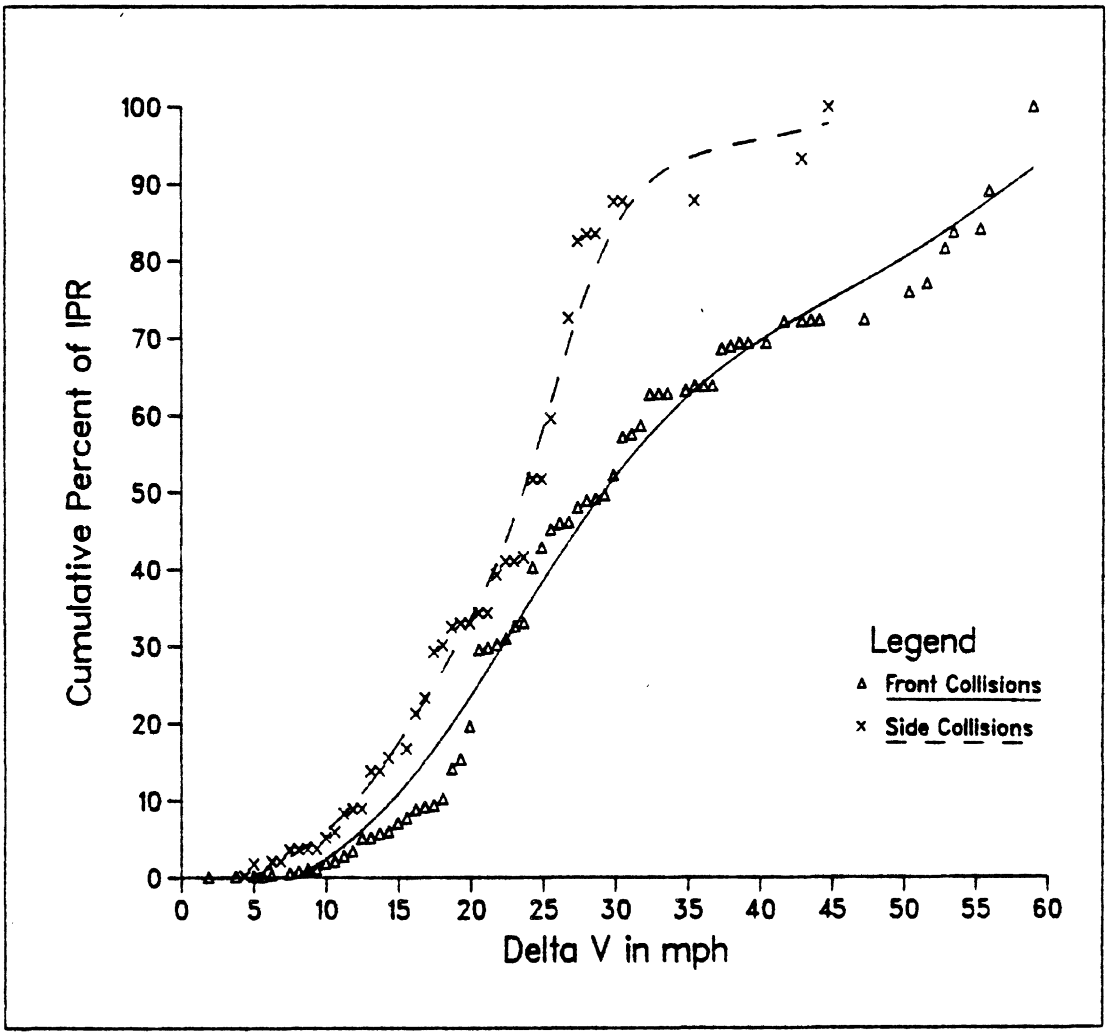


FIGURE 4. 1980 and 1981 NASS (Injury Level): Cumulative Percent of IPR by Delta V for Front and Side Collisions.

TABLE 17

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	5.8	1.5	11.5	3.2	0.0	4.7
2 o'clock	1.5	24.5	13.2	3.4	23.2	8.4
3 o'clock	2.8	0.2	0.1	0.3	0.0	1.8
4 o'clock	0.0	0.0	0.0	0.0	0.0	0.0
5 o'clock	0.1	0.0	0.0	0.0	0.0	0.1
6 o'clock	0.6	0.0	0.1	0.1	0.0	0.4
7 o'clock	0.2	1.0	0.0	0.0	0.0	0.4
8 o'clock	0.5	0.4	0.1	0.8	0.0	0.4
9 o'clock	2.9	2.0	0.1	22.4	36.1	4.3
10 o'clock	7.3	4.6	0.3	5.4	0.0	6.0
11 o'clock	3.9	6.0	30.9	6.0	0.0	5.9
12 o'clock	37.3	36.4	22.5	50.3	40.7	37.3
Non-horizontal	26.9	8.9	15.7	4.2	0.0	19.7
Unknown	10.3	14.5	5.4	3.7	0.0	10.6
Total	100.0	100.0	100.0	100.0	100.0	100.0
N	576	307	237	322	3	1445

forces at 2 o'clock. These collision forces at 2 o'clock as well as those at 1 o'clock also result in an appreciable share of the IPR to the upper extremities, but not of the IPR to the lower extremities. The upper extremities are also highly susceptible at 11 o'clock with 31 percent of their IPR, even more so than at 12 o'clock with 23 percent. Even so, because of the relative magnitude of the IPR to the head region, the overall distribution resembles that for the head.

Table 18 shows the distribution of IPR for injuries to the head region, with the added dimension of delta V. The distributions outside the 10 o'clock through 2 o'clock sector can be ignored because of small sample size. Once again, the high proportion of the share attributable to unknown delta V (80 percent overall) should be noted. Otherwise, what is perhaps most noticeable is that at 10 o'clock and at 12 o'clock, most of the IPR is attributable to crashes with a delta V greater than 20 mph. At 12 o'clock, of the IPR for known delta V, 81 percent is from a delta V greater than 20 mph. Overall, 66 percent of the IPR with known delta V is the result of the more severe crashes.

Table 19 has the same type of distribution for drivers with injuries to the trunk region. Here only the distributions for 1, 2, 10, 11, and 12 o'clock have sufficient cases, and of these the distributions for 2 and 10 o'clock are mostly unknown. Here, the

TABLE 18

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	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	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3
6-10 mph	1.9	3.6	0.0	0.0	0.0	0.0	0.0	5.4	3.0	4.8	0.3	0.0	0.0	0.8
11-15 mph	2.1	19.5	3.5	0.0	0.9	0.0	2.4	1.0	1.1	2.5	1.8	0.0	0.0	1.4
16-20 mph	5.3	23.9	0.0	77.1	1.9	0.0	0.0	0.0	2.5	38.0	4.9	0.0	0.0	4.3
21-25 mph	1.8	5.5	0.0	22.9	3.6	0.0	0.0	0.0	12.9	19.6	13.2	0.0	0.0	6.9
26-30 mph	2.0	1.5	0.0	0.0	2.4	0.0	0.0	0.0	1.8	0.4	3.2	0.0	0.0	1.5
31-35 mph	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.8	0.0	0.0	0.7
36-40 mph	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	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	4.0	0.0	0.0	1.5
46-50 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	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	6.4	0.0	0.0	2.4
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.3
Unknown .	86.9	45.3	87.3	0.0	91.3	100.0	97.6	93.6	78.7	33.2	63.2	100.0	100.0	79.8
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
N	48	34	10	3	11	2	3	12	33	55	217	72	76	576

collisions at 10 o'clock are the exception, with 96 percent of the IPR for cases with known delta V resulting from crashes with a delta V of 20 mph or less. At 12 o'clock by contrast, using only known delta V, 80 percent of the IPR is attributable to crashes with a delta V over 20 mph. The equivalent figure for the head, face, and neck region is 81 percent. Overall, 19 percent of the IPR with known delta V resulted from the less severe crashes.

The distribution for drivers with injuries to the upper extremities, given in Table 20, shows less than half of the IPR resulting from crashes with a delta V over 20 mph. Overall, only 45 percent of the IPR with known delta V resulted from such crashes. However there is an interesting clump of serious upper-extremity injuries occurring at a delta V between 26 and 30 mph and at a 12 o'clock direction of force. By contrast, a predominant share of the IPR for drivers with injuries to the lower extremities (shown in Table 21) resulted from the more severe collisions. Here, 93 percent of IPR with known delta V occurred as a result of crashes with a delta V over 20 mph. These crashes were mostly at 12 o'clock.

TABLE 19

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	0.1
6-10 mph	1.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	10.5	0.0	0.0	0.0	0.7
11-15 mph	18.3	0.2	2.3	15.3	0.0	2.1	0.0	1.6	4.7	0.0	0.0	0.0	0.7
16-20 mph	1.1	0.0	0.0	0.0	0.0	0.0	0.9	1.1	0.1	12.4	0.0	0.0	4.6
21-25 mph	0.0	1.5	0.0	84.7	100.0	0.0	8.0	0.1	0.2	17.2	0.0	0.0	7.8
26-30 mph	42.3	1.1	0.0	0.0	0.0	91.3	0.0	0.0	54.1	1.2	0.0	0.0	4.9
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.5	0.0	0.0	1.6
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0	0.0	2.9
41-45 mph	0.0	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
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
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	0.0	3.9
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	2.8
Unknown .	37.3	88.8	97.7	0.0	0.0	6.6	89.1	97.2	30.3	38.6	100.0	100.0	68.1
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	20	21	7	3	1	11	16	22	44	97	37	28	307

TABLE 20

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	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	15.0	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	0.1	4.9	0.0	0.0	0.0	0.0	20.6	19.4	0.0	0.1	0.0	0.0	0.0	0.7
11-15 mph	90.4	3.1	0.0	100.0	0.0	70.3	0.0	0.0	3.0	0.1	0.3	0.0	0.0	11.0
16-20 mph	0.5	1.6	0.0	0.0	0.0	0.0	0.0	80.6	0.0	22.6	10.3	0.0	0.0	9.7
21-25 mph	4.3	0.3	0.0	0.0	0.0	29.7	0.0	0.0	63.3	1.6	0.7	0.0	0.0	1.4
26-30 mph	3.8	0.1	0.0	0.0	0.0	0.0	28.3	0.0	0.0	0.0	59.0	0.0	0.0	13.7
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	9.0	0.0	0.0	2.0
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	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	0.1	0.0	0.0	0.0
Unknown .	0.9	90.0	85.0	0.0	100.0	0.0	51.0	0.0	33.8	75.6	19.5	100.0	100.0	61.1
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	21	24	2	1	1	2	5	3	7	24	70	40	37	237

TABLE 21

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	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
6-10 mph	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
11-15 mph	0.0	0.0	0.0	49.5	0.0	0.0	0.0	0.0	17.2	0.6	0.0	0.0	1.4
16-20 mph	21.9	0.7	99.4	0.0	0.0	0.0	4.8	2.3	2.6	0.2	0.0	0.0	2.5
21-25 mph	61.8	0.3	0.6	7.3	0.0	0.0	2.1	59.6	27.7	5.8	0.0	0.0	10.3
26-30 mph	2.1	0.2	0.0	0.0	0.0	2.7	0.0	0.6	0.5	5.0	0.0	0.0	2.7
31-35 mph	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.3	0.0	0.0	14.4
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.6	0.0	0.0	3.3
41-45 mph	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	0.1	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	29.5	0.0	0.0	14.9
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	11.7	0.0	0.0	5.9
Unknown .	9.7	98.5	0.0	43.2	100.0	97.3	93.0	37.5	51.4	12.1	100.0	100.0	44.5
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
N	23	9	2	4	3	4	16	22	44	133	17	45	322

The final set of tables depict injuries to right-front passengers. Table 22 shows the relative magnitude of the columns in the next four tables and also shows the distribution across direction of force for each grouped body region. Whereas driver IPR from head, face, and neck injuries occurs mainly at 12 o'clock and in non-horizontal crashes, here a third of IPR from head, face, and neck injuries occurs at 10 o'clock. A significant share of IPR to the trunk region occurs at 2 o'clock and at 3 o'clock. No large share of upper-extremity IPR occurs at 1 o'clock and 2 o'clock as it does for drivers, but, in contrast with the distribution for drivers, a large share of lower-extremity IPR does. Overall, IPR at 12 o'clock is less prominent than for drivers.

The next four tables, showing the distribution of right-front passenger IPR by delta V and direction of force for each of the grouped body regions, unfortunately suffer both from high rates of missing data and from sparse sample sizes. Thus little credence should be given to the individual column distributions, except for those in the "All" columns.

In Table 23, showing the distribution for the head, face, and neck region, 22 percent of the IPR for cases with known delta V results from crashes with a delta V of 20 mph or less. This compares with 34 percent for drivers. Thus it may be somewhat less easy to reduce serious head injuries for right-front passengers than for drivers.

Table 24 examines cases of injury in the trunk region. The overall distribution of IPR by delta V shows that, looking only at cases with known delta V, 11 percent is the result of the less severe crashes, and 89 percent of the more severe crashes. The comparable figures for drivers were 19 percent and 81 percent.

In Table 25, on upper-extremity injuries, the proportion of IPR for known delta V resulting from less severe crashes (delta V of 20 mph or less) at 61 percent is very similar to that for drivers at 55 percent. However, the proportion for unknown delta V is substantially higher at 93 percent. In Table 26, on the other hand, there is no reflection of the high incidence of lower-extremity IPR found for drivers in severe (delta V greater than 20 mph) crashes. Whereas, for drivers in crashes with known delta V, 93 percent of lower-extremity IPR resulted from the severe crashes, for right-front passengers the equivalent figure is only 54 percent. So, for right-front passengers, it seems likely that serious injuries to the lower extremities are more easily preventable than they are for drivers.

The data displayed in Tables 18 through 21 and 23 through 26 are summarized graphically in Figure 5. Here, the IPR for each grouped body region and seat position is shown with a split between the less severe crashes (delta V of 20 mph or less) and the more severe crashes (delta V over 20 mph).

TABLE 22

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	7.9	7.5	0.0	17.6	0.0	7.9
2 o'clock	8.9	12.8	4.0	34.1	100.0	11.3
3 o'clock	8.3	11.4	10.0	5.1	0.0	9.4
4 o'clock	0.0	0.0	0.0	0.0	0.0	0.0
5 o'clock	0.0	0.0	0.4	0.0	0.0	0.0
6 o'clock	2.2	0.0	2.5	0.3	0.0	1.3
7 o'clock	0.1	0.0	0.0	0.0	0.0	0.0
8 o'clock	3.1	0.9	0.0	0.0	0.0	2.1
9 o'clock	0.7	0.0	0.7	0.0	0.0	0.4
10 o'clock	31.0	2.9	0.6	5.3	0.0	18.3
11 o'clock	0.5	0.0	2.7	4.1	0.0	0.5
12 o'clock	21.2	36.1	67.1	29.9	0.0	28.4
Non-horizontal	4.1	15.3	1.4	2.4	0.0	8.4
Unknown	11.9	13.0	10.8	1.1	0.0	11.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
N	180	95	93	140	1	509

TABLE 23

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	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
6-10 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
11-15 mph	0.0	0.3	31.2	0.0	0.0	1.6	0.0	0.7	6.3	4.7	0.0	0.0	3.9
16-20 mph	0.0	0.2	0.0	0.0	0.0	0.0	56.8	11.8	33.8	0.8	0.0	0.0	4.4
21-25 mph	4.1	20.5	0.0	8.1	0.0	0.0	0.0	0.1	37.1	16.8	0.0	0.0	6.1
26-30 mph	0.0	1.1	0.0	91.7	0.0	96.4	0.0	0.5	0.0	6.4	0.0	0.0	6.7
31-35 mph	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.1
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.2	0.0	0.0	6.4
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.9	0.0	1.6	0.0	0.0	5.6
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
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.2
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	0.0	0.0	3.9
Unknown .	95.9	77.9	68.8	0.0	100.0	2.1	43.2	70.0	22.8	19.7	100.0	100.0	62.7
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
N	10	12	6	3	1	6	5	12	12	64	31	18	180

TABLE 24

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	8 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-15 mph	0.0	0.2	0.0	2.5	0.2	0.0	0.0	0.0	0.0	0.1
16-20 mph	0.0	8.4	29.7	0.0	14.0	0.0	0.0	0.0	0.0	4.9
21-25 mph	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.0	0.0	5.3
26-30 mph	0.0	0.0	67.2	96.8	2.1	70.6	0.0	0.0	0.0	8.6
31-35 mph	0.0	0.0	0.0	0.0	0.0	29.4	24.9	0.0	0.0	9.0
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-45 mph	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
51-55 mph	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	49.8	0.0	0.0	18.0
Unknown .	100.0	91.2	3.1	0.7	83.7	0.0	10.4	100.0	100.0	54.0
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	3	12	7	6	12	3	22	22	8	95

TABLE 25

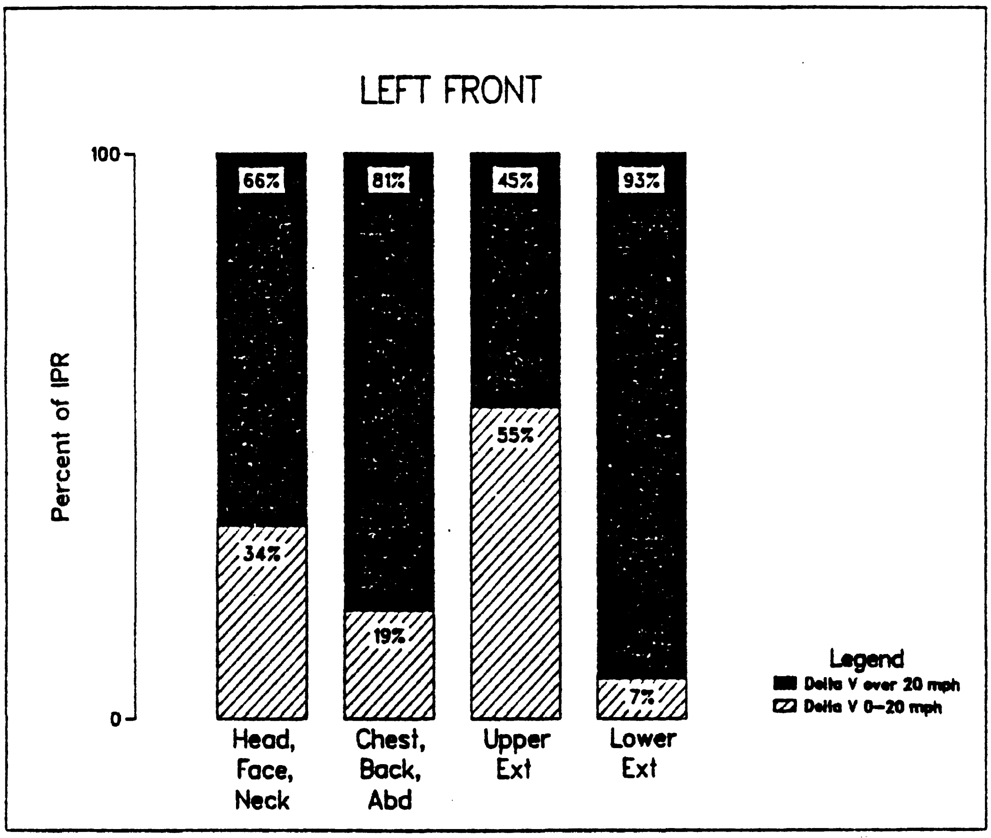
1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS WITH UPPER-EXTREMITY INJURIES BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force										
	2 o'clock	3 o'clock	5 o'clock	6 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
6-10 mph	0.0	0.0	0.0	9.6	0.0	30.2	0.0	0.7	0.0	0.0	0.9
11-15 mph	23.0	0.0	0.0	32.7	0.0	0.0	0.0	0.7	0.0	0.0	2.2
16-20 mph	0.0	0.0	100.0	0.0	0.0	0.0	10.9	1.0	0.0	0.0	1.3
21-25 mph	0.0	5.8	0.0	0.0	0.0	0.0	4.4	0.8	0.0	0.0	1.2
26-30 mph	5.7	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.3
31-35 mph	0.0	0.0	0.0	5.6	0.0	0.0	39.0	0.1	0.0	0.0	1.2
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
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	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
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
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown .	71.3	94.2	0.0	52.1	100.0	69.8	43.6	96.8	100.0	100.0	92.9
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	13	10	1	6	4	3	9	23	11	13	93

TABLE 26

1980 AND 1981 NASS (INJURY LEVEL):
PERCENT IPR 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	6 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
6-10 mph	0.2	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.3
11-15 mph	1.2	12.6	0.0	0.0	0.0	0.0	2.9	0.0	0.0	5.4
16-20 mph	1.7	51.3	0.0	67.2	35.3	8.0	4.2	0.0	0.0	21.4
21-25 mph	96.0	0.0	15.3	0.0	0.0	4.5	7.9	0.0	0.0	20.2
26-30 mph	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.1
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	31.1	0.0	0.0	9.3
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.2
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	1.1
46-50 mph	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	4.3	0.0	0.0	1.3
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown .	0.8	36.0	84.7	32.8	64.7	86.0	44.4	100.0	100.0	40.7
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	8	11	5	3	6	14	72	9	12	140



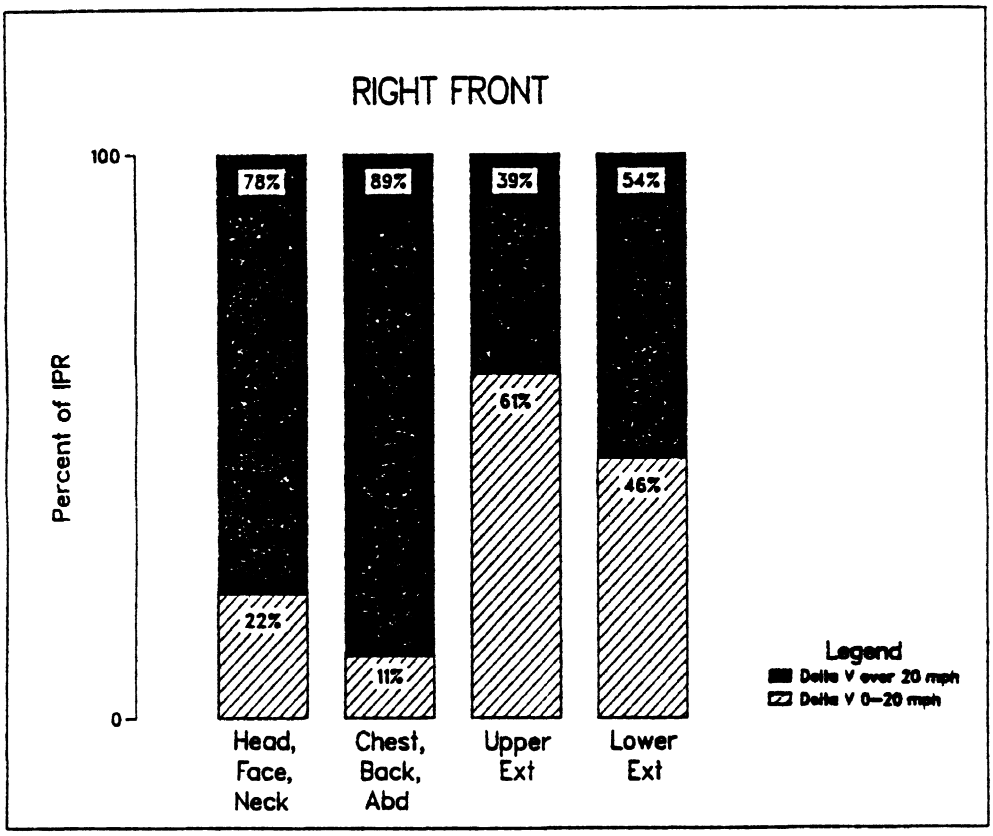


FIGURE 5. 1980 and 1981 NASS (Injury Level): Percent IPR for Cases with Known Delta V by Seat Position, Grouped Body Region, and Delta V.

COMPARISON OF IPR WITH HARM

This section compares the results obtained using the IPR model to those obtained by applying the Harm model developed by Malliaris et al. (1982). The Harm model applies a dollar amount to each injured person, based on that person's injury severity as measured by the AIS scale. Thus all AIS-2 injuries receive an identical weighting. The main source of the data presented by Malliaris et al. was the National Crash Severity Study (NCSS) of 1977 to 1979. NCSS sampled police-reported accidents in which at least one vehicle was towed from the scene for damage. The sample was drawn, not from the whole United States as in NASS, but from eight particular areas. The data, when run with their sampling weights, generate estimates for the aggregate of these eight areas. It should also be noted that, whereas NASS samples all police-reported accidents, NCSS only sampled accidents in which at least one vehicle was towed for damage. In practical terms, however, this makes little difference when looking at occupants who incurred injuries of AIS-2 or greater, since few of these occur in non-towed vehicles.

Results from applying the Harm model to both NCSS and NASS are presented here and compared with results obtained by applying IPR to NASS.[1] In contrasting the results, it should be possible to discern how far differences can be attributed to use of one model or the other and how far they can be attributed to use of one data source or the other.

Table 27 presents the distribution by direction of force of IPR and Harm for 1980 and 1981 NASS, and of Harm for NCSS. The distributions are limited to the occupants of passenger cars who incurred injuries of AIS 2 through 6, and are run at the occupant level using the first (i.e., the most severe) OIC. The results of applying Harm to NCSS and NASS are in broad agreement, as are the results of applying IPR and Harm to NASS. Neither a change in data file nor a change in model makes much difference, although the combination of Harm and NCSS does seem to give higher priority to oblique frontal collisions (1, 2, 10, and 11 o'clock) and lower priority to non-horizontal directions of force.

Table 28 shows a similar set of distributions, this time by a grouping of body region. Here, there are much greater differences among the three distributions. Comparing the two that apply the Harm model, the neck region is much more prominent in NCSS than in NASS. It is not clear why this is so—a number of hypotheses were tested, but none supplied the answer. When, the Harm model was applied to a NASS file limited to occupants of towed-for-damage passenger cars (to simulate the NCSS reporting threshold), the distribution of Harm by body region remained substantially the same. A run on body region by AIS level indicated that in NCSS 45 percent of AIS-6 injuries were to the neck region, whereas in 1980 and 1981 NASS the equivalent percentage was only 12. Since AIS-6 injuries receive a large weighting in the Harm model, this would seem to account for the observed difference. It does not, however, explain it. The explanation may lie, in part, in changes in OIC coding from the 1976 AIS manual used by NCSS to the 1980 AIS manual as adapted for NASS. A large proportion of the NCSS AIS-6 neck injuries are coded as neck fractures, a coding that is not permissible according to the 1980 manual.

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[1]The IPR model could not be applied to the NCSS data, because there were a number of OICs in NCSS for which the panels of physicians used by Chi Associates and UMTRI had not coded the consequences.

TABLE 27

COMPARISON OF PERCENT IPR AND PERCENT HARM
FOR PASSENGER CAR OCCUPANTS BY DIRECTION OF FORCE AND DATA FILE

Direction of Force	IPR 1980 & 1981 NASS[a]	Harm 1980 & 1981 NASS[a]	Harm NCSS[b]
1 o'clock	4.0	4.5	7.7
2 o'clock	10.4	11.0	11.1
3 o'clock	3.9	3.6	2.9
4 o'clock	0.0	0.0	1.5
5 o'clock	0.1	0.1	0.3
6 o'clock	0.7	0.9	1.3
7 o'clock	0.3	0.8	0.4
8 o'clock	1.2	2.3	1.4
9 o'clock	1.8	2.4	1.8
10 o'clock	8.2	6.4	10.1
11 o'clock	4.7	5.8	8.2
12 o'clock	36.1	36.7	34.3
Non-horizontal	17.5	15.9	12.7
Unknown	11.1	9.6	6.4
Total	100.0	100.0	100.0
N	1262	1262	4754

[a]The NASS files were used at the occupant level.

[b]The NCCS case vehicle occupant file was used.

The contrasts between the application of IPR and the application of Harm to the NASS files are easier to explain. The IPR model gives greater prominence to the head, the face, and the neck, and less prominence to the chest, the abdomen, and the extremities. Table 29 shows why this is so. The table gives the mean IPR calculated in applying the IPR model to the 1980 and 1981 NASS files at the occupant level. This mean IPR is shown by grouped body region and by AIS level. Also shown, for comparison, is the Harm quantity used by Malliaris et al. This quantity is constant for each AIS level. Injuries to the head, face, and neck, and in particular, to the head, receive far greater weighting in the IPR model than they do in the Harm model. Thus at AIS 3, head injuries are weighted eight times higher by the IPR model than injuries to the lower extremities. Other factors, such as the age and sex of the injured occupants, will affect these mean IPR scores, but the general pattern of assigning large weights to the head, face, and neck is clear.

TABLE 28

COMPARISON OF PERCENT IPR AND PERCENT HARM
FOR PASSENGER CAR OCCUPANTS BY BODY REGION AND DATA FILE

Body Region	IPR 1980 & 1981 NASS[a]	Harm 1980 & 1981 NASS[a]	Harm NCSS[b]
Head	47.2	35.5	33.0
Face	8.2	2.8	3.6
Neck	5.6	4.6	13.8
Chest	21.0	26.7	20.0
Abdomen	7.9	18.2	14.7
Upper extrem.	3.2	4.1	5.1
Lower extrem.	3.8	5.1	7.9
Other	2.7	2.7	2.0
Unknown	0.3	0.4	0.0
Total	100.0	100.0	100.0
N	1262	1262	4754

[a]The NASS files were used at the occupant level.

[b]The NCCS case vehicle occupant file was used.

TABLE 29

1980 AND 1981 NASS (OCCUPANT LEVEL):
COMPARISON OF MEAN IPR AND HARM FOR PASSENGER CAR OCCUPANTS[a]

Model	AIS Severity				
	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6
IPR:					
Head	7,245	49,188	85,421	200,206	200,662
Face	14,294	18,668	–	–	–
Neck	23,806	19,287	–	–	–
Chest	1,579	5,270	63,962	97,168	240,561
Abdomen	–	13,418	46,164	61,099	–
Upper extrem.	1,250	11,148	–	–	–
Lower extrem.	2,795	6,113	–	–	–
Other	531	14,881	–	–	–
Harm	3,900	10,200	107,100	264,500	307,800

[a]Some cells are empty because of insufficient data.

CONCLUSIONS

The application of a function that uses the societal cost of injury to the 1980 and 1981 NASS files has produced a number of interesting findings. Some of the salient results of performing the analysis are:

1. The combination of the head, face, and neck body regions accounts for 60 percent of the IPR to passenger car occupants.

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

3. Over one-third of driver IPR occurs from collisions with a 12 o'clock direction of force. A fifth results from collisions with non-horizontal directions of force.

4. Oblique side collisions account for more IPR than direct side collisions. This applies both to drivers and to right-front passengers. Thus, 9 o'clock collisions account for 4.3 percent of driver IPR, but 10 and 11 o'clock collisons account for 11.9 percent. Similarly 3 o'clock collisions account for 9.4 percent of IPR to right-front passengers; 1 and 2 o'clock collisions account for 19.2 percent.

5. Using only known values of delta V, 84 percent of the driver IPR with a 12 o'clock direction of force results from severe crashes, i.e., those with a delta V greater than 20 mph. For right-front passengers, the figure is 97 percent. However, it should also be noted that, for cases with known delta V, 81 percent of driver IPR and 77 percent of right-front passenger IPR was attributable to crashes with a delta V of 45 mph or less.

6. Again using only cases with known delta V, 66 percent of driver IPR for injuries to the head, face, and neck results from severe crashes. For injuries to the chest, back, and abdomen the comparable figure is 81 percent; for injuries to the upper extremities, 45 percent; and for injuries to the lower extremities, 93 percent. Thus one might conclude that, for drivers, serious injuries to the upper extremities are the most easy 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.

7. Comparison of IPR with the earlier Harm model indicated that the two models were in complete agreement in assigning relative priority to the directions of force in the 1980 and 1981 NASS data. When ranking body regions, however, the IPR model gives higher priority to the head, face, and neck, and correspondingly less prominence to the chest, abdomen, and extremities. This is because of the relatively severe long-term consequences of injury to the head, face, or neck.

Because of limitations in the data, it was not always possible to depict, to the extent that was desired, the crash environment in which the IPR to the various body regions was incurred. 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 1980 and 1981 NASS files combined have only some 2,262 injuries of severity AIS-2 or greater to passenger car occupants.[2] These injuries are sustained by 1,262 occupants. There are a total of 15,378 passenger car occupants in the combined 1980 and 1981 files. Thus 92 percent of the occupants sustain no injuries, injuries of AIS 1, or injuries of unknown severity.

One solution to the shortage of cases for analysis is to incorporate additional years of NASS. It is hoped that the 1982 NASS data can be added to the existing data structure so that the analyses reported here can be run with additional confidence and perhaps be extended to include such issues as contact point in more detail. Another solution 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. Such a revised sampling scheme could be combined with reducing the amount of investigation carried out on cases with no injuries or minor injuries.

Finally, the reader should bear in mind that the model used here is not completely satisfactory. In particular, it does not take into account the fact that a single person may have sustained more than one injury. It is hoped to pursue the development of a multi-injury model in the future.

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[2]This figure includes some injuries originally coded with an AIS of 7.

APPENDIX A

THE MEDICAL PANEL MEETING

As a part of the Task A effort to prioritize injuries as an input to the dummy design process, consulting advice was sought from a panel of physicians. There were several specific activities in which these physicians were called upon to participate; in addition, they have been regarded as a continuing resource for advice on the conduct and output of the project.

A panel meeting of the consulting physicians was convened at the University of Michigan Transportation Research Institute (UMTRI) on Sunday, November 20, 1983. Participants included Dr. Thomas Gennarelli, Dr. Robert Levine, Dr. James Mackenzie, and Dr. Charles E. Lucas. Professors Donald Huelke and John Melvin. Dr. Oliver Carsten, and Mr. James O'Day of the UMTRI staff also attended this session.

In general, the meeting of the panel of physicians represented an attempt to get information from such a group in a consistent form so as to implement the cost model. It was clear at the outset that numerical estimates derived from such a small group would be statistically unreliable. The data from the panel were quite useful, however, in confirming the ranking of numerical estimates from other sources.

IMPAIRMENT RANKING EXPERIMENTS

One of the desired outputs of the project was a rank ordering of the importance (in some quantitative terms) of various impairments. The Chi data, which had been developed by some of the physicians serving on the panel, provided estimates of the length of time that certain impairment conditions would obtain after an injury; they were not intended, however, to provide estimates of the relative importance of different kinds of impairments. While such was not needed for the original purposes of the Chi study, we wished to obtain such a relative ranking for use in this project.

We considered several methods for getting the physicians to produce such a ranking. There were essentially twenty cells in the impairment type and degree matrix, and we could have simply asked the medical experts to sort a set of cards into their "order of importance." Since the actual judgment process which would lead to this ranking had to involve a series of two-way comparisons, we chose instead to ask each physician to provide the relative ranking for each possible pair, using a short microcomputer program to present the alternatives. In addition to ordering each pair, the respondent was further asked to record whether the two impairments were only slightly different or much different or (in rare cases) equal.

Each of the physicians attending the panel meeting was asked to complete this test, and scores were subsequently derived. The results of the test are given in Appendix B, and they are used to provide a confirmation of the estimated ranking of impairments that was taken from the AMA *Guides* (1971) regarding impairment.

DEVELOPMENT OF ADDITIONAL IMPAIRMENT CODES

A second activity we asked the physicians to undertake was the development of codes for impairment to fill in those injuries which were not included in the Chi presentation. Some of these occurred because NASS coding conventions were different from those used in the Chi work. Others resulted from other reasons. In any case, we wished to have the type and degree of impairment defined for any injuries reported in NASS and divided up the task of completing this among the participating physicians. Some of these were completed during the meeting, and the remainder were provided to us within a few weeks of the meeting.

CHARACTERIZING THE DATA

A third activity was to ask the physicians to describe the characteristics of the data resulting from the Chi program. This was intended to provide a subjective estimate of the quality of the information and to tell us how much dependence should be placed on it. Particular problems discussed were (1) the fact that some OIC codes could represent a rather wide range of injury consequences and that the values reported in the survey would depend on the particular physician's interpretation; (2) any individual might be characterized as an optimist, a pessimist, or something in between, and one might expect considerable variation in estimates of consequences because of this difference; (3) all estimates provided in the Chi data emanated from a single respondent, and thus they may not well represent the values that would obtain from a larger survey of physicians. Nevertheless, it was apparent from our meeting that the individual physicians had worked diligently to provide their best estimates.

RECOMMENDATIONS FROM CLINICAL EXPERIENCE

Fourth, we asked the panel of physicians to tell the project team members what particular characteristics they thought the dummy should have, based mainly on their clinical experience. It should be noted that these judgments were not based on statistics or injury counts, but on individual observations. The most persistent suggestion to result from this activity was for some capability to simulate damage to organs in the abdominal and pelvic region. Several of the physicians reported what seemed to be an increase in abdominal organ injuries, which they associated with belt usage, and they indicated that there would be a value in being able to simulate the effects of restraints.

In this connection, the panel was briefed by Mr. Peter Cooley regarding his experience in investigating airbag deployment cases. He was asked to suggest dummy characteristics that might be important for airbag testing. Although there was some discussion of this matter, there were no specific suggestions resulting.

MULTIPLE INJURIES AND MULTIPLE IMPAIRMENTS

Lastly, we asked the physicians to complete a form that recorded estimates of the effect of combinations of impairments. The questionnaire for this topic was prepared from a knowledge of the reported frequency of combinations of injuries in the NASS data, and the results were to be used to assist in estimating the cost of impairments that resulted from such combinations.

APPENDIX B

DEVELOPMENT OF A DEPENDENT VARIABLE FOR NASS DATA ANALYSIS

This appendix describes the procedures used to develop a new dependent variable for analysis of the NASS data in connection with the dummy design project. The major purpose of this development was to include an estimate of the losses associated with permanent impairment which result from particular injuries. These results were intended to be combined with estimates of losses resulting from fatal injuries, and direct expenditures of treatment.

A recent study by Hirsch et al. (1984), of Chi Associates, has provided estimates of the degree of impairment (over several time frames) which are expected to result from essentially all injuries coded from the most recent version of the AIS manual (AAAM 1980). A team of physicians provided the numerical estimates, and these have been made available to us in tabular form on an IBM PC diskette. Briefly, each OIC code from level 2 to level 5 inclusive was associated with a degree of impairment in any of six categories—mobility, cognitive/mental, cosmetic, pain, sensory, and "daily living."

In our discussions with the AATD project medical panel, several limitations of the Chi data were discussed. The first of these comes about because the AIS manual does not uniquely identify injuries within a given category. A case in point is a severed nerve in the upper arm. The medical panel pointed out that there are three separate nerves which might be damaged. The AIS manual assigns the same severity code for each (and the same location and injury type codes), but the three have quite different long-term consequences. One repairs itself rather completely in six months, whereas the worst of the three leads to a permanent impairment.

A second limitation comes about because each estimate of impairment was made by only one physician/respondent. While there is a certain amount of determinism in such estimates, there is also much variability in individual physicians. Disagreements over the coding of the consequences of injury were aired at the panel meeting. Each injury had been coded by two physicians. During the discussion of one particular disagreement, one of the coders responded that he was a pessimist, the other that he was an optimist. The pessimist could visualize the potential for infection of a wound or other events which would worsen the situation and tended to estimate impairment to be greater than average. The optimist could visualize a completely normal and rapid recovery. In the present tabulation there is no accounting of the pessimism or optimism of the individual respondents.

The American Medical Association *Guides to the Evaluation of Permanent Impairment* (1971) contains detailed estimates of impairment, both with regard to individual parts or organs of the body and with regard to the "whole man." While this document was not prepared with the Abbreviated Injury Scale in mind, it does cover much of the same ground and seems to have a broader statistical basis. Nearly one hundred physicians participated over a period of many years. Tabulations in this document seem to complement the Chi work, and have been used in conjunction with it.

A third limitation of the present impairment coding is in the sensory area. "Sensory impairment" evidently may refer to hearing, sight, smell, taste, and tactile sense (e.g., in the case of an amputated limb or nerve damage). The sense of balance, which might be affected by damage to the inner ear, might also be considered under this category, although it is probably accounted for in the mobility group. In any case, there is so much variation in the "whole-man" consequences of impairments to the several senses that it is difficult to assign an average value for NASS-reported injuries.

For example, the "whole-man" impairment for total blindness as defined by the AMA study (1971) is 85 percent. However, there is essentially no "whole-man" impairment associated with 100 percent loss of taste or smell, and relatively little for total loss of hearing. For the purposes of the experiment to be described here, we asked respondents to consider the damaged sense to be the visual one. In analyzing the accident data, however, we accounted for the particular sense involved.

THE EXPERIMENT

The experiment to be described was conducted to help develop a scale, i.e., a single numeric value, which could be used to rate relative consequences of various injuries. The resulting data as well as the results of a parallel experiment which considered paired impairments were intended to complement the information provided by the AMA *Guides*. A combination of these sources would permit derivation of a "long-term consequence" value which could be associated with each OIC. This might range from 0 to 100 percent (in terms of "whole-man" impairment) or from 0 dollars to many dollars in an estimate of societal cost.

Table B.1 shows in summary form the four levels of impairment for each of five categories. More complete definitions are given in Hirsch et al. (1984). Each respondent who participated was asked to judge each possible two-way comparison in this set and to respond as to which was the greater impairment and whether the difference was great or small.

A computer program was written which presented the choices on a video screen, and the respondent entered answers by striking appropriate keys on the computer keyboard. Respondents were permitted, but not encouraged, to say that there was no difference between two cells. The computer program began by developing a random order for numbers between 1 and 20, and then presenting the questions in that order. The first item in the random order was presented at the top of the screen, and the item to be compared presented at the bottom.

The respondent was asked to choose 1 or 2 as the greater impairment (or a 3 for even), enter that number, and then enter an M for "much greater" or an L for a "little greater." These values were then recoded by the computer as a 1, 2, 3, 4, or 5 and stored.

A complete tabular output from one respondent is shown as Figure B-1. The 20 columns and 20 rows in order represent the four responses in each of the five areas. Rows and columns 1, 2, 3, 4 are Mobility-1 (walks with a limp), Mobility-2 (must use crutches), Mobility-3 (confined to a wheelchair), and Mobility-4 (confined to bed), etc. In the upper right area of the table (i.e., above the diagonal of zeroes) a value of 5 indicated that the column impairment was considered to be much greater than the row impairment. A value of 4 indicated slightly greater, 3 even, 2 slightly less, and 1 much less. Note that the complementary figure in the lower portion of the table is always equal to (6–n) where n is the upper value.

TABLE B.1

IMPAIRMENT CATEGORIES AND LEVELS OF IMPAIRMENT (Hirsch et al. 1984)

Level	Mobility	Cognitive	Cosmetic	Sensory	Pain
1	Impaired mobility with intact functional ability	Mild Inappropriate behavior, neurotic, increased irritability, intermittent confusion	Mild disfigurement, amenable to cosmetic coverup	Slight (10-25%) loss to sense or limbs	Occasional pain relieved by non-narcotic drugs
2	Impaired mobility with mildly abnormal function, e.g., needs crutches	Often disoriented, loss of ability to do simple arithmetic, slight impairment of language or memory	Moderate scar, can be covered by cosmetic or change in dress habits	Moderate (26-50%) lost to special senses or limbs	Normal function only with use of non-narcotic drugs
3	Severely impaired mobility with abnormal function, e.g. requires wheel chair	Severe memory impairment, often commitable behavior	Severe, prosthesis or coverup required	Severe, more than 50% loss to special senses or limbs	Can function only with narcotic drugs and/or invasive therapy
4	Entirely dependent on attendant or otherwise confined to bed	Vegetative, total amnesia, no purposeful response to stimuli	Severe, readily observable, not amenable to cosmetic, prosthetic, or clothing coverup	Maximum total loss to special senses or limbs	Cannot function normally even with narcotic drugs and/or invasive therapy

	Limp	Crutch	Wheelchair	Bed	Neurosis	Psychotic	Commitable	Vegetative	Scar1	Scar2	Scar3	Scar4	Pain1	Pain2	Pain3	Pain4	Sense1	Sense2	Sense3	Sense4	SUM	MEAN	--COUNTS--				
Limp	0	4	1	1	3	1	1	1	4	4	3	2	3	4	1	1	3	2	1	1	41	2.16	9	2	4	4	0
Crutch	2	0	5	1	4	1	1	1	4	3	2	2	4	4	3	1	3	1	1	1	44	2.32	8	3	3	4	1
Wheelchair	5	1	0	1	5	4	1	1	5	5	5	3	5	5	3	1	5	3	2	2	62	3.26	5	2	3	1	8
Bed	5	5	5	0	5	3	1	1	5	5	5	5	5	5	4	4	4	5	4	4	80	4.21	2	0	1	5	11
Neurosis	3	2	1	1	0	1	1	1	4	2	2	2	3	5	1	1	1	2	1	1	35	1.84	10	5	2	1	1
Psychotic	5	5	2	3	5	0	1	1	5	5	5	5	5	5	3	2	4	5	3	3	72	3.79	2	2	4	1	10
Commitable	5	5	5	5	5	5	0	1	5	5	5	5	5	5	5	3	5	5	5	3	87	4.58	1	0	2	0	16
Vegetative	5	5	5	5	5	5	5	0	5	5	5	5	5	5	5	5	5	5	5	5	95	5.00	0	0	0	0	19
Scar1	2	2	1	1	2	1	1	1	0	1	2	1	2	3	1	1	2	1	1	1	27	1.42	12	6	1	0	0
Scar2	2	3	1	1	4	1	1	1	5	0	2	2	4	3	3	1	2	1	1	1	39	2.05	9	4	3	2	1
Scar3	3	4	1	1	4	1	1	1	4	4	0	2	3	3	3	1	2	2	1	1	42	2.21	9	3	4	4	0
Scar4	4	4	3	1	4	1	1	1	5	4	4	0	5	4	3	1	4	1	1	1	52	2.74	8	0	2	7	2
Pain1	3	2	1	1	3	1	1	1	4	2	3	1	0	2	2	1	1	1	1	1	32	1.68	11	4	3	1	0
Pain2	2	2	1	1	1	1	1	1	3	3	3	2	4	0	1	1	1	1	1	1	31	1.63	12	3	3	1	0
Pain3	5	3	3	2	5	3	1	1	5	3	3	3	4	5	0	1	2	3	1	1	54	2.84	5	2	7	1	4
Pain4	5	5	5	2	5	4	3	1	5	5	5	5	5	5	5	0	5	5	5	3	83	4.37	1	1	2	1	14
Sense1	3	3	1	2	5	2	1	1	4	4	4	2	5	5	4	1	0	2	1	1	51	2.68	6	4	2	4	3
Sense2	4	5	3	1	4	1	1	1	5	5	4	5	5	5	3	1	4	0	1	1	59	3.11	7	0	2	4	6
Sense3	5	5	4	2	5	3	1	1	5	5	5	5	5	5	5	1	5	5	0	1	73	3.84	4	1	1	1	12
Sense4	5	5	4	2	5	3	3	1	5	5	5	5	5	5	5	3	5	5	5	0	81	4.26	1	1	3	1	13

FIGURE B-1. Example of Tabular Data from a Single Respondent.

The sum of all of the responses in a row is shown in the 21st column, and the mean value (the sum divided by 19) is shown in the 22nd column. Figure B–2 shows the data from one respondent in pictorial form. When the right-hand bar in a histogram has a high value, the respondent considered most other things to be less disabling than this one. When the left-hand bar has a high value, nearly everything is considered worse than this. This profile permits a quick visual measure of each set of responses.

The overall mean was computed as the average of the respondent means for each question and are shown in Figure B–3. These are plotted on a linear scale covering the range 1 to 5. Also shown on that plot are the "whole-man" impairment values for the nearest equivalent injury defined in the AMA *Guides*. Specific injuries used for illustration are shown in some cases.

Table B.1 then leads to another (Table B.2) which suggests an estimated whole-body" impairment for each of the twenty cells defined by Hirsch et al.

TABLE B.2

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 "Methodology" section describes how these impairments were combined with life expectancy tables and information on average wage by age and sex to compute an "Injury Priority Rating." This rating was transferred into the NASS files by a match on age, sex, and OIC. It was then used in the analysis of the NASS files in a manner similar to that suggested by Malliaris (1982).

PARTICIPANT INSTRUCTIONS AND APPLE PROGRAMS

Following is a copy of instructions to the participants in the experiment and the APPLE programs used for impairment ranking.

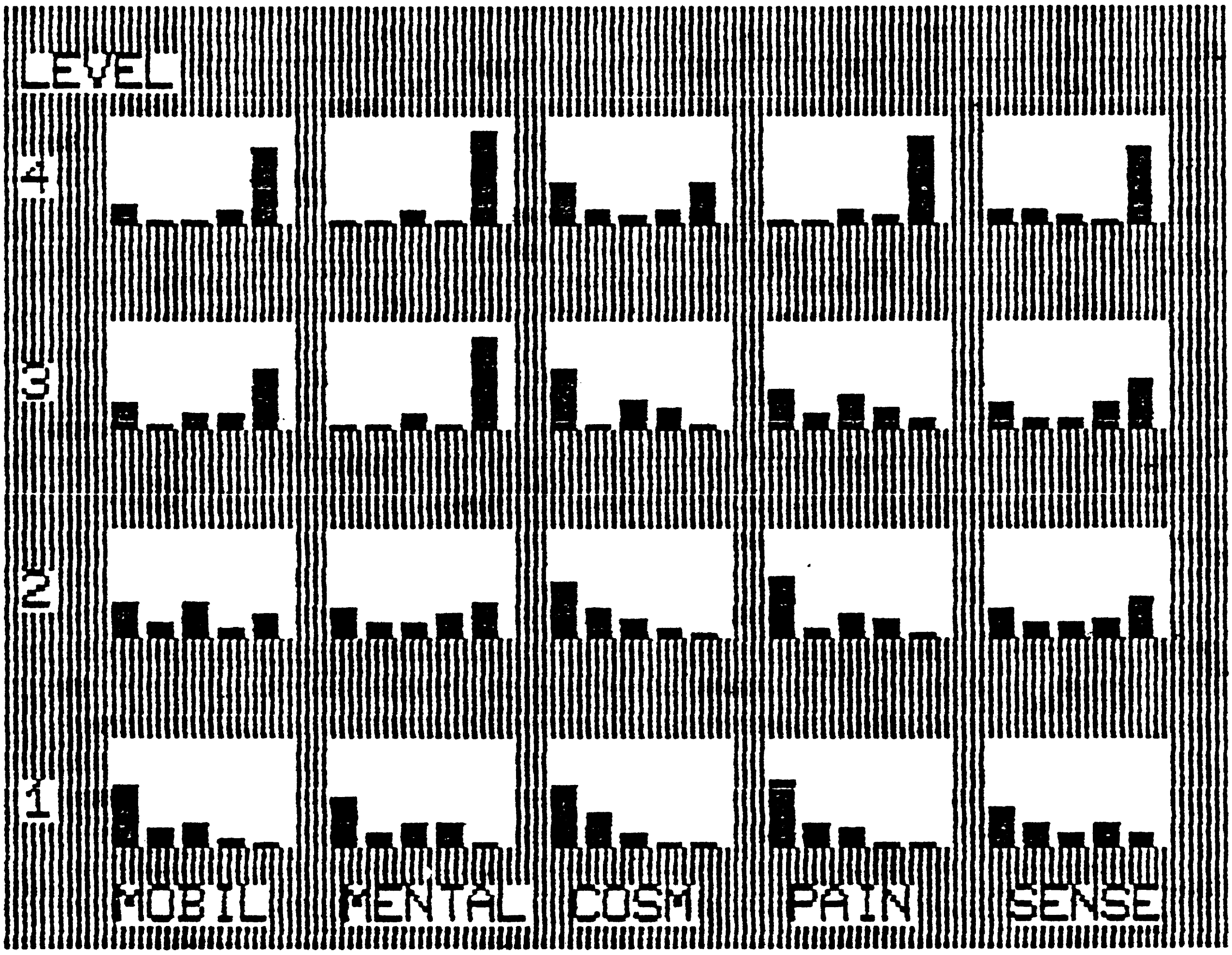

FIGURE B-2. Profile of Respondent Data.

			AMA "Whole Man"	
1.	(1.45)	COS 1	0%	
2.	(1.51)	PAIN 1	0%	
3.	(1.74)	PAIN 2	0%	[AMA <u>Guides</u>, p. 50]
4.	(2.06)	COS 2	0%	
5.	(2.24)	COG 1	5%	[Boor says 1-5%]
6.	(2.31)	MOB 1	5%	[5% (MOB 1) Amputation of Great Toe]
7.	(2.31)	COS 3	0%	
8.	(2.55)	COS 4	10%	[Severe Skin Disorder]
9.	(2.57)	PAIN 3	10%	
10.	(2.72)	SENS 1	0-5%	[Minor Visual Disorder]
11.	(2.86)	MOB 2	16-28%	[28% = Foot Amputation]
12.	(2.97)	SENS 2	10-20%	[Some Loss of Visual Field]
13.	(3.41)	COG 2	25%	[Sociopathic Personality]
14.	(3.56)	SENS 3	24%	[Lost Sight of One Eye]
15.	(3.80)	MOB 3	65%	[Spinal injury, can use upper extremities]
16.	(3.98)	SENS 4	85%	[Totally Blind]
17.	(4.17)	PAIN 4	60%	[AMA <u>Guides</u>, p. 50]
18.	(4.34)	MOB 4	85%	[Cannot use upper extremities]
19.	(4.66)	COG 3	90%	[Psychopath, Class 4]
20.	(4.80)	COG 4	95%	

FIGURE B–3. Experiment Responses and AMA "Whole-Man" Impairments.

INSTRUCTIONS FOR DEPENDENCE SCALING EXPERIMENT

This experiment is an intermediate step in the process of creating a usable dependent variable for the NASS data based on the impairment assignments developed in the Chi/Hirsch study. The intent is to develop a scale of the relative importance of certain impairments, within some defined framework.

The respondent is to consider a scale of dependency, i.e., how dependent is the injured person on assistance (moral, physical, etc.) from others as a result of his or her impairment. Hirsch has developed five impairment categories (plus one called "daily living" which has not been included here), with four levels of impairment for each. These have been described on the Hirsch coding sheets, and are described in somewhat briefer form on the attached page. They have intentionally been described in lay terms.

While these definitions were used in assigning injuries to impairment categories, for the present purpose we believe the respondents may need more specific concepts of the injuries. For this experiment we will add to the definitions where necessary to be specific.

The mobility group seems relatively clear as stated, as does the cognitive/ psychological group. For the cosmetic group, we have thought of the lowest level as a very slight facial scar which can be covered by makeup. The highest level of cosmetic impairment might be the disfigurement of a burn victim with severe facial scars, a missing jaw, etc.

The sensory group is probably the most difficult to picture. For purposes of this experiment we would like to think of a visual impairment, with the lowest level being a slight visual defect (which has resulted from an injury). This could be a requirement for wearing glasses. The second level might entail some difficulty in night vision, a lens injury which required very thick glasses and leads to a restricted capability to adjust for distance. The third level might be the loss of one eye, with perhaps some impairment to the other eye. The fourth level would be total blindness (or at least legal blindness). Other senses would perhaps have equivalents to this, for for this experiment we would like you to consider the sensory impairment to be a visual one.

THE EXPERIMENT

The twenty impairment descriptions on the table have been written in rather brief form into a computer file. These brief versions will be presented to you in pairs, and you will be asked to indicate which of these leads to a greater dependency of the individual on others, and then (on a two-point scale) how much greater. For example, you might be presented with the following display:

1. Constant Uncontrollable Pain
2. Psychotic/Commitable

Which is worse? ______
How much worse? ______

The computer will generate a random order for presenting the questions, but will keep the same first question (e.g., **1** of the above example) until it sequences through all remaining pairs for that one. Responses should be entered on the computer keyboard by pressing the 1 or 2 key for the first question, and pressing the M or L (for Much or Little) key for the second question. The computer keyboard locks out ay extraneous responses—you cannot enter an M or anything except a 1, 2, or 3 for the first question, etc. The 3 may be entered as a response to the first question if you believe that the two impairments are equal on the dependency scale; while permitted, this choice is discouraged, and you should use it only when you cannot differentiate at all.

There are 20 different combinations of kind and level of impairment, and this leads to 190 two-way comparisons. This seems like a lot, and it dos take more than a trivial amount of time to answer all questions. However, the experiment will not work if you don't get through the whole set, so please be diligent. In trials we have found that it can be done in 20 to 25 minutes. The computer will sound a beep each time it changes impairment 1, so this should warn you of the change.

Please fill out the information requested at the bottom of the page, fold this up and insert it into the diskette envelop.

Finally, I have not prepared any way to correct your data by backing up and redoing a previous entry. If you feel that you have made a wrong entry please make a note of the circumstances on the back of this sheet, and we will correct it at the time of analysis.

Your name: ____________
Date: ______________

Any comments: ____

____

Listing of PASCAL.SCALE

```
(*$S++*)
(*$L console:*)
program scaleit;
uses applestuff,yesandget;
TYPE RECFILE = RECORD
                  first:INTEGER;
                  second:integer;
                  COMPARISON:char;
                  DISTANCE:CHAR;
                END;
   scorr = record
            name:string;
            score:array[1..200] of recfile;
           end;
VAR LEFT,num,COUNT,LOW,HIGH,start,l,distance,pair,I,J,K:INTEGER;
    storr,STORY:ARRAY[1..24,1..2] of string[70];
    ANS,ans2:array[1..24,1..24] of char;
    ERR: BOOLEAN;
    x:array[0..30] of integer;
    scoor:scorr;
    things: recfile;
    result:array[1..20,1..20] of integer;
    ff:file of integer;
    numfile,outfile,name:string;
FUNCTION RAND(LOW,HIGH:INTEGER; VAR ERROR:BOOLEAN):INTEGER;
  VAR MX, C, D: INTEGER;
  BEGIN
    RAND:=0;
    ERROR:=TRUE;
    IF LOW>HIGH THEN EXIT(RAND); {error exit}
    IF LOW<=0 THEN
      IF HIGH> MAXINT+ LOW THEN EXIT(RAND); {error exit}
    ERROR:=FALSE; {no errors}
    IF LOW = HIGH THEN RAND := LOW
                  ELSE BEGIN
                          C:=HIGH - LOW + 1;
                          MX := (MAXINT - HIGH + LOW) DIV C + 1;
                          MX := MX * (HIGH - LOW) + (MX - 1);
                          REPEAT D := RANDOM UNTIL D <=MX;
                          RAND := LOW + D MOD C
                        END
  END;
procedure information;
    procedure nameit;
      begin
        write('Please enter your name: ');
        readln(name);
        if length(name)<5 then name:=concat(name,'xxxxx');
        outfile:=copy(name,1,1);
        numfile:=concat(outfile,'num.data');
        outfile:=concat(outfile,'out.data');
      end;
```

```

  begin
    page(output);
    Writeln('This program displays pairs of impairments as defined by the');
    writeln('Chi study, and asks the respondent to provide inputs which');
    writeln('are to be used to develop a scale of these impairments.');
    writeln;
    writeln('When a pair of impairments is shown, the respondent may answer');
    writeln('with the number (1 or 2) of the one with the greater degree');
    writeln('of impairment (or by entering a "3" if they are considered to be');
    writeln('even.  If a 1 or 2 has been entered, the respondent will be');
    writeln('prompted to tell how different the two impairments are on a');
    writeln('distance scale with two levels--M)uch or L)ittle.');
    writeln('A zero distance is assigned if a "3" has been');
    writeln('entered above.');
    writeln;
    writeln('Scores are automatically recorded, and will be processed');
    writeln('subsequently.');
    writeln;
    nameit;


    writeln('Press <return> to continue');
    readln;
  end;

procedure showit(a,MAXONE:integer);
var q:integer;

  begin
    for i:=1 to MAXone DO
      BEGIN
        WRITE('|');
        FOR Q:=1 to (37-length(storr[a,i])) DIV 2 do
          begin write(' ')  end;
        WRITE(storr[a,i]);
        for q:=1 to (37-length(storr[a,i])) div 2 do
          begin write (' ') end;
        if not ODD(length(storr[a,i])) then write(' ');

        writeln('|');
      end;
  END;

procedure makeit;
  begin
    story[1,1]:='Walks with a limp';
    story[1,2]:='(Mobility impairment)';
    story[2,1]:='Must use crutches';
    story[2,2]:='(Mobility impairment)';
    story[3,1]:='Confined to Wheel Chair';
    story[3,2]:='(Mobility impairment)';
    story[4,1]:='Confined to Bed';
    story[4,2]:='(Mobility impairment)';
    story[5,1]:='Occasional Neurosis';
    story[5,2]:='(Cognitive impairment)';
    story[6,1]:='Sometimes psychotic';
    story[6,2]:='(Cognitive impairment)';
```

```
        story[7,1]:='Psychotic--committable';
        story[7,2]:='(Cognitive impairment)';
        story[8,1]:='Vegetative';
        story[8,2]:='(Cognitive impairment)';
        story[9,1]:='Scar--cover with makeup';
        story[9,2]:='(Cosmetic impairment)';
        story[10,1]:='Extensive scar--coverable';
        story[10,2]:='(Cosmetic impairment)';
      end;

    procedure makeit2;
      begin
        story[11,1]:='Very bad scars, not easy to cover';
        story[11,2]:='(Cosmetic impairment)';
        story[12,1]:='Severe scars, needs prosthesis';
        story[12,2]:='(Cosmetic impairment)';
        story[13,1]:='Occasional pain, no drugs needed ';
        story[13,2]:='(Pain impairment)';
        story[14,1]:='Pain controlled by non-narcotic ';
        story[14,2]:='(Pain impairment)';
        story[15,1]:='Pain controlled by narcotic';
        story[15,2]:='(Pain impairment)';
        story[16,1]:='Constant uncontrollable pain';
        story[16,2]:='(Pain impairment)';
        story[17,1]:='0-25% loss of sense or limb';
        story[17,2]:='(Sensory impairment)';
        story[18,1]:='25-50% loss of sense or limb';
        story[18,2]:='(Sensory impairment)';
        story[19,1]:='50-75% loss of sense or limb';
        story[19,2]:='(Sensory impairment)';
        story[20,1]:='75-100% loss of sense or limb';
        story[20,2]:='(Sensory impairment)';
      end;


    procedure callit(c,d:integer);
      var q:integer;
    PROCEDURE RECODEM;
     PROCEDURE ONE;
      BEGIN
        if ((ans[c,d]='1') and (ans2[c,d] in ['m','M'])) then
          begin
            if x[d]>x[c] then
              BEGIN
                result[x[c],x[d]]:=5;
                RESULT[X[D],X[C]]:=1;
              END  else
              BEGIN
                result[x[D],x[C]]:=1;
                RESULT[X[C],X[D]]:=5;
              END;

          end;
        END;


      BEGIN (*RECODEM*)
        ONE;
```

```
    if ((ans[c,d]='1') and (ans2[c,d] in ['1','L'])) THEN
    begin
        if x[d]>x[c] then
          BEGIN
            result[x[c],x[d]]:=4;
            RESULT[X[D],X[C]]:=2;
          END  else
          BEGIN
            result[x[C],x[D]]:=4;
            RESULT[X[D],X[C]]:=2;
          END;
      end;
    if ((ans[c,d]='3') and (ans2[c,d] in ['Z','z'])) then
    begin
            result[x[c],x[d]]:=3;
            result[x[d],x[c]]:=3;
      end;
    if ((ans[c,d]='2') and (ans2[c,d] in ['1','L'])) then
    begin
        if x[d]>x[c] then
          BEGIN
            result[x[c],x[d]]:=2;
            result[x[D],x[C]]:=4;
          END ELSE
          BEGIN
            result[x[C],x[D]]:=2;
            result[x[D],x[C]]:=4;
          END;
      end;
    if ((ans[c,d]='2') and (ans2[c,d] in ['m','M'])) then
    begin
        if x[d]>x[c] then
          BEGIN
            result[x[c],x[d]]:=1;
            result[x[D],x[C]]:=5;
          END ELSE
          BEGIN
            result[x[C],x[D]]:=1;
            result[x[d],x[c]]:=5;
          END;
      end;
    END;
        PROCEDURE QUERY;
          BEGIN
            num:=num+1;
            writeLN('Which is the greater impairment?');
            WRITE('(1 or 2, 3=same)  ');
            ANS[c,d]:=GETCHAR(['1'..'3']);
            if ans[c,d] in ['1'..'2'] then
              begin
                WRITELN;writeln('How much greater?  ');
                WRITE('M)uch  L)ittle ');
                ans2[c,d]:= getchar(['L','1','M','m']);
              END else ans2[c,d]:='Z';
```

Listing of PASCAL.SCALE

```
            writeln;

    RECODEM;


            writeln;
            writeln('Thank you for your answers');
            for q:=1 to 200 do;
          END;

      begin {callit}
        writeln;
        WRITE('                ');
        writeln('Impairment # 1: ');
        WRITELN('----------------------------------------');
        showit(c,2);
        WRITELN('----------------------------------------');
        WRITELN;
        writeln;
        WRITE('                ');
        writeln('Impairment # 2: ');
        WRITELN('----------------------------------------');
        showit(d,2);
        WRITELN('----------------------------------------');
        writeln;
        QUERY;

      end;

    PROCEDURE MAKERAND;
      VAR C,I:INTEGER;
          randflag:boolean;
      BEGIN
        x[0]:=0;
        C:=1;
        i:=1;
        writeln('Generating random numbers!!');
        writeln('Please wait');
        repeat
           randflag:=false;
           X[I]:=RAND(1,20,ERR);
           C:=C+1;
             FOR J:=0 TO I-1 do
               begin
                 IF X[I]=X[j] then randflag:=true;
               end;
          if randflag=false then i:=i+1;
        until i=21;
        WRITELN('It took ',c,' tries to get 20 non-repeat random numbers');
        WRITELN('END OF SEARCH, PRESS <RETURN>');
        READLN;
        WRITELN('Storing the list of 20 random numbers without replacement');
        rewrite(ff,numfile);
        FOR I:=1 to 20 do
          begin
             ff^:=(X[i]);
             PUT(FF);
          end;
```

```
      WRITELN('Numbers stored in file ',numfile);
      close(ff,lock);
    end;

  PROCEDURE RESTATE;
    BEGIN
      FOR I:=1 TO 20 dO
        BEGIN
          STORR[i,1]:=story[x[i],1];
          storr[i,2]:=story[x[i],2];
        end;
   end;

  procedure initialize;
    var i,j: integer;
    begin
      for i:=1 to 20 do
        begin
          for j:=1 to 20 do
            begin
              result[i,j]:=0;
            end;
        end;
    end;


  begin
    left:=190;
    initialize;
    information;
    num:=0;
    RANDOMIZE;
    makerand;
    WRITELN('PRESS <RETURN> TO CONTINUE');
    readln;
    makeit;
    makeit2;
    restate;
    start:=1;
    for k:=start to 19 do
      begin
        for l:=start+1 to 20 do
          begin
            page(output);
            write(k,'/',l);
            write('   ');
            writeln(LEFT,' responses to go!');
            left:=left-1;
      if ((l-k=1) and (k>1)) then
        begin
          write(chr(7));
          write(chr(7));
          write(chr(7));
          writeln('***   CHANGING IMPAIRMENT #1   ***');
        end;
            CALLIT(k,l);
          end;
        start:=start+1;
```

Listing of PASCAL.SCALE

```
      end;
    rewrite(ff,outfile);
    for i:=1 to 20 do
      begin
        for j:=1 to 20 do
          begin
            ff^:=RESULT[i,j];
            put(ff);
          end;
      end;
    close(ff,lock);

  end.
```

APPENDIX C

TABLES AT THE OCCUPANT LEVEL

TABLE C.1

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR FOR PASSENGER CAR OCCUPANTS
BY BODY REGION AND RESTRAINT USE

Body Region	Restrained[a]	Unrestrained[b]	All
Head	90.6	46.2	47.2
Face	4.9	8.3	8.2
Neck	3.3	5.7	5.6
Shoulder ..	0.1	0.3	0.3
Chest	0.5	21.4	21.0
Back	0.2	1.7	1.7
Abdomen ..	0.1	8.1	7.9
Pelvis	0.0	1.1	1.1
Thigh	0.0	1.7	1.6
Knee	0.0	0.8	0.7
Lower leg ..	0.0	0.2	0.2
Ankle/foot .	0.0	0.1	0.1
Lower limb .	0.0	0.0	0.0
Upper arm .	0.0	1.5	1.5
Elbow	0.0	0.0	0.0
Forearm ..	0.0	1.1	1.1
Wrist/hand .	0.2	0.1	0.1
Upper limb .	0.0	0.3	0.3
Whole body	0.0	1.1	1.1
Unknown ..	0.0	0.3	0.3
Total	100.0	100.0	100.0

[a]The restrained group accounts for 2.1 percent of the total IPR for passenger car occupants.

[b]The unrestrained group accounts for 97.9 percent of the total IPR for passenger car occupants.

TABLE C.2

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR FOR PASSENGER CARS BY SEAT POSITION

Seat Position	Distribution of IPR
Front left . .	71.4
Front center	1.4
Front right .	17.0
All other . .	10.2
Total	100.0

TABLE C.3

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR FOR PASSENGER CAR FRONT OCCUPANTS
BY BODY REGION AND SEAT POSITION

Body Region	Seat Position			
	Front Left	Front Center	Front Right	All Front
Head	45.5	54.9	44.1	45.4
Face	9.1	0.0	8.4	8.8
Neck	7.0	0.0	3.8	6.3
Shoulder ..	0.3	0.0	0.1	0.3
Chest	23.1	0.6	19.4	22.0
Back	0.4	0.0	7.9	1.8
Abdomen ..	5.0	39.8	13.7	7.2
Pelvis	1.4	0.5	0.5	1.2
Thigh	1.9	0.0	1.1	1.7
Knee	0.9	3.3	0.2	0.8
Lower leg ..	0.2	0.3	0.3	0.2
Ankle/foot .	0.1	0.1	0.1	0.1
Lower limb .	0.0	0.0	0.0	0.0
Upper arm .	2.1	0.0	0.0	1.7
Elbow	0.0	0.0	0.0	0.0
Forearm ..	1.4	0.3	0.2	1.2
Wrist/hand .	0.1	0.1	0.1	0.1
Upper limb .	0.4	0.0	0.0	0.3
Whole body	0.7	0.0	0.0	0.5
Unknown ..	0.4	0.0	0.0	0.3
Total	100.0	100.0	100.0	100.0

TABLE C.4

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	3.7	7.8	0.1	4.0
2 o'clock	9.1	11.4	17.2	10.4
3 o'clock	2.0	9.9	6.4	3.9
4 o'clock	0.0	0.0	0.0	0.0
5 o'clock	0.1	0.0	0.0	0.1
6 o'clock	0.4	1.4	1.7	0.7
7 o'clock	0.4	0.0	0.0	0.3
8 o'clock	0.4	1.5	5.4	1.2
9 o'clock	2.3	0.4	0.7	1.8
10 o'clock	6.2	18.7	5.7	8.2
11 o'clock	5.8	0.4	4.2	4.7
12 o'clock	36.0	28.0	49.2	36.1
Non-horizontal	22.1	8.0	2.9	17.5
Unknown	11.5	12.6	6.7	11.1
Total	100.0	100.0	100.0	100.0
N	815	278	169	1262

TABLE C.5

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2
6-10 mph	1.5	0.6	0.0	0.0	0.0	0.1	0.0	0.1	0.5	0.9	3.2	0.1	0.0	0.0	0.4
11-15 mph	12.7	2.2	8.1	100.0	0.0	1.0	0.0	6.2	0.8	1.0	2.4	1.0	0.0	0.0	1.7
16-20 mph	4.6	2.9	7.1	0.0	76.2	23.2	0.0	0.3	6.0	5.5	21.3	5.1	0.0	0.0	4.4
21-25 mph	3.3	2.6	1.8	0.0	21.8	4.6	67.7	0.0	1.9	9.8	8.4	13.6	0.0	0.0	6.9
26-30 mph	1.5	8.0	14.7	0.0	0.0	28.7	0.0	69.1	0.0	4.3	15.1	2.0	0.0	0.0	4.3
31-35 mph	0.1	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.2	4.8	0.0	0.0	1.8
36-40 mph	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	1.5
41-45 mph	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	2.1	0.0	0.0	1.7
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	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	2.9
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	4.4
Unknown .	76.3	79.5	64.8	0.0	2.0	38.2	32.3	24.3	90.8	72.1	49.5	46.8	100.0	100.0	69.9
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	87	92	36	1	5	26	6	24	35	80	120	428	152	170	1262

TABLE C.6

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	0.2	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2
6-10 mph	2.2	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.6	1.4	1.0	0.1	0.0	0.0	0.4
11-15 mph	18.9	2.4	3.5	100.0	0.0	2.1	0.0	2.5	0.9	1.1	2.0	1.1	0.0	0.0	1.6
16-20 mph	6.7	1.5	1.5	0.0	75.5	1.9	0.0	0.0	4.0	1.4	23.1	7.1	0.0	0.0	4.5
21-25 mph	4.5	1.3	0.0	0.0	22.4	5.0	69.5	0.0	2.1	11.1	8.6	14.4	0.0	0.0	7.0
26-30 mph	2.2	3.3	0.0	0.0	0.0	0.9	0.0	0.6	0.0	0.5	17.0	2.3	0.0	0.0	2.2
31-35 mph	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6	0.0	0.0	0.6
36-40 mph	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	1.1
41-45 mph	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	1.6
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	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	11.3	0.0	0.0	4.1
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	1.5
Unknown .	65.2	83.7	85.8	0.0	2.1	90.2	30.5	96.6	92.5	84.6	48.0	51.7	100.0	100.0	75.0
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	100.0	100.0
N	62	56	16	1	4	14	5	12	23	47	82	285	96	112	815

TABLE C.7

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	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	0.0	0.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
11-15 mph	0.1	1.5	15.6	0.0	0.5	0.0	2.6	0.0	0.7	5.0	2.2	0.0	0.0	2.5
16-20 mph	0.2	10.1	14.8	100.0	0.3	0.0	0.0	60.0	12.3	25.9	0.4	0.0	0.0	5.4
21-25 mph	0.7	9.5	0.3	0.0	7.8	0.0	0.0	0.0	0.1	30.7	15.2	0.0	0.0	5.7
26-30 mph	0.0	0.5	33.6	0.0	88.4	0.0	97.1	0.0	0.7	0.4	2.7	0.0	0.0	7.0
31-35 mph	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.1	14.8	0.0	0.0	4.1
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.0	0.0	3.8
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.3	0.0	0.0	3.2
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	0.1	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	36.1	0.0	0.0	10.1
Unknown .	99.0	78.2	35.7	0.0	2.4	100.0	0.3	40.0	69.6	36.9	14.7	100.0	100.0	58.2
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
N	14	24	13	1	8	1	5	6	20	21	89	38	38	278

TABLE C.8

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	4.6	0.1	14.8	4.6	0.0	3.7
2 o'clock	1.3	25.7	11.0	4.1	23.2	9.1
3 o'clock	3.1	0.2	0.0	0.7	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	0.0	0.0	0.0	0.1
6 o'clock	0.7	0.0	0.0	0.1	0.0	0.4
7 o'clock	0.2	1.0	0.0	0.0	0.0	0.4
8 o'clock	0.5	0.0	0.1	1.4	0.0	0.4
9 o'clock	1.2	1.7	0.0	15.3	36.1	2.3
10 o'clock	7.8	4.7	0.3	0.3	0.0	6.2
11 o'clock	3.5	5.5	42.0	6.4	0.0	5.8
12 o'clock	36.0	37.1	5.5	56.3	40.7	36.0
Non-horizontal	30.0	8.8	20.1	7.4	0.0	22.1
Unknown	11.0	15.2	6.0	3.3	0.0	11.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
N	363	178	127	144	3	815

TABLE C.9

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	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	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3
6-10 mph	2.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.3	0.2	0.0	0.0	0.4
11-15 mph	2.7	23.0	3.6	0.0	0.9	0.0	2.4	2.7	1.0	1.5	1.6	0.0	0.0	1.3
16-20 mph	6.4	15.1	0.0	77.1	1.9	0.0	0.0	0.0	1.5	42.7	5.2	0.0	0.0	4.1
21-25 mph	1.3	4.9	0.0	22.9	3.6	0.0	0.0	0.0	13.9	16.3	14.6	0.0	0.0	7.1
26-30 mph	2.6	1.0	0.0	0.0	0.9	0.0	0.0	0.0	0.6	0.5	3.1	0.0	0.0	1.3
31-35 mph	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.1
36-40 mph	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	1.7
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	7.4	0.0	0.0	2.7
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.3
Unknown .	84.2	50.3	86.8	0.0	92.7	100.0	97.6	97.3	81.2	38.3	61.8	100.0	100.0	80.6
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	32	22	8	3	9	2	3	7	23	31	120	50	53	363

TABLE C.10

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	0.1
6-10 mph	18.5	0.0	0.0	0.0	0.0	0.0	2.4	0.0	3.2	0.0	0.0	0.0	0.2
11-15 mph	0.0	0.2	2.4	26.5	0.0	51.9	0.0	1.6	0.5	0.0	0.0	0.0	0.2
16-20 mph	11.9	0.0	0.0	0.0	0.0	0.0	1.1	0.4	0.0	12.8	0.0	0.0	4.8
21-25 mph	0.0	1.0	0.0	73.5	100.0	0.0	9.7	0.0	0.2	16.9	0.0	0.0	7.7
26-30 mph	0.0	0.6	0.0	0.0	0.0	48.1	0.0	0.0	61.8	1.0	0.0	0.0	4.0
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.6	0.0	0.0	1.7
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0	3.0
41-45 mph	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
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	0.0	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0	3.9
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	3.0
Unknown .	69.6	89.7	97.6	0.0	0.0	0.0	86.8	97.9	34.1	38.0	100.0	100.0	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
N	8	15	5	2	1	2	6	14	22	66	17	20	178

TABLE C.11

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	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	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
6-10 mph	0.1	8.0	0.0	0.0	0.0	0.0	28.8	100.0	0.0	0.1	0.2	0.0	0.0	1.0
11-15 mph	98.6	3.3	0.0	100.0	0.0	0.0	0.0	0.0	3.8	0.0	1.9	0.0	0.0	15.1
16-20 mph	0.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1	8.6	0.0	0.0	10.5
21-25 mph	0.4	0.1	0.0	0.0	0.0	100.0	0.0	0.0	81.9	0.7	1.1	0.0	0.0	0.8
26-30 mph	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.1
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.0	0.0	0.0	2.8
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	0.0	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	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 .	0.2	86.5	0.0	0.0	100.0	0.0	71.2	0.0	14.3	76.1	34.1	100.0	100.0	69.7
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	11	13	1	1	1	1	4	1	5	9	40	20	20	127

TABLE C.12

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	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
6-10 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
11-15 mph	0.0	0.0	0.0	87.2	0.0	0.0	0.1	0.0	26.0	1.0	0.0	0.0	2.4
16-20 mph	29.7	1.1	99.4	0.0	0.0	0.0	12.3	38.4	4.7	0.1	0.0	0.0	4.5
21-25 mph	62.0	0.0	0.6	12.8	0.0	0.0	0.0	7.7	46.8	5.9	0.0	0.0	9.2
26-30 mph	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.3
31-35 mph	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.9
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	0.0	3.3
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
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	0.0	0.0
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.1	0.0	0.0	28.7
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	20.0	0.0	0.0	11.3
Unknown .	2.3	98.7	0.0	0.0	100.0	100.0	87.6	53.9	21.2	14.4	100.0	100.0	39.4
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
N	11	5	2	2	2	3	8	5	20	58	9	19	144

TABLE C.13

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	8.0	7.9	0.0	1.1	0.0	7.8
2 o'clock	8.3	13.1	4.7	58.3	100.0	11.4
3 o'clock	8.7	12.0	2.5	1.6	0.0	9.9
4 o'clock	0.0	0.0	0.0	0.0	0.0	0.0
5 o'clock	0.0	0.0	2.1	0.0	0.0	0.0
6 o'clock	2.4	0.0	10.7	0.3	0.0	1.4
7 o'clock	0.1	0.0	0.0	0.0	0.0	0.0
8 o'clock	2.7	0.0	0.0	0.0	0.0	1.5
9 o'clock	0.7	0.0	2.3	0.0	0.0	0.4
10 o'clock	32.7	0.3	2.7	5.6	0.0	18.7
11 o'clock	0.5	0.0	8.1	2.6	0.0	0.4
12 o'clock	20.9	38.0	8.2	27.8	0.0	28.0
Non-horizontal	2.9	15.3	6.6	1.7	0.0	8.0
Unknown	12.2	13.4	52.1	1.0	0.0	12.6
Total	100.0	100.0	100.0	100.0	100.0	100.0
N	116	53	46	62	1	278

TABLE C.14

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	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
6-10 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
11-15 mph	0.0	0.0	31.3	0.0	0.0	1.9	0.0	0.7	6.6	5.1	0.0	0.0	4.1
16-20 mph	0.0	0.0	0.0	0.0	0.0	0.0	61.5	11.9	32.9	0.5	0.0	0.0	4.6
21-25 mph	1.1	23.2	0.0	8.1	0.0	0.0	0.0	0.1	38.9	16.2	0.0	0.0	5.8
26-30 mph	0.0	1.1	0.0	91.9	0.0	98.0	0.0	0.5	0.0	6.4	0.0	0.0	6.4
31-35 mph	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
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.5	0.0	0.0	6.8
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	0.0	0.6	0.0	0.0	5.7
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
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
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	0.0	0.0	4.1
Unknown .	98.9	75.7	68.7	0.0	100.0	0.1	38.5	69.8	21.6	19.0	100.0	100.0	62.5
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
N	7	5	4	2	1	3	4	10	10	39	16	15	116

TABLE C.15

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	8 o'clock	10 o'clock	11 o'clock	12 o'clock	Non-Hor.	Unknown	All
1-5 mph .	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-10 mph	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-15 mph	0.0	0.2	0.0	79.1	2.1	0.0	0.0	0.0	0.0	0.1
16-20 mph	0.0	8.3	29.8	0.0	75.0	0.0	0.0	0.0	0.0	4.9
21-25 mph	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.0	0.0	5.6
26-30 mph	0.0	0.0	67.4	0.0	19.3	100.0	0.0	0.0	0.0	8.2
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	25.1	0.0	0.0	9.5
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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
51-55 mph	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	50.1	0.0	0.0	19.0
Unknown .	100.0	91.4	2.8	20.9	3.6	0.0	10.1	100.0	100.0	52.7
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	2	8	5	2	5	1	13	10	7	53

TABLE C.16

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR FOR PASSENGER CAR RIGHT-FRONT OCCUPANTS WITH UPPER-EXTREMITY INJURIES BY DELTA V AND DIRECTION OF FORCE

Delta V	Direction of Force										
	2 o'clock	3 o'clock	5 o'clock	6 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
6-10 mph	0.0	0.0	0.0	12.1	0.0	37.0	0.0	23.2	0.0	0.0	4.2
11-15 mph	0.0	0.0	0.0	15.0	0.0	0.0	0.0	20.6	0.0	0.0	3.3
16-20 mph	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
21-25 mph	0.0	31.8	0.0	0.0	0.0	0.0	8.0	14.1	0.0	0.0	2.6
26-30 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-35 mph	0.0	0.0	0.0	7.1	0.0	0.0	12.9	3.1	0.0	0.0	2.1
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
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
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
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
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown .	100.0	68.2	0.0	65.8	100.0	63.0	79.1	39.0	100.0	100.0	85.7
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	3	2	1	4	2	2	5	9	9	9	46

TABLE C.17

1980 AND 1981 NASS (OCCUPANT LEVEL):
PERCENT IPR 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	6 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
6-10 mph	7.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.3
11-15 mph	17.1	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5
16-20 mph	47.1	53.8	0.0	50.6	0.0	5.6	6.8	0.0	0.0	34.1
21-25 mph	28.9	0.0	85.5	0.0	0.0	2.0	9.0	0.0	0.0	4.2
26-30 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-35 mph	0.0	0.0	0.0	0.0	0.0	0.0	31.8	0.0	0.0	8.8
36-40 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-45 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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
51-55 mph	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.8
> 55 mph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown .	0.0	33.6	14.5	49.4	100.0	92.4	48.8	100.0	100.0	44.3
Total . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	5	7	2	2	3	5	28	3	7	62

APPENDIX D

NASS CODES FOR BODY REGION

NASS uses the Occupant Injury Classification to represent the body region injured as follows:

"A": Arm (upper)
"B": Back/thoracolumbar spine
"C": Chest
"E": Elbow
"F": Face
"H": Head/skull
"K": Knee
"L": Leg (lower)
"M": Abdomen
"N": Neck/cervical spine
"O": Whole body
"P": Pelvis
"Q": Ankle/foot
"R": Forearm
"S": Shoulder
"T": Thigh
"U": Unknown region
"W": Wrist/hand
"X": Upper limb (whole or unknown part)
"Y": Lower limb (whole or unknown part)

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