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Reinfurt, Donald W., et al. (1978). Injury Scaling Research. Chapel Hill, NC: University of North Carolina Highway Safety Research Center.

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Report No. DOT-HS-7-01539

DOT-HS-7-01539
March 1978

INJURY SCALING RESEARCH

D. W. Reinfurt
J. R. Stewart
R. G. Hall
A. K. Dutt
J. C. Stutts
L. K. Li
J. B. Markley

March 1978

UNC/HSRC-78/3/2

FINAL REPORT
November 30, 1976 - March 31, 1978

Prepared for

DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
Washington, D.C. 20590

Prepared for the Department of Transportation, National Highway Traffic Safety Administration, under Contract No.: DOT-HS-7-01539.
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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-HS-7-01539		

4. Title and Subtitle	5. Report Date
INJURY SCALING RESEARCH	March 28, 1978
	6. Performing Organization Code
7. Author(s) D. W. Reinfurt, J. R. Stewart, R. G. Hall, A. K. Dutt, J. C. Stutts, L. K. Li, J.B.Markley	8. Performing Organization Report No.
9. Performing Organization Name and Address The Highway Safety Research Center University of North Carolina Chapel Hill, NC 27514	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-HS-7-01539
12. Sponsoring Agency Name and Address Department of Transportation National Highway Traffic Safety Administration 400 Seventh Street, S.W. Washington, D.C. 20590	13. Type of Report and Period Covered Final Report Nov. 30, 1976 - March 31, 1978 14. Sponsoring Agency Code

15. Supplementary Notes

None

16. Abstract

In an attempt to improve the usefulness of accident data for NHTSA's safety systems analyses, threat-to-life, disability, and (direct) cost scales are developed using somewhat limited existing accident and injury data. The resulting scales utilize data elements which are readily available from Level 2-type accident investigations, are easily automated, and are compatible with medical codes on other existing files.

Using the Illinois Trauma Registry, a 14-point ICDA threat-to-life scale is developed which predicts the unconditional probability of death prior to release from the hospital as a function of primary injury, occupant age, presence or absence of a severe secondary injury, and extent (or number) of injuries. Secondly, a 9-point AIS threat-to-life scale is presented which predicts the probability of fatality given that the occupant has arrived alive at the treatment facility.

The acute disability scale predicts compensation awarded for disability as a function of primary injury (described by body part and nature), age and sex of occupant, and extent (or number) of injuries. The calibration of the scale is carried out using data from the N.C. Workmen's Compensation File (WCF). In brief, a hierarchical clustering scheme is utilized to combine injury types with similar compensation distributions (upper, middle and lower quartiles). The seven

(Cont' on next page)

17. Key Words	18. Distribution Statement
injury scaling injury classifications: ICDA, OIC, AIS threat-to-life, disability medical costs scale validation	available to the public

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	166, xv	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

16. Abstract (Cont')

resulting injury groups provide input to the final regression model containing main effects for injury category and two-way interactions with age and sex of occupant and extent of injury. This regression model represents the acute disability scale.

The direct cost scale predicts disability costs and medical costs by place of treatment for injuries sustained in accidents. The medical portion is derived primarily from the N.C. Blue Cross Blue Shield File and is specific to place-of-treatment. For example, for the hospital inpatient cases, ICDA's are initially grouped according to similar medical payments. The 102 resulting groups (17 injury groups by 6 age-sex groups) are then further combined using weighted least squares procedures for categorical data. Somewhat similar procedures are used for the doctor's office and the emergency room cases with adjustments in the latter using the WCF data. The final direct cost scale then is a composite of the disability scale together with the medical cost by place of treatment scale.

Validation, to the extent possible, is carried out using both the Restraint Systems Evaluation Program File and the initial 1320 cases on the National Crash Severity Study File. A number of recommendations are then made related primarily to the future evolution of the injury information aspects of the Continuous Sampling System of NASS.

TECHNICAL SUMMARY

The primary goal of this research is to expand the usefulness of accident data for safety systems analyses. This improvement is sought by devising, calibrating and then validating several injury scales which will, in turn, reliably predict "societal" consequences of motor vehicle accidents. These scales are constrained to utilize field data elements that are easily obtainable in Level 2-type accident investigations, readily automated, and compatible with existing medical codes on non-accident data files. Finally, the research experience is documented in a form which should provide valuable injury-related input to NHTSA in their evolution of the National Accident Sampling System (NASS).

For the purposes of this research, a scale is defined as a method of describing societal consequences of injuries. These injuries are measured by a variety of codes such as the ICDA, AIS, Occupant Injury Classification, and the consequences or scales considered are threat-to-life probabilities, disability compensation, and medical costs. At the simplest level, such scales can describe these various consequences from a single injury (for instance, the expected medical costs from a fractured femur for an elderly male accident victim). At a more general level, such a scale can be utilized with accident data to describe the consequences of various crash configurations (for instance, the expected medical costs of injuries to drivers involved in side collisions).

To begin the research, a detailed literature search was carried out covering over 100 articles dealing with scaling in general (i.e., properties of a reasonable scale, procedures for developing scales) as well as with specific scales developed in areas of traumatic injuries and diseases. In contrast to the current effort, the vast majority of existing scales are not based on actual case-by-case injury data -- in fact, many have resulted from medical concensus.

Three classes of scales were explored, each of which measured a different aspect of injury consequences. Specifically, the candidate scales were <u>threat-to-life</u>, <u>disability</u> (as measured by financial consequences rather than the more traditional activity limitations), and <u>direct costs</u> of injuries (eventually accounting for medical and disability costs).

The development of the corresponding models required case-by-case, automated data in as great a quantity as feasible on the following types of variables:

1. Type of accident
2. Injury description (ICDA, AIS, OIC)
3. Consequences (fatality or disability or medical costs)
4. Demographic characteristics of the victim (age, sex, previous medical condition)

An extensive search for data sets meeting the majority of these requirements led to the conclusion that no existing data sets even begin to approximate these stipulations. As a result, the research required a variety of assumptions using the most appropriate data sets that were available. (The alternative of a prospective study collecting all of the required data in sufficient quantity certainly was not realistic!)

With these caveats in mind, two threat-to-life scales were developed using data primarily from the Illinois Trauma Registry. The 14-point ICDA threat-to-life scale predicts the probability of a fatality prior to release from the hospital as a function of specific primary injury, age of occupant, and the extent (or number) and severity of secondary injuries. The estimation of these unconditional probabilities required additional information on dead-at-scene (DAS) and dead-on-arrival (DOA) cases. This information was obtained from data provided by the N.C. Medical Examiner's Office.

Briefly, the analysis procedure first involved grouping ICDA codes according to the following criteria: (1) Injuries within a group were of a similar medical nature; and (2) the proportions of people who died did not differ significantly among the ICDA codes within the group. Next, interactions of the resulting injury groups with each of three subsidiary injury variables (extent, pre-existing condition, and severe secondary injury) and with age of occupant were examined and the important ones accounted for. For example, if the proportion dying in a given injury group differed according to the age of occupant, then the age by injury interaction would be important to include in the scale. Finally, CHAID (automatic interaction detection program for categorical data) was utilized to provide the 14-point ICDA threat-to-life scale given in Table S.1.

Table S.1 Fourteen point threat-to-life scale.

	Fatality Percentage	Standard Deviation	Description
1.	.35	.08	$I_1A_1N_1$
2.	.65	.10	$I_1A_2N_1$ and $I_1A_1N_2$
3.	1.25	.20	$I_1A_3N_1$ and $I_1A_2N_2$
4.	2.13	.20	$I_2A_{1-3}N_{1-2}$, $I_1A_3N_2$, and $I_1A_1N_3$
5.	4.18	.53	$I_1A_4N_1$ and $I_1A_2N_3$
6.	6.55	.56	$I_3A_{1-3}N_1$ and $I_1A_3N_3$
7.	8.30	.65	$I_3A_{1-3}N_2$, $I_2A_{1-3}N_3$, $I_2A_4N_{1-2}$, and $I_1A_4N_2$
8.	15.47	.72	$I_5A_1S_1$, I_4A_1, $I_3A_4N_{1-2}$, $I_3A_{1-3}N_3$, and $I_1A_4N_3$
9.	26.37	1.79	I_4A_{2-3} and $I_2A_4N_3$
10.	31.97	1.58	I_6A_1, $I_5A_{2-4}S_1$, and $I_3A_4N_3$
11.	49.74	2.07	I_7 and I_6A_{2-4}
12.	57.88	2.99	I_5S_2 and I_4A_4
13.	69.05	2.26	I_8
14.	82.24	2.61	I_9

I ≡ Primary injury group (9 levels) as defined in Table 3.6.

A ≡ Age (A_1:$\leq$20, A_2:21-55, A_3:56-70, A_4:>70).

S ≡ Severe scondary injury (S_1 : no secondary injury with AIS as high as first, S_2 : one or more secondary injuries as severe as first).

N ≡ Extent (or number) of injuries (N_1 : 1 or 2, N_2 : 3 or 4, N_3 : 5 or more).

Data Source: Illinois Trauma Registry supplemented by N.C. Medical Examiner's File.

The 9-point AIS threat-to-life scale predicts the conditional probability that death will result given that the individual does not die before reaching an initial treatment facility. It is particularly useful with accident data since it is generally known if the occupant is DAS or DOA. The scale is calibrated using the Illinois Trauma Registry data and is a function of the AIS severity score, the extent (or number) of injuries, and the age of the victim. The resulting 9-point AIS scale is given in Table S.2.

The disability scale predicts compensation awards (i.e., compensation for lost workdays and permanent bodily loss such as through amputation) associated with acute or traumatic injuries. It is calibrated using data from the N.C. Workmen's Compensation File (WCF) and is a function of age and sex of accident victim along with the corresponding injury information in the form of body part by nature of injury.

A variety of approaches were investigated for grouping the various body part by nature of injury combinations on the basis of compensation paid. Of those examined, the preferred technique was a hierarchical clustering technique which clustered injury groups on the basis of similar compensation distributions as determined by the median and upper and lower quartiles. Seven injury clusters were selected which had similar compensation distributions within clusters but differing distributions among clusters.

The development of the disability scale was carried out by fitting various multiple regression models to the compensation data. The independent variables included the seven injury clusters, age and sex of occupant and extent of injury (single or multiple injuries). As the more general model with higher order interactions added little to the proportion of the compensation variability already accounted for by the model with main effects for injury category and various two-way interactions, the latter was selected as the preferred disability scale. See Table S.3 for the components of this scale.

The goal of the final scale was to predict overall cost consequences of traumatic injuries. It became apparent all too soon that, at best, adequate case-by-case data was available to predict the major direct costs only. Thus, the cost scale predicts a combination of medical costs (by place of treatment) and disability consequences. The cost scale is calibrated using

Table S.2 Nine point threat-to-life scale.

	Fatality Percentage	Standard Deviation	Description
1.	.40	.06	$J_1A_{1-3}N_{1-2}$, $J_2A_{1-3}N_1$, $J_3A_1N_1$
2.	.86	.15	$J_2A_{1-3}N_2$, $J_3A_2N_1$
3.	3.19	.26	$J_1A_{1-3}N_3$, $J_1A_4N_1$, $J_2A_{1-3}N_3$, $J_3A_1N_{2-3}$, $J_3A_2N_2$, $J_3A_3N_{1-2}$, $J_4A_{1-4}N_1$
4.	5.73	.72	$J_2A_4N_{1-2}$, $J_3A_2N_3$
5.	7.67	.54	$J_3A_4N_{1-2}$, $J_4A_{1-4}N_2$
6.	13.81	1.47	$J_1A_4N_{2-3}$, $J_3A_3N_3$, $J_3A_4N_3$, $J_4A_{1-4}N_3$, $J_5A_{1-2}N_1$
7.	23.94	2.60	$J_2A_4N_3$, $J_5A_{1-2}N_{2-3}$, $J_5A_{3-4}N_1$
8.	60.87	10.18	$J_5A_{3-4}N_{2-3}$
9.	100.00	0.00	dead-at-accident dead-on-arrival

$J \equiv$ AIS class (J_1 : AIS-1, ..., J_5 : AIS-5).

$A \equiv$ Age (A_1:$\leq$20, A_2:21-55, A_3:56-70, A_4:>70).

$S \equiv$ Severe secondary injury (S_1 : no secondary injury with AIS as high as first, S_2 : one or more secondary injuries as severe as first).

$N \equiv$ Extent (or number) of injuries (N_1 : 1 or 2, N_2 : 3 or 4, N_3 : 5 or more).

Data Source: Illinois Trauma Registry.

Table S.3 Predicted disability amounts (in dollars) by the reduced interaction model for sex, age, extent and injury category combinations.

			Injury Category						
Sex[1]	Age[2]	Extent[3]	1	2	3	4	5	6	7[4]
M	Y	1	$285.09	$309.47	$658.58	$1,153.07	$2,141.34	$3,257.12	$12,294.26
		>1	329.64	354.02	703.13	1,197.62	2,316.87	3,657.59	12,294.26
	0	1	364.76	522.20	871.31	1,365.80	2,354.07	3,786.81	12,294.26
		>1	409.31	566.75	915.86	1,410.35	2,529.60	4,187.28	12,294.26
F	Y	1	180.23	204.61	274.95	769.44	1,044.17	2,159.95	12,294.26
		>1	224.78	249.16	319.50	813.99	1,219.70	2,560.42	12,294.26
	0	1	259.90	417.34	487.68	982.17	1,256.90	2,689.64	12,294.26
		>1	304.45	461.89	532.23	1,026.72	1,432.43	3,090.11	12,294.26

[1] M = male
F = female

[2] Y = 40 and under
0 = over 40 years of age

[3] 1 = single injury
>1 = multiple injury

[4] Estimates cannot be made for the effects of age, sex, and extent on the compensation awards associated with Category 7 because of the small number of cases involving Category 7 injuries and because of the model formulation.

Data Source: North Carolina Workmen's Compensation File

mainly data from Blue Cross Blue Shield (BCBS) of North Carolina with supplementary data from the N.C. Workmen's Compensation File. It is a function of the individual's primary injury along with his age and sex and the extent (or number) of his injuries.

Basically, starting with the hospital inpatient file where ICDA was available, injury types were grouped by costs first on the basis of standardized distance matrices and then by testing for similarities within groups using analyses of variance. Next, as age and sex clearly interact within injury groups to provide differing cost estimates, the final 102 cells, formed by the cross-classification of 17 ICDA groups and 6 age-sex groups, were examined to determine which cells, if any, could be combined. This investigation was carried out using a generalized weighted least squares procedure for categorical data (GENCAT). The final inpatient medical cost components of the scale are shown in Table S.4. A similar procedure was followed for the doctor's office data and for the emergency room data (see Tables S.5 and S.6, respectively). In the latter case, extrapolations from the WCF were required as the BCBS emergency room cases generally lacked injury data.

The final cost scale then predicts a combination of disability compensation from Table S.3 and the respective place of treatment medical costs from Tables S.4, S.5, or S.6. The prediction of medical costs for multiple injuries is illustrated in the report.

Validation of the derived scales was carried out to the extent the data allowed. To examine face validity of the threat-to-life and disability scales, the predicted scale values were applied to the Restraint Systems Evaluation Program (RSEP) data in re-calculating belt effectiveness estimates. For the most part, the results were reasonable.

Finally, quasi-validation was carried out on the first 1320 accident cases of the National Crash Severity Study (NCSS) data. For example, the lost workdays by injury group distribution for the two files (WCF vs NCSS) were compared. Although severely limited by data quantity on the NCSS, the distributions appeared fairly similar; likewise for days of hospitalization. However, with the paucity of the data, conclusions regarding the validity of any of these scales are tenuous at best.

Table S.4 Medical cost estimates, (standard errors) in dollars by injury class, sex and age for hospital inpatient cases.

Inj.Class \ Sex / Age	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	[1*] 1017.93 (44.42)	[2] 1209.29 (37.35)	[3] 662.78 (146.47)	[1] 1017.93 (44.42)	[2] 1209.29 (37.35)	[3] 662.78 (146.47)
2	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)
3	[7] 789.56 (49.06)	[8] 967.96 (70.57)	[11] 526.21 (65.42)	[9] 666.95 (33.66)	[10] 809.42 (30.59)	[11] 526.21 (65.42)
4	[12] 7120.58 (1163.81)	[14] 4099.95 (402.14)	-	[13] 3235.32 (707.93)	[14] 4099.95 (402.14)	[14] 4099.95 (402.14)
5	[15] 2184.44 (108.61)	[16] 2933.81 (174.52)	-	[15] 2184.44 (108.61)	[16] 2933.81 (174.52)	[16] 2933.81 (174.52)
6	[17] 1974.93 (126.39)	[18] 2408.11 (114.88)	[19] 528.19 (261.81)	[17] 1974.93 (126.39)	[18] 2408.11 (144.88)	[20] 1931.07 (347.45)
7	[21] 886.24 (26.07)	[21] 886.24 (26.07)	[21] 886.24 (26.07)	[21] 886.24 (26.07)	[21] 886.24 (26.07)	-
8	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)
9	[21] 886.24 (26.07)	[21] 886.24 (26.07)	-	[21] 886.24 (26.07)	[21] 886.24 (26.07)	-
10	[22] 1046.84 (35.01)	[24] 1349.39 (64.82)	-	[23] 1179.64 (53.29)	[24] 1349.39 (64.82)	[24] 1349.39 (64.82)
11	[25] 541.66 (43.63)	[26] 645.15 (33.13)	[27] 697.89 (241.66)	[25] 541.66 (43.63)	[26] 645.15 (33.13)	[27] 697.89 (241.66)
12	[28] 502.02 (28.79)	[30] 623.39 (18.18)	[32] 388.28 (56.42)	[29] 636.12 (46.99)	[31] 708.82 (17.28)	[32] 388.28 (56.42)
13	[1] 1017.93 (44.42)	[2] 1209.29 (37.35)	[3] 662.78 (146.47)	[1] 1017.93 (44.42)	[2] 1209.29 (37.35)	-
14	[33] 1960.63 (329.80)	[34] 1782.43 (306.49)	-	[33] 1960.63 (329.80)	[34] 1782.43 (306.49)	[35] 530.60 (110.10)
15	[36] 1689.59 (285.11)	[37] 769.51 (81.38)	[37] 769.51 (81.38)	[36] 1689.59 (285.11)	[37] 769.51 (81.38)	-
16	[38] 3435.02 (382.75)	[38] 3435.02 (382.75)	-	[38] 3435.02 (382.75)	[38] 3435.02 (382.75)	-
17	[39] 362.27 (32.69)	[40] 471.87 (28.81)	-	[39] 362.27 (32.69)	[40] 471.87 (28.81)	-

* Superscripts indicate the cells that were combined in the modeling and thus have the same estimates.

\- Cells had virtually no data for reliable estimates. However, if medical cost estimates are required for these cells then the following approximation is recommended:
  a) Use estimate from same age group from opposite sex, i.e., ignore sex effect.
  b) If age group estimates missing in both sexes, use medical cost from next closest age category.

Data Source: BCBS inpatient file.

Table S.5 Medical cost estimates, (standard errors) in dollars by injury class, sex and age for doctor's office cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	[1]* 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)
2	[2] 26.45 (0.35)	[3] 28.58 (1.45)	[4] 23.50 (1.43)	[2] 26.45 (0.35)	[3] 28.58 (1.45)	[4] 23.50 (1.43)
3	[5] 58.51 (1.04)	[5] 58.51 (1.04)	[5] 58.51 (1.04)	[5] 58.51 (1.04)	[6] 91.64 (5.07)	[6] 91.64 (5.07)
5	[7] 192.70 (38.10)	[8] 57.00 (34.12)	-	[7] 192.70 (38.10)	[7] 192.70 (38.10)	-
6	[9] 200.24 (47.21)	[10] 703.00 (114.44)	[9] 200.24 (47.21)	[11] 483.44 (152.21)	[11] 483.44 (152.21)	[11] 483.44 (152.21)
7	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)
8	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)
9	[1] 79.82 (2.13)	[1] 79.82 (2.13)	-	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)
10	[14] 51.77 (3.90)	[14] 51.77 (3.90)	[17] 29.50 (0.50)	[15] 41.97 (3.58)	[16] 75.16 (15.19)	[17] 29.50 (0.50)
13	[18] 21.67 (0.44)	[20] 24.85 (1.35)	[19] 20.56 (2.56)	[18] 21.67 (0.44)	[21] 29.89 (1.78)	[19] 20.56 (2.56)

* Superscripts indicate the cells that were combined in the modeling and thus have the same estimate.

\- Cells had virtually no data for reliable estimates. However, if medical cost estimates are required for these cells then the following approximation is recommended.

a) Use estimate from same age group from opposite sex, i.e., ignore sex effect.

b) If age-group estimates missing in both sexes, use medical cost from next closest age category.

Data Source: BCBS doctor's office file.

Table S.6 Medical cost estimates, (standard errors) in dollars by injury class, sex and age for emergency room cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	[1]* 151.53 (38.32)	[3] 217.98 (78.47)	[5] 89.00 (17.19)	[2] 96.25 (8.65)	[4] 127.16 (18.42)	[6] 257.00 (95.23)
2	[7] 87.60 (5.23)	[8] 150.99 (17.81)	[8] 150.99 (17.81)	[7] 87.60 (5.23)	[8] 150.99 (17.81)	-
3	[9] 112.83 (2.59)	[11] 103.63 (33.72)	[12] 89.51 (9.80)	[10] 96.60 (7.68)	[11] 103.63 (33.72)	[12] 89.51 (9.80)
7	[13] 84.41 (1.60)	[14] 97.38 (2.60)	[14] 97.38 (2.60)	[15] 67.02 (2.60)	[16] 79.50 (2.38)	[16] 79.50 (2.38)
8	[17] 136.00 (21.54)	[18] 171.01 (22.20)	-	-	[20] 120.42 (15.99)	-
9	[17] 136.00 (21.54)	[18] 171.02 (22.20)	-	[19] 179.45 (61.35)	[20] 120.42 (15.99)	-
10	[21] 146.00 (32.27)	[21] 146.00 (32.27)	-	[22] 78.80 (9.69)	[23] 70.00 (16.95)	-
11	[24] 66.82 (1.68)	[26] 88.92 (5.63)	[25] 91.37 (9.80)	[24] 66.82 (1.68)	[27] 74.44 (2.82)	[25] 91.37 (9.80)
12	[28] 83.78 (3.14)	[29] 117.09 (5.44)	[30] 164.67 (65.44)	[28] 83.78 (3.14)	[29] 117.09 (5.44)	[31] 70.75 (10.39)
13	[32] 69.59 (2.42)	[33] 93.60 (5.44)	[33] 93.60 (5.44)	[32] 69.59 (2.42)	[34] 76.76 (5.51)	[35] 143.00 (19.44)
15	[36] 168.95 (11.36)	[37] 219.13 (20.25)	[38] 115.44 (7.81)	[38] 115.44 (7.81)	[39] 165.52 (20.86)	-
17	[40] 70.91 (2.69)	[41] 94.80 (5.65)	[41] 94.80 (5.65)	[40] 70.91 (2.69)	[42] 82.49 (6.31)	[42] 82.49 (6.31)

* Superscripts indicate the cells that were combined in the modeling and thus have the same estimate.

\- Cells had virtually no data for reliable estimates. However, if medical cost estimates are required for these cells then the following approximation is recommended:

a) Use estimate from same age group from opposite sex, i.e. ignore sex effect.

b) If age group estimates missing in both sexes, use medical cost from next closest age category.

Data Source: WCF cases with zero or one workdays lost.

Recommendations for future work are included. These recommendations concern the following:

1. Overall management of the Continuous Sampling System (CSS) within NASS.
2. Sampling procedures for CSS investigations.
3. Investigator training and field data forms for the Phase I program of NASS.
4. (Injury) data elements on the CSS data forms.

In conclusion, acknowledging the limitations on the data used to calibrate the scales, it is felt that each of the scales provides at least a reasonably sound ranking of the corresponding societal consequences (threat-to-life, disability, medical cost) of various types of traumatic injuries. With an "ideal" data source, the scale values (or predicted societal consequences) might shift but the relative magnitudes would be expected to be retained. The injury effect in each scale played the dominant role in predicting the corresponding societal consequences. Particularly with the disability and medical cost scales, age and sex of occupant played lesser roles.

The scales are similar in that they all are functions of injury category and age; sex is utilized in the disabiity and medical cost scales while extent (or number) of injuries is differentially important to each scale depending on the data source from which the scale was calibrated.

Biases and limitations in the scales derive primarily from the assortment of data sources used to calibrate the scales. The problem of multiple injuries remains unsolved with the disability and the medical cost scales since the data sources (WCF and BCBS) had little if any information on multiple injuries. To adequately account for the effects of combinations of injuries would require much larger , more detailed data sources than were available. Finally, as a variety of injury classifications (ICDA, AIS, surgical and professional procedure, body part by nature of injury) were used, mappings between injury classifications became necessary. To the extent that these mappings assigned injuries to the "correct" combined injury groups, there would be no biases in this process. However, the extent of such biases is not known at present.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

ACKNOWLEDGMENTS

There are many people who have contributed greatly to this project. HSRC is especially grateful to those individuals who helped to provide the necessary data. In particular we wish to thank Ms. Doreene Bahr at the Illinois Department of Public Health, Ms. Margaret Higgason with the North Carolina Industrial Commission, Mr. Phillip Schinhan with the North Carolina Medical Examiner's Office, Mr. Sherman Owens at N.C. Blue Cross and Blue Shield and Dr. Donald Brand at the Yale University School of Medicine. Without their enthusiastic cooperation and assistance, this injury scaling project certainly could not have been carried out.

Consultative assistance in the project has come from a number of sources. Ms. Constance Fox and Dr. Lawrence Rose, both with the Health Services Research Center in Rockville, Maryland, are thanked for their considerable interest and input throughout the project. Members of the AMA Injury Scaling Committee are also thanked for their helpful suggestions and guidance. HSRC is especially indebted to Ms. Susan Baker with the Office of the Chief Medical Examiner in Baltimore, Maryland, for allowing us to use her ICDA-AIS conversion scheme.

Closer to home, HSRC has received valuable input from Dr. Gary Koch with the University of North Carolina Department of Biostatistics and from Dr. Leonard West at Research Triangle Institute. Both individuals reviewed the Interim and Final Reports and provided consultation as needed. Also, valuable medical consultation was provided by Dr. John Feegel with the N.C. Medical Examiner's Office and Ms. Lyn Johnson with Duke University Hospital.

There are many on the HSRC staff who have been involved at some time in the project, and we express our appreciation to all. In particular, though, we would like to commend Ms. Anita Leung and Ms. Mai Mai Ma for their computer programming efforts. Special thanks are also due our librarians Ms. Deborah Webster and Ms. Beth Boone, our typists Ms. Peggy James and Ms. Teresa Parks, and our graphic artist Mr. John Ryan.

And finally, we wish to acknowledge Dr. James Hedlund, the Contract Technical Manager, and Mr. Donald Mela, both with NHTSA. Their support, guidance and input through all phases of the project are deeply appreciated.

I. INTRODUCTION AND LITERATURE REVIEW

Introduction

Injuries due to traffic accidents have a variety of societal consequences including both direct and indirect costs, potential threat-to-life, and long-term disability and/or disfigurement. Direct costs would include such items as property damage costs, medical costs, and lost wages, while indirect costs would include such items as legal costs and insurance administration and accident investigation costs. Information about these various societal consequences of crash injury is critical for determining the magnitude of the highway safety problem relative to other health problems, for identifying those types of crashes where new countermeasures are urgently needed, or for evaluating the safety benefits of various alternative countermeasures.

To gain insight into the magnitude of the problem, there are at least two critical prerequisites. First, it is essential to have data on a large, nationally representative sample of motor vehicle accidents. To date, no such sample has been available especially on a continuing basis. The National Highway Traffic Safety Administration (NHTSA) is actively working to implement a program referred to as the National Accident Sampling System (NASS) which, upon full implementation in several years, should fill this void.

Second, there should be complete, detailed information on the societal consequences for each accident in the sample--again on a continuing basis. However, because of the time and expense of trying to collect this information on a routine basis, it has appeared imperative to derive, calibrate and then validate a variety of "injury scales" which can be generated from field data elements obtainable in a vast majority of accidents by accident investigators carrying out Level 2-type accident investigations.

The main objective of this research effort was to derive, calibrate and validate at least three such scales--threat-to-life, disability, and (direct) cost--that can readily be calculated from field data elements to be collected by the eventual NASS teams, can readily be automated, and are compatible (or translatable) with codes on existing non-accident medical files. An additional objective, as a result of the investigation leading to the development of the scales, was to devise a detailed experimental design which will provide for the continuous evaluation of the societal consequences of accidents by NASS. The purpose of this report is to summarize the research efforts undertaken to develop the three types of injury scales and their results.

In brief, to learn what has been done in the general area of injury scaling, a rather extensive literature search and review was carried out which was intentionally not limited to the area of highway accidents but was extended to the broader area of accidents in general. Examples of existing injury scales with which we became acquainted include the AIS (Abbreviated Injury Scale), the CIS (Comprehensive Injury Scale), the OAIS (Overall AIS), the ISS (Injury Severity Score), the CIRS (Cumulative Injury Rating Scale), and the ICDA. In addition, the review included special injury scales developed by Cornell, UCLA, Wayne State, Yale, Birmingham, Road Accident Research in England, and Traffic Injury Research Foundation of Canada; a variety of disability scales (e.g., functional life scales, chronic activity limitation scale); some threat-to-life scales (Champion et al.), and a few trauma scales for burns, shock, and head injuries.

The remainder of this chapter details most of the useful aspects of the rather extensive literature review carried out for this project. This review covered over 100 studies on non-highway accidents and diseases as well as those specific to traffic accidents.

In order to derive the desired injury scales, it was necessary to obtain relevant data from which to build the corresponding models. Chapter II documents the odyssey followed by HSRC in our search for automated data files that could be used in the model-building process. Essentially what was required were automated data files that contained information on injury and disease generally. The ideal file would be a large file containing, on a case-by-case basis, information on the following: (1) Type of accident (e.g., home, traffic); (2) Injury information (using ICDA, AIS, OIC or some other injury description); (3) Cost (e.g., professional (medical), hospital, workdays lost); (4) Victim information (e.g., age, sex, previous medical condition); and (5) Outcome of the accident (e.g., workdays lost, days of restricted activity). As described in Chapter II, the ideal file does not begin to exist. Nevertheless, what does exist and is available to the project is described in Chapter II.

Chapters III, IV and V present in considerable detail the development of threat-to-life, disability, and (direct) cost scales, respectively. In each, the data files that were useful in deriving the scales are further described along with any important limitations. Then, each of the scales is precisely defined (e.g., for threat-to-life scale using the Illinois Trauma Registry, a subject is categorized as "dead" if he dies at the scene, on the way to a treatment facility, or, after admission but prior to being released from the treatment facility). When the data need to be supplemented with information from other files (e.g., the dead-at-scene in the Illinois file with those from the North Carolina Medical Examiner's File), the assumptions required and the details of the process are elucidated.

In the case of each scale, there is an initial grouping of "similar" injury types ("similar" being defined by the scale under consideration). The remaining scale development generally involves rather complex grouping of the resulting injury groups in conjunction with such auxiliary variables as age, sex, previous medical condition, etc. This is essentially the modeling process that yields the eventual desired scales.

A final section in Chapters III, IV and V describes use of available NCSS data for validating the proposed injury scales. Because the quantity of valid NCSS data was less than anticipated and the data elements somewhat different from those used in the modeling, the analysis is limited to a "quasi-validation."

Finally, Chapter VI discusses the problems that HSRC has uncovered in the Restraint Systems Effectiveness Program (RSEP) and in the National Crash Severity Study (NCSS), the two NASS prototypes. The focus here is on recommendations for future NASS planning. A final project overview and discussion is also presented in this chapter.

Review of the Literature

Background

As noted earlier, a first step in accomplishing the goals of this project was to carry out an in-depth review of the literature. This review focused on consequences of disease and injury in general as well as consequences of injury resulting specifically from highway accidents. The key areas examined were injury scaling, threat-to-life measurement, disability evaluation, the societal costs of injuries, and cost-benefit analysis.

The references were derived from a variety of sources, including the original project RFP, specific recommendations by the Contract Technical Manager, an in-house literature search (including the holdings of the UNC Health Affairs Library), and suggestions arising from personal contacts with individuals knowledgeable in the field. An attempt was made to locate all studies related to injury scales, and then to concentrate on those that reflected recent developments in the field and that seemed most relevant to the project. Over 100 studies were reviewed and an annotated bibliography compiled. A listing of these studies is included here as Appendix A. It might also be noted that only about a third of the studies reviewed were judged "useful" to the current project.

By far the strongest impression generated by this body of research was the great diversity in approaches taken to measuring injuries and their associated disabilities and costs. This diversity reflects to a great extent the wide selection of available outcome measures. Thus, injury severity might be measured only in terms of a subjective judgment of threat-to-life, or factors such as length of treatment or extent of impairment might also be considered. Disability, in turn, might be defined in terms of time-off-work, the extent one is able to carry out his normal daily activities, or one's total physical, social, occupational, economic and mental health, to name a few. As a final example, injury costs might be restricted to one or more direct costs such as doctor fees, hospital charges, lost wages, rehabilitation services, and the like, or it might also incorporate figures for pain and suffering, productivity losses, losses of community services, and other "indirect" costs.

It is important to note at the outset that virtually all of the scales reviewed were intuitively based, i.e., they were <u>not</u> calibrated from actual data on injuries and their consequences. As such, their greatest usefulness to the project was in terms of suggesting potential variables for inclusion in a given scale. Another observation about these scales is that they were predominantly directed at assessing overall injury severity, health status, etc., rather than predicting a specific aspect of societal consequences such as medical costs. In these two respects--a basis in actual data and the prediction of specific societal consequences--the scales that are proposed in the current project differ substantially from those found in existing injury scaling literature.

The following discussion highlighting the literature review illustrates the diversity in past (and present) efforts to categorize the consequences of injuries. As a matter of convenience, work in the general area of injury scaling is discussed first, followed by disability measurement and finally cost measurement and cost-benefit analysis.

Injury

Two of the most widely used injury scales are the police or K, A, B, C, O scale (KABCO) and the Abbreviated Injury Scale (AIS). The KABCO scale was developed for use by non-medically trained police personnel and has the following five levels (as referenced in the Manual on Classification of Motor Vehicle Traffic Accidents, 1970, D16.1):

K = Fatal

A = Incapacitating injury which includes: Severe lacerations, broken or distorted limbs, skull fracture, crushed chest, internal injuries, unconscious when taken from scene; unable to leave scene without assistance.

B = Non-incapacitating evident injury which includes: Lump on head, abrasions, minor lacerations.

C = Possible injury which includes: Momentary unconsciousness, claim of injuries (not evident), limping, complaint of pain, nausea, hysteria.

O = No injury

Most state accident reporting systems have adhered to this system. A somewhat unique approach, however, has recently been taken by New York State, which in 1973 introduced an injury coding system not too dissimilar from the Occupant Injury Classification System (OIC) developed at HSRI. The New York State Traffic Records injury code is comprised of the following three parts (Spence, 1974):

a. Location of the most severe physical complaint (12 categories--head, face, eye, etc.)

b. Type of physical complaint (13 categories--amputation, concussion, internal, etc.)

c. Victim's status (6 categories--apparent death, unconsciousness, etc.)

Following its successful field testing the new injury code was incorporated into the 1975 revision of the state's accident report form.

Like the KABCO scale, the AIS has gained wide acceptance as a tool for classifying injuries resulting from motor vehicle accidents. The AIS was developed in 1969 by a joint committee of the AMA, SAE, and AAAM and was based on a scale already used by General Motors Corporation. The AIS as currently revised (1976) has the following levels:

0	No injury
1	Minor
2	Moderate
3	Severe (not life-threatening)
4	Serious (life-threatening, survival probable)
5	Critical (survival uncertain)
6	Maximum (currently untreatable)
9	Unknown

Shortly after the original AIS scale was published in 1971, the AMA developed the more detailed and objective Comprehensive Injury Scale, or CIS (Committee on Medical Aspects of Automotive Safety, 1972). The CIS rates injuries in terms of the amount of energy dissipated, the threat-to-life, the amount of permanent impairment, the length of treatment period, and the frequency with which the injury occurs.

As noted earlier, a large number of injury scales have been developed in addition to the KABCO and AIS scales. One of the most promising of these is the Injury Severity Score (ISS) proposed by Baker, O'Neill, Haddon and Long (1974). The ISS is defined as the sum of the squares of the highest AIS grades in each of the three most severely injured areas. By taking into consideration the combined effects of multiple injuries, the ISS was found to dramatically improve on the AIS level for the most severe injury only, in terms of predicting mortality (i.e., threat-to-life). Also in this study, the importance of controlling for the patient's age was clearly demonstrated.

Subsequent research on the ISS has substantiated these claims. Bull (1975) assigned ISS ratings to 1,333 in-patients and found: 1) a positive relationship to mortality, with greater mortality with increasing age; 2) a barely significant relationship of ISS to time of death, again with an age effect; 3) a generally positive relationship with length of in-patient treatment time, though with a high degree of scatter; and 4) some ability to differentiate grades of disability, particularly between very severe, severe, and the remaining categories, using the ISS.

In a similar investigation of the ISS using data from the Illinois Trauma Registry, Semmlow and Cone (1976) reported rapidly increasing mortality rates after ISS scores of 25, and a general linear relationship of ISS to length of hospital stay and to percent of patients requiring surgical procedures. Finally, in an update article, Baker and O'Neill (1976) summarize some of this and other recent research confirming the validity of the ISS. They caution, however, that while the scale may be useful in overall evaluation, it should not be used for individual prognosis.

Another injury scale which has been shown to reliably predict death and/or length of hospital stay is the Trauma Index (TI), developed by Kirkpatrick and Youmans (1971) as a tool for classifying trauma patients and grading the severity of their injuries. The index rates trauma victims according to the region of the body injured, type of injury, cardiovascular status, central nervous system status and respiratory status. Thus, unlike the AIS and ISS, the TI does require some bodily function measurements to be taken by trained medical personnel. In evaluating the TI, Kirkpatrick and Youmans found an overall error rate of only three percent, but still cautioned that, while useful for initial assessment and routing of patients, the instrument was not sensitive enough to be used as a diagnostic tool.

The Cumulative Illness Rating Scale (CIRS) introduced by Linn, et al., at the Veteran's Administration Hospital in Coral Gables, Florida, goes beyond the TI in requiring that a licensed physician make the pertinent medical judgments. This scale, which is described in Linn, Linn and Gurel (1968) involves assigning a score from '0' (representing no impairment) to '4' (representing life-threatening impairment) to 13 different organ areas of the body. The authors found a high degree of consistency in the use of the CIRS by six raters, and cited other studies where CIRS scores had been found to correlate at better-than-chance levels with death, vital organ involvement, and number of previous illnesses.

There have been other scales developed for the purpose of describing injuries and their consequences. One of these, the OIC, has already been referenced. This scale essentially combines AIS severity ratings with a system of coding an injury according to body region, aspect, lesion type and system/organ involvement. Having both injury location and severity information has made the OIC a popular scale for use in the multidisciplinary accident investigation (MDAI) programs. Less familiar injury scales include an anatomical injury scale for multiple trauma victims developed by Champion, Sacco, Ashman, Long and Gill (1975), and a new approach to evaluating multiple head injuries proposed by Stalnaker, Mohan and Melvin (1975).

Finally, two very fine review articles comparing a number of the injury indices described above have been prepared by Krischer (1976) and Gibson (1976). The first of these examines six severity indexes (CIRS, AIS, CIS, ISS, TI and Multiattribute Severity Scale) in terms of their ability to satisfy the underlying properties of the class of additive value functions to which they belong. Gibson, on the other hand, reviews 17 injury severity indices according to the five criteria he deems essential for injury scaling, namely reliability, validity, data accessibility, parsimonious generalizability, and mathematical consistency.

In way of summary, the scales reviewed in this section represent a wide range of efforts to categorize and predict injury severity. They differ greatly in their level of objectivity, the amount of medical expertise required, and the extent to which they have been tested for reliability and validity. The more recent pattern in scale development is to first formulate an injury scale on the basis of medical judgment, intuition, etc., and then to test the extent to which the scale correlates with mortality (i.e., threat-to-life). In contrast, the objective of the current research project is to use actual injury data as the starting point for scale development.

Disability

Disability is clearly related to injury severity. However, the relationship is far from simple, as evidenced by the fact that what is severely disabling to one person may have few, if any, adverse effects on another (see, for example, Haber, 1969). Again, the problem is primarily one of definition. How one chooses to define disability, in turn, affects the choice of criteria for evaluating the extent of impairment.

As a starting point, Greenberg (1972) notes that the ANSI Standard Z16.1 describes degrees of disability in terms of causing a fatality, a permanent total disability (PT), a permanent partial disability (PP), or a temporary total disability (TT). In contrast, the AMA guides express disability as a percent loss of normal function of a specific body part. Various agencies such as the VA, the American Academy of Orthopedic Surgeons, and the Workmen's Compensation Board have established their own renditions of these basic guidelines.

The 1966 "Social Security Survey of the Disabled" defined disability as "limitation in work due to impairment or chronic health condition, extending for more than six months" (Haber, 1967). However, the survey revealed that disability is related to the extent of functional limitations as well as personal and environmental factors such as age, sex, type of work, or socio-economic status. The functional limitations examined were activity limitations, personal care restrictions, mobility restrictions, use of orthopedic aids, and sensory limitations. Of these five, severity of disability was found to have the highest correlation with activity limitation and the lowest with use of orthopedic aids. Haber concluded that functional limitations should be a primary consideration in the evaluation of disability.

Perhaps one of the best examples of a functional-oriented disability scale is the Sickness Impact Profile (Gibson, Gibson and Bergner, 1975, as referenced in Bergner et al., 1976). The SIP is an interviewer-administered measure of health status that asks the subject to identify those items from a list of 235 that accurately describe himself. The items are grouped into 14 types of activity or areas of living where dysfunctional behavior can occur. Examples of test items include, "I sit down, lie down, or get up only with someone's help" (Movement of body) and "I dress myself, but do so very slowly" (Personal hygiene).

Others in the health field apparently share the view that functional limitations are an important aspect of disability measurement. Grogono (1973) described five of the most commonly used health (disability) scales. These were 1) Fanshel's 11 dysfunction states--well-being, dissatisfaction, discomfort, minor disability, major disability, disabled, confined, bedridden, isolated, coma, and death; 2) Grogono and Woodgate's 6-point ratings for work, recreation, pain, worry, communication, sleep, dependency on others, excretion, and sex; 3) Maddox's scores for physical health, mental health, social resources, economic resources, and capacity for carrying out daily living activities; 4) Wasser and Watt's 8-point scale for disability combined with a 4-point scale for distress; and 5) Chiang and Cohen's continuum of health from well-being to extreme illness. Another scale which might be added to this list is the "functional life scale" (Sarno, Sarno, and Levita, 1973), whose 44 items sample five different types of activities--cognition, daily living, home, outside, and social interaction.

Thus, it appears that disability is a complex phenomenon requiring a variety of measures for its appropriate assessment. This, indeed, was the conclusion of Gallin and Given (1976), who examined four basic approaches to evaluating the severity of disability. These were a restricted activity approach emphasizing such factors as days lost from work or days of bed confinement on a relatively short-term basis; an activity limitation approach describing levels of ability to perform one's normal daily activities over a longer time span; a classification system based on functional capacity limitations (ability to move about, perform self-care activities, etc); and also a multidimensional classification system incorporating a variety of disability criteria. The authors recommend that the multidimensional classification system be used because it combines social and medical measures in explaining the interactive processes of disability and disease. Back in 1973 Akpom had come to a similar conclusion. He recommended that disability classification systems include information on the patients' demographic and socio-economic characteristics, their physical and mental functioning status, and also their medical status (diagnosis, impairments, risk factors, etc.).

In evaluating a disability scale, Gibson's (1976) five criteria for injury scaling listed earlier would be expected to apply here as well. In addition, Fanshel (1972) has discussed his own criteria for a reasonable health scale. These are that the scale be operational, feasible, comprehensive, responsive, discriminant, specific, and, of course, reliable and valid.

Overall, these and other studies on disability evaluation have brought into sharp focus the need for considering a broad range of factors in assessing the extent of disability. The studies cited here have been primarily directed at the disabling effects of chronic diseases. However, one would expect that the disabling effects of injuries, such as those that might result from automobile accidents, could be assessed using similar outcome measures.

Injury Costs and Cost-Benefit Analysis

If there is some disagreement as to the proper approach to measuring disability, there is even greater discord regarding injury costs. The differences stem not only from the particular cost components selected, but also from the data used in estimating these costs and the specific methodological procedures adopted. Generally, the direct costs of injuries, such as property damage losses, medical costs and income losses are easier to measure than such indirect costs as loss in productivity, insurance and legal costs, community service losses, pain and suffering, and the like. Even if one restricts one's cost measures to direct costs, however, one must ultimately face the problem of placing a dollar value on human life.

Much of the initial work in estimating the societal costs of injuries was carried out by Rice at the National Center for Health Statistics. Her 1966 report presents a detailed description of the economic concepts employed, the methodological problems encountered, and the estimating procedures followed in her use of some 1963 data for estimating the direct and indirect costs of illness as well as the cost of mortality. Rice and Cooper (1967) estimate the economic value of human life in terms of lifetime earnings for various age, sex, race, and educational groups. In doing so, they are able to account for the varying life expectancies for the different groups, varying labor force participation rates, and the constant changing pattern of earnings at successive ages.

In a 1968 report, Rice lists the various components of direct and indirect injury costs, and emphasizes that, here again, age and sex need to be adjusted for because productivity (the major component under indirect costs of illness) varies by age and sex groups. Finally, a 1969 report (also by Rice) compares the direct and indirect costs for several major groups of illnesses. Among the findings reported here were that the overall societal costs for deaths due to injuries fall below those for deaths from circulatory disease, neoplasms, and diseases of the nervous system.

In a more recent study and one directed specifically at the consequences of injuries resulting from motor vehicle accidents, Flora, Bailey and O'Day (1975) relied on findings from personal interviews of a small sample of occupants in motor vehicle accidents for estimating direct injury costs associated with various AIS levels. The particular cost components incorporated in their measure were medical costs (ambulance service, hospitalization, physician, ancillary services, drugs, and special equipment), wage loss, property damage loss, incidental costs (substituted transportation, extra child care, etc.), sick leave pay, and insurance payments. Their results showed that cost increased progressively as AIS level increased from one to three. (Higher level AIS injuries were not included in the sample.)

For the "average" injury resulting from a motor vehicle accident, NHTSA (1972) has computed a total cost of $7,300. For fatalities, this figure was in the $200,000 range, while for property damage only cases, the loss averaged $300. The specific cost components estimated in these analyses were property damage, medical costs, productivity losses, insurance administration, losses to other individuals, employer losses, funeral costs, community services losses, pain and suffering, and other miscellaneous cost items.

The cost analyses described above are all examples of the human capital approach to estimating societal costs of injury and disease. Such an approach measures the cost of a disease by summing up various financial and nonmonetary costs. An alternative approach is based on "willingness to pay." This model treats health as a consumption goal and measures the costs of disease by how much people are willing to pay to avoid it. Keeler (1970) discusses both of these models of disease costs, the assumptions involved, and their particular strengths and weaknesses. He notes that until reliable consumer tradeoffs are discovered, we will have to continue to use the human capital model, even though it does not deal adequately with such personal costs as pain and anxiety. Other alternatives to the human capital model are discussed by Acton (1976).

Regarding the use of societal costs of motor vehicle accidents for cost-benefit analysis, Faigin (1975) emphasizes the fact that costs have been computed differently by various investigators, and cites as an example the NHTSA figures for a fatality which are much higher than those derived by the National Safety Council. She suggests that other criteria in addition to cost-benefit be used in evaluating highway safety standards or programs--criteria such as lives saved, injuries reduced, duration of benefits, and various social or political outcomes.

Along this same line, O'Neill and Kelly (1974) have concluded that programs such as the highway safety standards which are directed at saving lives and reducing injuries are _not_ amenable to cost-benefit analysis simply because their benefits can not be adequately expressed in monetary units. They note, however, that one can conduct a _cost-effectiveness_ analysis comparing the costs of alternative programs for effectively achieving a set goal (see also Morganstein, 1975).

Working on the opposite (and more commonly accepted) assumption that cost-benefit analysis can be used for evaluating highway safety programs, Joksch (1975) outlines the problems associated with quantifying economic and non-economic costs and benefits, and elaborates on the concepts underlying the two methods (i.e., cost-benefit ratios and net present value) for comparing program effectiveness. Also in the area of cost-benefit analysis, Williams (1974) has outlined some of the other assumptions behind a cost-benefit analysis to health services and has presented guidelines for deciding whether or not, in light of the expenses involved, a cost-benefit study is warranted.

To summarize, the literature suggests that the greatest problem in estimating the societal costs of injury and disease lies not in determining what variables should be included in a cost model, but in assigning monetary values to these variables. This is true not only for estimating pain and suffering, anxiety, and other indirect effects of illness, but also such direct costs as medical costs, death costs, etc. Most studies in this area have restricted themselves to the more easily measured direct costs, but even here there is still considerable disagreement.

The literature review highlighted in this section provided the necessary background for the data search and injury modeling to follow. It brought us up to date on the more recent developments in the field, suggested variables that should be included in the modeling, and even led to an eventual data source (the Illinois Trauma Registry). As the following chapter will reiterate, however, knowing what variables should be included in a threat-to-life, disability, or cost model is of limited value if appropriate data sources can not be located.

II. DATA FOR INJURY SCALING RESEARCH

Introduction

Extensive efforts were made to locate and review potentially useful data files for calibrating the proposed injury, disability and cost scales. As noted in Chapter I, the key variables of interest here were those describing the accident victim (age, sex, occupation, etc.), the type of accident (traffic, work, etc.), the precise nature of the injury (using ICDA, OIC, AIS or other codes), the associated disability components (lost workdays, days of restricted activity, etc.), and the various cost components (physician, hospital, insurance, etc.).

It was anticipated from the outset that several different data files would need to be accessed since no single file would likely contain all or even the majority of the necessary data items. However, after communicating with dozens of individuals and organizations across the country and following up on numerous leads and suggestions, it became apparent that no completely satisfactory data file would be found for calibrating even one of the three proposed scales.

By the conclusion of the data search, four data files had been obtained for use in the project. These were 1) the Illinois Trauma Registry (for the threat-to-life modeling); 2) the North Carolina Medical Examiner's file (to supplement the Illinois data); 3) the North Carolina Workmen's Compensation data (for the disability and likewise the cost modeling); and 4) the Yale Trauma File (which unfortunately did not prove useful). In addition to these sources, a decision was made to use a data file already available from Blue Cross Blue Shield (BCBS) of North Carolina for deriving estimates of direct medical costs of injuries. As might be expected, the data used in calibrating the threat-to-life model were generally felt to be the most adequate, while those used in the cost modeling were deemed the least satisfactory.

This chapter presents a brief overview of the generally discouraging and yet informative data search that was carried out. Also included are more detailed descriptions of the data files that form the basis for the model development in Chapters III, IV and V.

The Data Search

In attempting to locate and review potentially useful data files, a variety of sources were contacted. These included individuals experienced in the field, various private organizations, hospital and related sources, federal and state agencies, and insurance organizations. Most of the contacts were made by phone, and, depending on the response, a follow-up letter was sent that further described the goals of the project and its specific data requirements. Appendix B contains a listing of virtually all of the contacts made.

As a start, the National Emergency Medical Services Evaluation Symposium, which was held in New Orleans on January 11-13, 1977, afforded a unique opportunity for learning first-hand about the kinds of data that might be available to the project.

However, while participants were quite helpful in terms of suggesting possible data sources and other leads, they generally were not optimistic about the chances of locating adequate data, particularly for the proposed cost modeling. Two files were suggested at this time. One of these, the Yale Trauma File, was accessed but, as noted earlier, was not found useful to the project largely due to sample size and injury description limitations. The other file suggested was the Florida Trauma Registry. However, after receiving documentation on the file and examining more closely the data elements available, HSRC decided not to pursue this potential source of threat-to-life data.

One of the many data contacts suggested by the EMS Symposium participants was Ms. Susan Baker with the Office of the Chief Medical Examiner in Baltimore, Maryland. Ms. Baker, who was instrumental in the development of the ISS described in Chapter I, volunteered the use of some of her data for the project. These data were not accessed primarily because they had been collected in the late 1960's. However, the project has utilized Ms. Baker's ICDA/AIS conversion scheme in both the threat-to-life and cost modeling.

The first file to be accessed and used in the project resulted directly from the literature search. This was the Illinois Trauma Registry, used by Semmlow and Cone (1976) to validate the relationship between ISS scores and mortality. HSRC contacted Dr. Semmlow and was referred to the Illinois Department of Public Health for obtaining a copy of the file. Additional information on the file came from Professors Gelfand and Mueller at the University of Illinois working on an HEW grant directed at evaluating the data.

HSRC had originally anticipated that data for calibrating a threat-to-life scale and possibly a cost scale might derive from hospital in-patient and out-patient records, supplemented with data from a Medical Examiner's Office for those victims dying before reaching a treatment facility. One of the first contacts made along this line was with the Professional Activities Services (PAS) in Ann Arbor, Michigan, which contracts with hospitals across the country to process and maintain their in-patient records systems. PAS does not routinely collect cost information, but there is detailed injury and treatment information. In addition, hospitals have the option of submitting an overall cost figure for each case.

The possibility of obtaining data directly from PAS was precluded by time and administrative constraints, but HSRC was given a listing of over 100 hospitals in North Carolina using the system. Since a good source of threat-to-life data had already been located in the Illinois file, HSRC was most interested in the possibility of obtaining hospital PAS records that could be linked with in-patient billing records, as well as some out-patient treatment and billing records. Several hospitals were contacted, but all responses indicated either that their records were not all computerized or that linking the computerized treatment and cost files was not possible.

Two other promising hospital-type sources contacted were Humana, Inc. in Louisville, Kentucky, and the Kaiser Permanente Medical Care Program operating in the Portland, Oregon region. Humana owns and operates 62 hospitals in the U.S. and is presently planning a medical records system that would satisfy most of the data requirements for this project. The Kaiser Health Plan, on the other hand, already has available a wealth of computerized information on both in-patient and out-patient members of the program, although there is no cost data. While a promising source of both injury and disability information, documentation on this latter source arrived too late to be of much use in this project.

In addition to the various private contacts made and the hospital and related sources investigated, HSRC contacted numerous Federal and local government agencies in search of appropriate data files. These included such agencies as the Consumer Product Safety Commission, the Social Security Administration, the National Center for Health Statistics, the Veteran's Administration, the North Carolina Department of Human Resources and the North Carolina Automobile Insurance Rating Bureau.

None of the Federal organizations was able to furnish data of the kind and detail needed for this project. At the state level, however, HSRC located a valuable source of both disability and cost data in the computerized records maintained by the Workmen's Compensation Division of the North Carolina Industrial Commission.

The final category of sources investigated were insurance-related, and included several of the large insurance companies, the National Association of Independent Insurers, the National Council on Compensation Insurance, and other such organizations across the country. While most of these had some computerized information on injuries and their associated costs, the data were generally not detailed enough to be useful to the project. There was also some concern expressed for the confidentiality of the data. These responses generally confirmed HSRC's earlier expectations that more detailed cost data would have to be derived from the Blue Cross Blue Shield data file already accessed for an earlier HSRC project for NHTSA.

As noted earlier, none of the data sources located for use in this Injury Scaling Research project was entirely satisfactory. Nevertheless, the sources have served as starting points for developing improved threat-to-life, disability, and cost scales based on actual data rather than on "expert judgement" or "intuition". The following section describes in greater detail each of the four data files that form the basis for the modeling presented in Chapters III, IV and V.

Data Bases Utilized in the Injury Scaling Research

Described below are the Illinois Trauma Registry, the N.C. Medical Examiner's file, the N.C. Workmen's Compensation data, and the data from Blue Cross Blue Shield of North Carolina. The Illinois and N.C. Medical Examiner's files were both utilized in the threat-to-life modeling, the Workmen's Compensation file in the disability and cost modeling, and the BCBS insurance file for the major portion of the cost modeling. Data contents for each of the files are given in Appendix C.

Several of the data files required considerable pre-processing before they could be used in the analysis. This pre-processing is detailed in the appropriate threat-to-life, disability, and cost modeling chapters. The discussion here focuses on a more general overview of each of the data sources -- the data base, method of data collection, type of data collected, etc.

The Illinois Trauma Registry and N.C. Medical Examiner's File

The Illinois Trauma Registry is a computerized information system that has played a central role in the Illinois Statewide Trauma Program. The Trauma Program is based on the concept of developing specific treatment centers for the care of the critically injured, and has two major goals: 1) Upgrading transportation and emergency medical capabilities in communities with substandard resources, and 2) developing a comprehensive, uniform, simple, practical and workable communications capability (Boyd, 1973).

In order to accomplish these goals, the Trauma Registry was initiated in July of 1971, with five treatment centers in the Cook County area participating at the outset. Information for the registry was entered onto computer card "worksheets" by trained personnel who directly interviewed patients and other observers and also searched hospital charts, police records and other relevant documents (Boyd, Rappaport, Marbarger, Baker, Nyhus, 1976). Up to 16 cards were submitted for each case, giving information on epidemiological factors and the extent of anatomical damage as well as surgical and non-operative treatment employed and specific complications encountered.

By the end of the first year, some 20 treatment centers had provided data on 12,000 trauma victims, and by the time computerization of the data was halted in July of 1973, 39 treatment centers were involved in the program and approximately 33,000 cases had been entered in the registry. Moreover, the treatment centers were located across the state with a distribution approximately as follows: Southern Illinois Area (8 percent), St. Louis Area (15 percent), Champaigne Area (12 percent), Springfield Area (15 percent), Chicago Area (27 percent), Peoria Area (16 percent), and Rockford Area (7 percent).

The tape received by HSRC for Injury Scaling Research was essentially a copy of this complete trauma file, dating from July 1, 1971 to June 30, 1973. The variables of greatest interest were those describing the nature of the injury or injuries using ICDA codes, number of complications, victim's age and sex, and of course, survival status. Unfortunately, HSRC found that detailed injury and treatment information was missing for all but a few of those cases that died at the scene of the accident or enroute to the treatment center. This made it necessary to locate a second data source to supplement the Illinois data, one that had similarly detailed information for a fairly large number of fatal accident or trauma victims.

Such a file was found in the computerized records maintained by the North Carolina State Medical Examiner's Office. This office investigates virtually all accidental or violent deaths in the state, approximately one-fifth of which are motor vehicle-related. The file that HSRC received contained data on approximately 39,000 cases for the years 1972 through 1975. A large percentage of these cases, however, contained no injury information, so that the final working file was based on approximately 14,000 cases. Variables on the file included the victim's age and sex, time of injury, time of death, place of death (home, hospital, street or highway, etc.), and manner of death (natural, homicide, accident, etc.), with ICDA and AIS codes for up to five injuries. Thus, this file was able to provide injury information on a fairly large number of fatal cases to supplement the Illinois data.

N.C. Workmen's Compensation Data

The N.C. Workmen's Compensation File (WCF) is based on data collected and processed by the N.C. Industrial Commission. When a work-related injury occurs in the state, the employer is required by law to report this injury to the insurance carrier or directly to the Commission. The standard form used is a First Report of Injury Form (usually a Form 19). There is also a Form 51 which may be used in cases where all of the following conditions are satisfied: the injured employee is not absent from work for more than one working day as a result of the injury, the total medical expense does not exceed $100 and is in compliance with set medical fee standards, and there is no indication of any permanent disability or disfigurement. During fiscal year 1975-76, 66,604 cases were reported on the standard form, while 126,064 medical only cases were reported on Form 51.

Since September 1975, the Industrial Commission has utilized an on-line computer system for processing claims and for storing information. Claims submitted on a standard First Report of Injury Form are entered into the terminal daily; however, relevant information on the nature of the injury and its consequences is not entered until all of the necessary forms have been received and the case is closed. Due to the minor nature of the injuries involved, cases that are reported on a form 51 are not processed by the computer. The Commission keeps a tally of the total number of such cases and their total medical costs, but the cases are not further classified.

The tape that HSRC received from the Industrial Commission contained information on 118,500 cases submitted on a First Report of Injury Form from September, 1975 through mid-May, 1977. Of these, some 77,000 had been closed. The additional information that was made available for these 77,000 cases included the age and sex of victim, date of injury, nature of injury (amputation, contusion, etc.), accident type, part of body injured, number of lost workdays, total medical expenses paid and compensation awarded. Having the above mentioned information made the file useful for both the disability and cost modeling.

N.C. Blue Cross Blue Shield Data

Blue Cross Blue Shield of North Carolina provides medical insurance coverage for approximately 35 percent of the state's population, with roughly 75 percent of this coverage coming through employer groups. Data from the Plan had been made available to HSRC during the fall of 1975 in conjunction with the Restraint Systems Effectiveness Project (DOT-HS-5-01255). The data tape that was received at that time consisted of approximately 680,000 accident-related claims records with the following items of information:

- Patient identification number
- Type of services (hospital in-patient, hospital out-patient, professional surgery or professional medical)
- Year of birth
- Sex and relationship to insurance policy holder (male subscriber, female spouse of subscriber, etc.)
- Days of hospital care paid
- Beginning date of service
- Ending date of service
- Total charge
- Treatment type (surgery, anesthesia, diagnostic, x-ray, etc.)
- Diagnosis (ICDA or professional procedure code)
- Type of record (hospital or professional services)

As several claims may be submitted for a given accident case, a necessary first step in processing this data was to group together claims relating to a single accident to form a case-oriented file. This procedure is detailed in Chapter V. The end result generated about 317,000 case-oriented records, broken down approximately as follows: 22,200 hospital in-patient cases, 93,000 doctor's office cases, and 202,000 emergency room cases. For those admitted to the hospital, ICDA codes are given for the injury diagnosis. For out-patients, professional procedure codes are given, but there is no injury diagnosis for those treated in the emergency room. By combining the costs on the individual claims records, a total cost figure could be computed for each injury case and added to the file.

These, then, were the data files available for injury scaling research. Their use in developing threat-to-life, disability and cost scales is detailed in the following three chapters.

III. THREAT-TO-LIFE SCALES

Introduction

Since injuries such as might be sustained in an automobile accident sometimes result in loss of life, the idea of developing a threat-to-life scale which assigns to each injury or combination of injuries a number representing the likelihood that that injury (or injuries) will result in the death of the individual, seems quite reasonable. The form of the development of such a scale, however, should depend to some extent on the potential uses of the scale.

Two different types of uses come immediately to mind. In the first of these, the threat-to-life scale is used primarily as a transformation applied to injury data such as might be collected in accident investigations. For an individual with some injury (or combination of injuries), say I_j, the transformation would assign this individual some numerical value p_j which represents our best estimate of the probability that the individual will die from injury I_j. From a collection of data of this type, the transformation (or application of the injury scale) will result in estimates of the total fatalities resulting from the collection of specific injuries in the data set. If follow-up information is available then no such transformation is necessary, since in that case the number of fatalities is known and does not need to be estimated. It should also be noted that if the injured person is killed instantly or is dead at the time the injury information is recorded, then again the outcome is not in doubt and he should be assigned a scale value $p = 1$ regardless of the specific nature of his injuries. Thus, scale values $p < 1$ represent conditional probabilities, conditional on the individual being alive at the time the injury information is recorded.

For the second type of application it is necessary to obtain estimates of the unconditional (in the sense of not distinguishing whether or not death results instantly from the injury or at some later time) probabilities of death from each specific type of injury. The threat-to-life scale in this case would consist of the collection of unconditional probabilities corresponding to certain classes of injuries. A scale of this type could be used to identify injuries that are especially life threatening, so that possible countermeasures could be developed to prevent or reduce the number of these injuries.

It was toward the development of this second type of threat-to-life scale that our primary efforts were directed. This, in turn, dictated what our data needs would be. Thus, for example, hospital in-patient data would not meet our needs since not only would the very minor injuries (for which the victim would probably not be hospitalized) be missing, but quite likely many of the most serious injuries, which often would result in the individual dying before being admitted to the hospital, would also be missing. The use of this type of data would result in overestimating the severity of the more minor injuries and underestimating the severity of the more major injuries or groups of injuries.

Data Base

Of the possible data sources that were available to HSRC, the Illinois Trauma Registry data seemed to be the most appropriate for the development of threat-to-life scales as described above. As described in Chapter II, the registry contains data collected from a number of trauma centers located throughout the state. The data contains detailed information on the nature of the injuries to each patient in the form of ICDA codes, for up to twelve injuries ordered by decreasing severity. In addition to the injury data, demographic information concerning the individual's age, sex, race, occupation, and education is included, as is information concerning the date and time of injury, the time and distance to the initial care facility, the time in the emergency care unit, detailed information concerning various surgical and other procedures he received, and a variable indicating survival status. A detailed description of the Illinois Trauma Registry is given in Boyd, Lowe, Baker, and Nyhus (1973); a complete description of the data extracted for the present study is included in Appendix C. The survival variable was coded at seven levels as follows:

1. Survived, present admission
2. Death within 1 hour of admission
3. Death between 1 and 6 hours of admission
4. Death between 6 and 24 hours of admission

5. Death after 24 hours of admission
6. Dead at scene (DAS)
7. Dead on arrival (DOA)

with a separate category for not stated.

Since no follow-up information was available, an individual was assumed to have survived the injury if his survival variable was coded as a "1" and a discharge date was present on his record.

Of the 32,802 cases on the file, 2,362 were non-survivors, and a separate "Fatal" file containing only these cases was set up, so that the injury patterns leading to fatalities could be examined in detail. One of the initial examinations of this file revealed information shown in Table 3.1. This table shows the number of injuries coded on the file as a function of the survival variable (with, of course, the survivors omitted). Of particular interest was the fact that for those cases that were dead at accident (survival code = 6), 92 percent had no injury information on the record, and for those dead on arrival (survival code 7), 63 percent had no injury information. For cases with survival codes 2-5, the number of injuries coded on the file tended to increase with increasing survival time. To further investigate the dead-at-accident cases, a table was generated showing the number of injuries coded by the accident type for these cases. From Table 3.2 it can be seen that 726 out of the 733 dead-at-accident cases with no injury information were involved in motor vehicle accidents. This clearly indicated that additional information concerning the nature of the injuries to persons found dead-at-accident scenes (especially motor vehicle accidents), and found dead-on-arrival at emergency facilities, was needed.

A source of such information was obtained from the North Carolina State Medical Examiner's Office. That office maintains a computerized file containing data on all accidental and violent deaths in the state. The data file that was obtained contained approximately 39,000 cases and covered the years 1972-1975. This file contained injury information in the form of ICDA codes for 14,000 cases, along with many of the same demographic variables and variables describing the nature of the accident as the Illinois file. A complete listing of the data extracted from this file is also included in Appendix C.

Table 3.1 Number of injuries versus survival status for fatal cases.

urvival Status	Number of Injuries Coded 0	1	2	3	4	5	6	7	8	9	10	11	12	Total
< 1 hr.	88 (54.0)[1]	23 (14.1)	11 (6.7)	12 (7.4)	11 (6.7)	1 (0.6)	5 (3.1)	2 (1.2)	3 (1.8)	0 (0.0)	1 (0.6)	1 (0.6)	5 (3.1)	163
1-6 hr.	108 (52.2)	9 (4.3)	25 (12.1)	22 (10.6)	17 (8.2)	4 (1.9)	6 (2.9)	3 (1.4)	4 (1.9)	2 (1.0)	2 (1.0)	0 (0.0)	5 (2.4)	207
6-24 hr.	47 (38.2)	15 (12.2)	14 (11.4)	12 (9.8)	14 (11.4)	3 (2.4)	7 (5.7)	2 (1.6)	4 (8.3)	2 (1.6)	3 (2.4)	0 (0.0)	0 (0.0)	123
> 24 hr.	159 (24.8)	83 (12.9)	96 (15.0)	113 (17.6)	78 (12.1)	28 (4.4)	34 (5.3)	22 (3.4)	6 (0.9)	4 (0.6)	9 (1.4)	4 (0.6)	6 (0.9)	642
DAS	733 (92.1)	19 (2.4)	15 (1.9)	8 (1.0)	10 (1.3)	3 (0.4)	7 (0.9)	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	796
DOA	271 (62.9)	78 (18.1)	42 (9.7)	19 (4.4)	9 (2.1)	3 (0.7)	3 (0.7)	2 (0.5)	1 (0.2)	0 (0.0)	0 (0.0)	1 (0.2)	2 (0.5)	431

[1]Row percent.

Table 3.2 Number of injuries versus accident type for dead-at-accident cases.

Accident Type	Number of Injuries Coded 0	1	2	3	4	5	6	7	Row Total
Not Stated	3 (60.0)[1]	2 (40.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.6)
Motor Vehicle	726 (93.7)	13 (1.7)	12 (1.5)	5 (0.6)	9 (1.2)	3 (0.4)	6 (0.8)	1 (0.1)	775 (97.4)
Industrial or Farm	4 (80.0)	1 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.6)
Home or Recreation	0 (0.0)	1 (25.0)	2 (50.0)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.5)
Violence	0 (0.0)	2 (28.6)	1 (14.3)	3 (42.9)	0 (0.0)	0 (0.0)	1 (14.3)	0 (0.0)	7 (0.9)
Column Total	733 (92.1)	19 (2.4)	15 (1.9)	8 (1.0)	10 (1.3)	3 (0.4)	7 (0.9)	1 (0.1)	796 (100.0)

[1]Row percent.

Definition of Injury Variables

Several complete listings of the injury information (or diagnoses) from the Illinois Fatal file were made together with the values of certain other variables in order to try to identify certain patterns of injuries occurring among the non-survivors. Several facts could be seen from an examination of these listings. These included the following:

1. When more than two injuries were coded, each case was essentially unique. That is, there were no two cases on the file with exactly the same pattern of three or more injuries. (There were, of course, groups of cases when only a single injury was coded, and a few cases with exactly two matching injuries.)

2. Not infrequently the injury (ICDA code) listed first on the record appeared to be of a less severe nature than one listed later on the record. In particular, using a transformation from ICDA code to AIS obtained from Sue Baker, it was often the case that the first listed injury had a lower AIS severity than one listed later on.

3. Many records contained ICDA codes corresponding to medical conditions other than injury (e.g., heart conditions, etc.).

4. Age appeared to be an important factor. For example, ICDA code 820 (Fracture of upper end of femur) was one of the most frequent injuries listed (in the first position). In nearly every case, the corresponding age of the individual exceeded seventy years.

Discussions were held between HSRC project staff and Dr. John Feegel of the State Medical Examiner's Office concerning the most appropriate way to use the information on multiple injuries in developing a threat-to-life scale. A consensus of opinion from these meetings was that a certain amount of grouping could be done on the basis of the first listed injury (primary injury), and that certain general descriptor variables of the secondary injuries might be more useful than more specific injury information.

The first phase in grouping primary injuries was accomplished by generating a table of ICDA code (primary injury) by survival (coded as survived or not), using the complete Illinois file. Using the information from this table, groups of ICDA codes were formed when two conditions were met:

1. The individual ICDA codes within a group appeared to refer to injuries that were of a similar nature (e.g., fracture of some part of arm); and

2. The proportions of people who died did not differ significantly among the ICDA codes within the group, as tested by a χ^2-test.

This grouping resulted in a reduction from 180 different ICDA codes to 43 injury categories, shown in Table 3.3.

The general descriptor variables that were defined to describe the secondary injuries were:

1. Extent of injury	1 if 1 or 2 ICDA codes 2 if 3 or 4 ICDA codes 3 if 5 or more ICDA codes
2. Pre-existing condition	1 if ICDA code <800 present 0 otherwise
3. Severe secondary injury	1 if a secondary injury with an AIS $\geq$ the AIS of the primary injury is present 0 otherwise

In addition to the injury variables, there were other variables on the file which seemed potentially related to survival. As mentioned earlier, age was one such variable; others that were considered were sex, time to initial care, distance from initial care facility, and time in emergency service. Contingency tables of survival versus lack of these variables showed that only age was shown to be significantly related to survival. After examining several different age breakdowns, four age groupings were chosen: 0-20, 21-55, 56-70, 71 and over.

At this point the remaining tasks in the development of a threat-to-life scale were, first, to obtain a set of interactions between the primary injury categories, the three secondary injury variables, and age in as nearly an optimal manner as possible; and secondly, to obtain the best possible estimate of the proportion of fatalities corresponding to each such interaction.

The first task involved collapsing the 43 primary injury categories to some extent and then splitting the collapsed categories by some of the

Table 3.3 Injury categories for primary injuries.

ICDA Codes	Description
1. 800-801	Skull fractures
2. 802	Fracture of face bones
3. 803-804	Other unqualified skull fractures and head bones
4. 805	Fracture of spinal column without spinal cord lesion
5. 806	Fracture of spinal column with spinal cord lesion
6. 807, 808, 809	Fracture of ribs, sternum, pelvis, and other fractures of trunk
7. 810-812	Fracture of shoulder and upper arm
8. 813	Fracture of lower arm
9. 814-819	Fracture of wrist and hand
10. 820	Fracture of upper end of femur
11. 821	Other fractures of femur
12. 822-823	Fracture of lower leg
13. 824-827	Fractures of ankle and foot and multiple
14. 828-829	Multiple and unspecified fractures
15. 830-849	Sprains and dislocations
16. 850	Concussion
17. 851+854	Cerebral laceration and contusion and other intracranial injury
18. 852-853	Intracranial hemorrhage
19. 856, 857	Other head injury of unspecified nature
20. 860	Traumatic pneumothorax and hemothorax
21. 861-862	Injury to heart, lungs, other intrathoracic organs
22. 863	Injury to gastrointestinal tract
23. 864-865	Injury to liver and spleen
24. 866-868	Injury to kidney, pelvic organs, other intra-abdominal organs
25. 869	Multiple and unspecified internal injuries
26. 870-872	Eye and ear wounds
27. 873	Laceration of scalp and face
28. 874-875	Open wound of neck and chest
29. 876-886 888-895	Open wounds on other parts of body

Table 3.3 Continued.

	ICDA Codes	Description
30.	887, 896-897	Amputation of hand and arm, foot, leg
31.	898-907	Multiple open wounds of various body parts
32.	910-918	Superficial injuries
33.	920-928	Contusions
34.	929	Multiple contusions
35.	940-941	Burns of eye, head, neck
36.	942	Burns on trunk
37.	943-945	Burns on arms and legs
38.	946-947	Burns of head or trunk and limbs
39.	948-949	Multiple and unspecified burns
40.	950-957	Injuries to nerves
41.	958	Injury to spinal cord
42.	995	Early complications (includes shock)
43.	996	Other and unspecified

other variables. The second task involved the use of the information from the Medical Examiner's file to adjust the number of fatalities in certain of the injury categories to compensate for the missing data for the dead-on-arrival and dead-at-accident cases.

Injury Category Grouping and Adjustment

A computerized analytical procedure which performs analyses similar to those required for the two tasks described above was made available through the University of North Carolina Department of Biostatistics. This procedure called CHAID - Chi-squared Automatic Interaction Detection - takes as input the frequencies from a (K+1)-way contingency table formed by a criterion variable with two levels and K independent variables with $n_1, n_2 \ldots, n_K$ levels, respectively. For the present application, the criterion variable would be survival, and the independent variables would be primary injury category, the three secondary injury variables, and age. The program proceeds in a stepwise manner as follows. At the initial stage the data are combined into a single group with a proportion P_0 of cases falling into, say, the first level of the criterion variable and $(1 - P_0)$ of the cases falling into the second level. At the next stage, the group is split into S_1 subgroups defined in terms of the levels of the independent variable X_j, where $2 \leq S_1 \leq n_j$. The subgroups have proportions $P_{11}, P_{12}, \ldots, P_{1S_1}$ of cases falling into the first level of the criterion variable. The variable X_j and the number of subgroups are chosen in such a way as to maximize the significance of a χ^2 statistic for testing the equality of $P_{11}, \ldots, P_{1S_1}$. In subsequent stages each of the S_1 subgroups may, in turn, be further split according to the levels of the remaining independent variables. The procedure continues until either

1) No further significant splits are possible according to some prespecified significance level, or

2) Subgroup sizes reach some prespecified minimum number, or

3) A prespecified maximum number of steps is reached.

The output from CHAID is a set of subgroups defined by certain combinations of the levels of the independent variables. The proportion of cases in the two levels of the criterion variable will differ from subgroup to subgroup, where the subgroups are chosen in such a way that the statistical significance of these differences is maximized (at each stage). A complete description of CHAID can be found in Kass (1975).

A limitation of the CHAID program is that the number of levels of a variable cannot exceed nine. Thus, to use the program with respect to the threat-to-life scale development required that either several analyses be done, using only a part of the primary injury categories each time and then combining these analyses in some way, or that the 43 primary injury categories be further collapsed to 9 or fewer prior to the use of CHAID.

As a first step toward the latter approach, contingency tables of survival versus each of the three secondary injury variables and age were generated within each of the 43 primary injury categories to identify interactions between the injury categories and the other variables. Thus, for example, it was found that age was significantly related to survival for certain of the injury categories but not for others. The 43 injury categories were then ranked according to their fatality proportions (based on the unadjusted data) and grouped as shown in the first two columns of Table 3.4 Three criteria were used in forming the eight groups of Table 3.4. First, the fatality proportions were split up at what seemed to be natural break points. Secondly, χ^2 tests showed no significant differences between the fatality proportions within a group. And finally, interactions with the other variables were preserved in the sense that, if a given injury category had a significant interaction with one of the other variables, the group which included that variable also had a significant interaction with the same variable. For example, survival was significantly related to age within each of the three injury categories of group three as it was in the combined category.

Before inputting the grouped data to the CHAID program, the fatality frequencies needed to be adjusted to compensate for the missing data. Initially, as a check on the injury category grouping, the adjustment procedure was applied only to the original 43 categories.

The rationale behind the adjustment procedure is as follows. The Illinois data was virtually complete in the sense that only about 1 percent of the survivors had no injury information, so no adjustment was made to these frequencies.

Table 3.4 Grouping of injury categories from unadjusted data.

Primary Injury Category	Unadjusted Fatality Percentage	Group	Adjusted Fatality Percentage
25	59.99	8	85.45
3	52.94		82.73
18	47.61		68.79
14	39.99		71.43
21	28.92	7	69.50
42	24.59		33.30
17	21.44		41.63
1	20.95		34.40
39	13.28	6	27.92
41	12.90		30.77
23	12.90		24.58
34	12.63		21.16
5	12.04		29.54
20	8.87	5	23.53
24	8.27		24.22
10	8.22		12.34
31	6.25	4	26.23
43	5.69		50.17
30	5.26		10.00
22	5.23		8.12
36	5.05		7.84
6	4.18	3	8.66
38	3.87		6.06
11	2.74		4.23
28	1.86	2	10.68
27	1.73		3.20
4	1.45		4.92
7	1.17		1.89
33	1.17		2.93
32	1.07		2.13
16	.94	1	1.55
29	.59		1.79
S	.28		≈1.00

where S is a cluster of categories with very small frequencies and small fatality percentages. S contains categories 2, 8, 9, 12, 13, 15, 19, 26, 35, 37, 40.

Of those who died after having been admitted, 35.4 percent ($\approx$400)[1] had no injury information. From those cases with injury information, let n_j be the number of cases whose primary injury belongs to injury Category j for j = 1,2,...,43, and let $N = \sum_{j=1}^{43} n_j$. Thus,

$$p_j^{(1)} = \frac{n_j}{N}, \qquad j = 1,\ldots,43,$$

is the proportion of cases for which there is injury information falling into Category j, and

$$f_j^{(1)} = 400\ (p_j), \qquad j = 1,\ldots,43$$

is an estimate of the number of the missing cases that should have fallen into the j-th category.

For the dead-on arrival and dead-at-accident cases, 81.8 percent ($\approx$1000)[1] had missing injury information. Now, denote by m_j the combined frequency of dead-on-arrival or dead-at-accident cases from the Illinois file and dead-on-arrival or dead-on-street or highway[2] cases from the Medical Examiner's file, having primary injury in Category j, j = 1,...,43. Again let

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[1]The actual numbers of missing cases were 403 and 1004, but since there were some missing cases for survivors and since adjusted frequencies were rounded to the nearest whole number the approximate values 400 and 1000 were used.

[2]The N.C. Medical Examiner's data does not contain a code for dead-at-accident. Since nearly all of the Illinois dead-at-accident cases involved motor vehicle accidents, taking N.C. cases whose place of death was street or highway seemed to provide the most comparable data set.

$$M = \sum_{j=1}^{43} m_j \ ,$$

$$p_j^{(2)} = \frac{m_j}{M} \ , \quad \text{and}$$

$$f_j^{(2)} = (1000)p_j^{(2)} \ .$$

Thus, $f_j^{(2)}$ is an estimate of the missing dead-on-arrival or dead-at-accident cases which should have fallen into Category j, based upon the available data from the Illinois file and the Medical Examiner's data.

The unadjusted percentages $p_j^{(u)}$ given in the second column of Table 3.4 are of the form

$$p_j^{(u)} = \frac{f_j^{(d)}}{f_j^{(d)} + f_j^{(s)}} (100) \quad ,$$

where from the Illinois file there were $f_j^{(s)}$ cases with primary injury in Category j who survived, and $f_j^{(d)}$ cases who died. The third column of Table 3.4 gives adjusted percentages which are of the form,

$$p_j^{(a)} = \frac{f_j^{(d)} + f_j^{(1)} + f_j^{(2)}}{(f_j^{(d)} + f_j^{(1)} + f_j^{(2)}) + f_j^{(s)}} \quad (100) \quad .$$

If the type of injuries and the classifying of the injuries by ICDA codes were essentially the same in Illinois and North Carolina, the effect on the adjusted fatality percentages should be to increase the separation between them by increasing the percentages for the most severe injuries by a substantial amount, and by increasing the less severe ones very little. The ordering should remain essentially the same.

A comparison of the two columns of percentages of Table 3.4 reveals that, to some extent, this is, in fact, what happened. On the other hand, some re-ordering does occur, and the groups do not appear to be as optimally separated on the basis of the adjusted percentages as with the unadjusted ones. Of particular interest is the fact that the percentage for Category 43 increases from 5.69 percent to 50.17 percent. This category contains the single ICDA code 996 - other and unspecified injury, and seems to be an indication that this very general code is used more heavily in North Carolina than it was in the Illinois Trauma Registry.

Because of the reasons mentioned above, the injury categories were regrouped based on the adjusted fatality percentages. These new groups are given in Table 3.5. Since most of the groups shown there are somewhat similar to those based upon the unadjusted percentage, it was assumed that the interaction structure with the other variables would be preserved for the new groups, and hence, a new injury variable with nine levels corresponding to these groups was defined to be used in the CHAID analysis. A description of the nine primary injury groups is given in Table 3.6.

CHAID Analysis

The basic data input to CHAID consisted of the frequencies from a contingency table with 2 rows and 432 columns. The two rows corresponded to survival or death, and the 432 columns to all combinations of the 9 levels of the injury variable, 4 levels of age, 3 levels of the extent of injury variable, 2 levels of the pre-existing condition variable, and 2 levels of the severe secondary injury variable. All of the frequencies in the second row were adjusted by the same type of procedure as described earlier, except that in this case the subscript j ranges over the 432 interaction terms rather than the 43 injury categories.

The first step of the analysis resulted in the selection of the injury variable with all nine levels kept separate. Thus, the first split of the data was into the nine primary injury groups. The remaining steps further split some of these injury groups by various combinations of age and the secondary injury variables. A tree diagram showing how each of the primary injury groups was further split according to the other variables is shown in Figure 3.1. Fatality percentages are also given for each subgroup. A considerable amount of overlap in these percentages may be noted, indicating that some further collapsing or consolidating of subgroups may be possible.

Table 3.5 Grouping of injury categories using adjusted data.

Injury Category	Adjusted Fatality Percentage	
25	85.45	9
3	82.73	
14	71.43	
21	69.50	8
18	68.79	
43	50.17	7
17	41.63	6
1	34.40	5
42	33.30	
41	30.77	
5	29.54	
39	27.92	
31	26.23	4
23	24.58	
24	24.22	
20	23.53	
34	21.16	
10	12.34	3
28	10.68	
30	10.00	
6	8.66	
22	8.12	
36	7.84	
38	6.06	
4	4.92	2
11	4.23	
27	3.20	
33	2.93	
32	2.13	1
7	1.89	
29	1.79	
16	1.55	
S	*1.00	

where S is the same cluster of categories as in Table 3.4.

Table 3.6 Primary Injury Groups

I_9 -	Other unqualified skull fractures, multiple and unspecified fractures, multiple and unspecified internal injuries.
I_8 -	Intercranial hemorrhage; injury to heart, lungs, and other intra-thoracic organs.
I_7 -	Other and unspecified injury.
I_6 -	Cerebral laceration, contusion, and other intracranial injury.
I_5 -	Skull fractures, fracture of spinal column with spinal cord lesion, multiple and unspecified burns, injury to spinal cord, early complications (including shock).
I_4 -	Traumatic pneumothorax and hemothorax, injury to liver, spleen, kidney, other intra-abdominal or pelvic organs; multiple open wounds of various body parts; multiple contusions.
I_3 -	Fracture of upper end of femur, ribs, sternum, pelvis, other fractures of trunk; injury to gastrointestinal tract; open wound of neck or chest; amputation of hand, arm, foot or leg; burns on trunk or head and limbs.
I_2 -	Fracture of spinal column without spinal cord lesion, other fractures of femur, laceration of face and scalp, contusions.
I_1 -	Fracture of face bones, shoulder, arm, hand, lower leg, foot; sprains and dislocations; concussion; eye and ear wounds; other open wounds; burns on face, neck, arms, legs; superficial injuries; injury to nerves.

Figure 3.1 CHAID splits of injury groups.

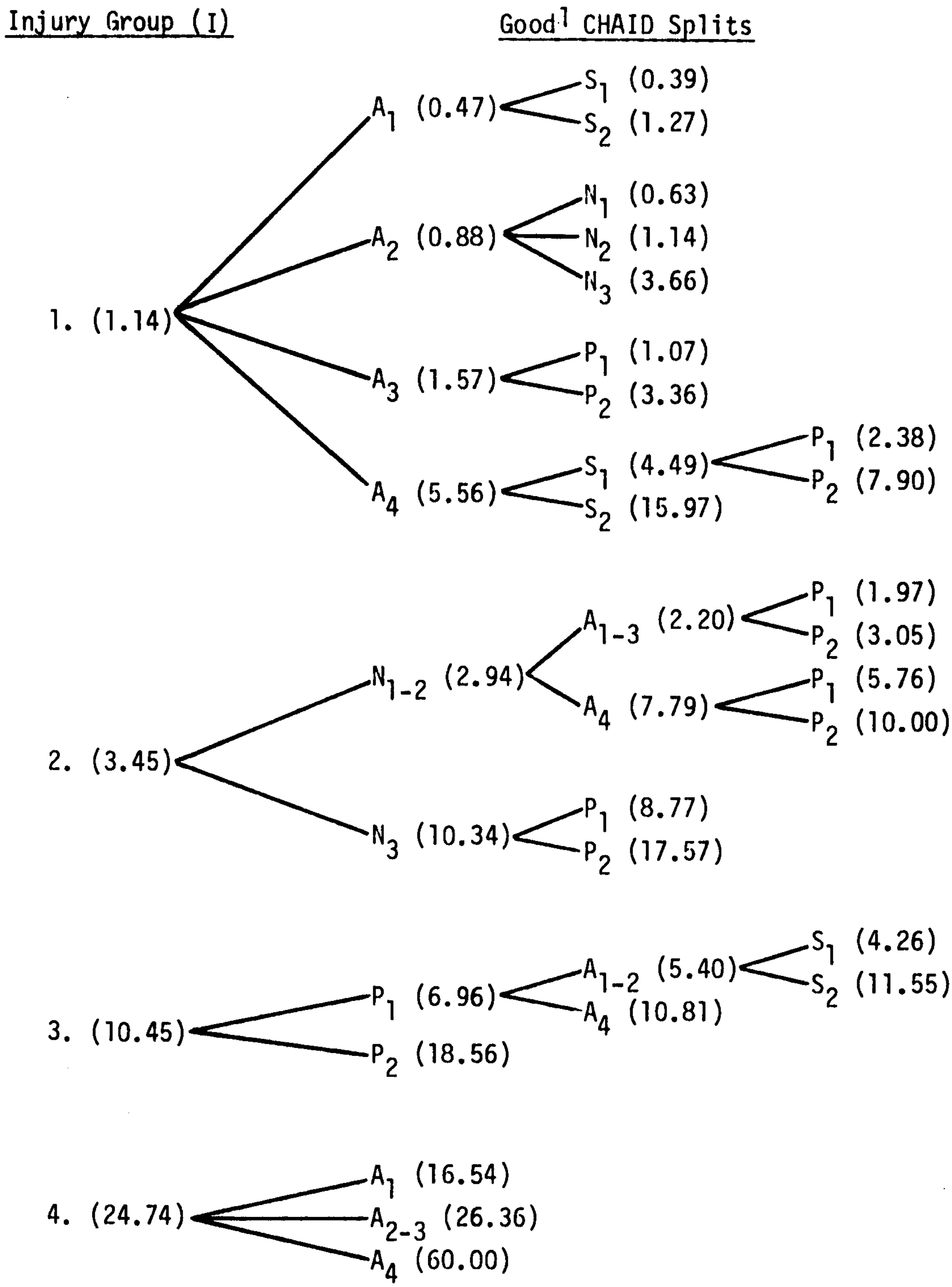
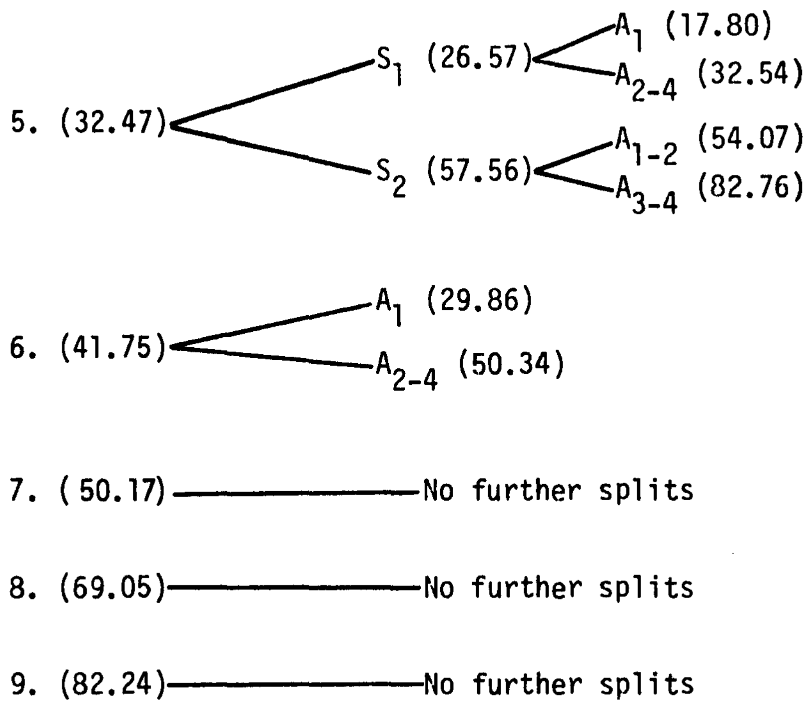


Figure 3.1. Continued.

<u>Injury Group (I)</u> <u>CHAID Splits</u>



<u>Key</u>: The letter A refers to the variable age, N to extent of injury, P to pre-existing condition, and S to severe secondary injury. The subscripts indicate the levels of the variable included in the group, (e.g., A_{1-3} indicates age levels 1 through 3).

Fatality percentages for each subgroup are given in parentheses.

[1]The allowable number of steps and group sizes input to CHAID were quite generous so that the procedure would stop by criterion #1. This resulted in some further splitting beyond that shown, but group sizes were too small to be considered to represent meaningful relationships. Furthermore, some of the more severe injury groups were split by the extent of injury variable in such a way that the greater the extent the lower the fatality proportion. While this does reflect the data in that survivors often have more diagnoses on their records than nonsurvivors, this does not seem to represent a meaningful relationship in the prospective sense.

An examination of the figure revealed that the primary injury groups were most frequently split by the age variables, and that the extent of injury variable was important for some groups. These two variables seem to be more usable than the other two in the sense that the presence of some pre-existing medical condition, in many cases, would probably not be known, and the severe secondary injury could result when two or more injuries were of equal severity or through a coding error (i.e., a lesser injury is coded first).

Thus, it seemed appropriate to further examine the splitting procedure to see to what degree age and extent could substitute for the other two variables. In particular, analyses were performed to test the significance of age and extent in groups which CHAID had split first on one of the other two variables, (e.g., Group 3). When either age or extent was found to be significant, the group was first split on one or both of these variables, and further testing was done to determine if the other variables (selected by CHAID) produced significant splits of the resulting subgroups. The results indicated that for all groups except Group 5, the other variables (selected by CHAID) were no longer significant after the groups were first split on age and/or extent. Severe secondary injury remained significant for Group 5. When CHAID indicated certain combinations of levels for age and extent, these same level combinations were used in the above analyses.

This breakdown of the nine injury groups, their frequencies, and fatality proportions are shown in Table 3.7. It was felt that this collection of subgroups formed a more useful basis for a threat-to-life scale than those coming directly from the CHAID analysis.

Final Clustering of Subgroups

The next step in the scale development was to combine the subgroups of Table 3.7 whose fatality proportions did not differ significantly. This was done by fitting a categorical linear model to the frequencies of Table 3.7, and then essentially "clustering" the model coefficients. This was done by reordering the subgroups of Table 3.7 so that the fatality proportions were in increasing order. Then a model was fit using an

Table 3.7 Injury subgroups based on age and extent of injury.

Subgroups				Freqencies Survived	Died	Fatality Proportions
1	I_1	A_1	N_1	5369	19	.0035
2	I_1	A_1	N_2	1022	8	.0077
3	I_1	A_1	N_3	238	4	.0165
4	I_1	A_2	N_1	5807	37	.0063
5	I_1	A_2	N_2	1478	17	.0113
6	I_1	A_2	N_3	369	14	.0365
7	I_1	A_3	N_1	1509	21	.0137
8	I_1	A_3	N_2	301	5	.0163
9	I_1	A_3	N_3	68	4	.0555
10	I_1	A_4	N_1	998	46	.0440
11	I_1	A_4	N_2	172	17	.0899
12	I_1	A_4	N_3	35	8	.1860
13	I_2	A_{1-3}	N_{1-2}	4748	107	.0220
14	I_2	A_{1-3}	N_3	356	37	.0941
15	I_2	A_4	N_{1-2}	675	57	.0778
16	I_2	A_4	N_3	17	6	.2608
17	I_3	A_{1-3}	N_1	1757	124	.0659
18	I_3	A_{1-3}	N_2	467	41	.0807
19	I_3	A_{1-3}	N_3	168	30	.1515
20	I_3	A_4	N_1	1286	221	.1466
21	I_3	A_4	N_2	64	13	.1688
22	I_3	A_4	N_3	18	10	.3571
23	I_4	A_1		222	44	.1654
24	I_4	A_{2-3}		427	153	.2638
25	I_4	A_4		14	21	.6000
26	I_5	A_1	S_1	337	73	.1780
27	I_5	A_1	S_2	39	54	.5806
28	I_5	A_{2-4}	S_1	427	206	.3254
29	I_5	A_{2-4}	S_2	62	83	.5724
30	I_6	A_1		148	63	.2986
31	I_6	A_{2-4}		145	147	.5034
32	I_7			149	144	.4915
33	I_8			130	290	.6905
34	I_9			38	176	.8224

identity matrix as the design matrix. This resulted in the estimation of thirty-four model coefficients $\beta_1,\ldots,\beta_{34}$ which were identical to the corresponding fatality proportions. At the same time a sequence of contrasts were tested of the form $\beta_1 = \beta_2$, $\beta_2 = \beta_3,\ldots,$ $\beta_{33} = \beta_{34}$. A level of significance (e.g., $\alpha_1 = .85$) was chosen and, at the first stage, all pairs of columns of the design matrix were combined when the corresponding contrast was significant at a level not less than α_1. A second model was fit using the reduced design matrix, again a sequence of contrasts of the same form were tested and compared with an $\alpha_2 \leq \alpha_1$, (e.g., $\alpha_2 = .50$) and further reductions in the design matrix made. The process was continued until no further reductions could be made at a significance level exceeding .05.

These analyses resulted in the collapsing of the 34 subgroups to 14 combinations having significantly different fatality proportions. The 14 distinct proportions, along with the corresponding combination of subgroups, thus form a 14 point threat-to-life scale. That is, an individual whose age and injury pattern place him in Category k, would be expected to have a probability of dying from those injuries equal to p_k, where p_k is the fatality proportion corresponding to Category k, $k = 1,2,\ldots,14$. This scale is shown in Table 3.8.

An AIS Threat-to-Life Scale

A second threat-to-life scale has also been developed based upon the transformation of the primary injury ICDA code to an AIS severity code. For this analysis, HSRC utilized an ICDA-AIS conversion scheme provided by Ms. Susan Baker with the Office of the Chief Medical Examiner in Baltimore, Maryland. The AIS scale was developed along the lines of the first type of scale described in the introduction, with a separate category set aside for dead-at-accident and dead-on-arrival cases. Thus, the development of the other scale points could be accomplished using only the unadjusted Illinois data, with dead-at-accident and dead-on-arrival cases omitted. Furthermore, since the AIS severity variable contained only five levels, no collapsing or grouping of primary injury categories was necessary.

The approach taken for the development of this scale was first to split the data into five groups corresponding to AIS, then, within each

Table 3.8 Fourteen point threat-to-life scale.

	Fatality Percentage	Standard Deviation	Description
1.	.35	.08	$I_1A_1N_1$
2.	.65	.10	$I_1A_2N_1$ and $I_1A_1N_2$
3.	1.25	.20	$I_1A_3N_1$ and $I_1A_2N_2$
4.	2.13	.20	$I_2A_{1-3}N_{1-2}$, $I_1A_3N_2$, and $I_1A_1N_3$
5.	4.18	.53	$I_1A_4N_1$ and $I_1A_2N_3$
6.	6.55	.56	$I_3A_{1-3}N_1$ and $I_1A_3N_3$
7.	8.30	.65	$I_3A_{1-3}N_2$, $I_2A_{1-3}N_3$, $I_2A_4N_{1-2}$, and $I_1A_4N_2$
8.	15.47	.72	$I_5A_1S_1$, I_4A_1, $I_3A_4N_{1-2}$, $I_3A_{1-3}N_3$, and $I_1A_4N_3$
9.	26.37	1.79	I_4A_{2-3} and $I_2A_4N_3$
10.	31.97	1.58	I_6A_1, $I_5A_{2-4}S_1$, and $I_3A_4N_3$
11.	49.74	2.07	I_7 and I_6A_{2-4}
12.	57.88	2.99	I_5S_2 and I_4A_4
13.	69.05	2.26	I_8
14.	82.24	2.61	I_9

I ≡ Primary injury group (9 levels) as defined in Table 3.6.

A ≡ Age (A_1:$\leq$20, A_2:21-55, A_3:56-70, A_4:>70).

S ≡ Severe secondary injury (S_1 : no secondary injury with AIS as high as first, S_2 : one or more secondary injuries as severe as first).

N ≡ Extent (or number) of injuries (N_1 : 1 or 2, N_2 : 3 or 4, N_3 : 5 or more).

Data Source: Illinois Trauma Registry supplemented by N.C. Medical Examiner's File.

AIS level, the group was further subdivided by either age or extent of injury, whichever was more significant. The number and combinations of levels were chosen in such a way as to make the subdivision most significant. The resulting subgroups were then further split in the same way by the other (age or extent) variable when it was significant. This process resulted in 31 subgroups which are shown along with their frequencies and fatality percentages in Table 3.9. An examination of the percentages of this table reveals a considerable amount of variation within AIS levels over the subgroups defined by age and extent.

A clustering of the fatality percentages (or proportions) was then carried out by the same procedure that was described in the previous section. A nine point AIS threat-to-life scale resulted from the clustering procedure and is shown in Table 3.10.

Discussion of Threat-to-Life Scales

The scale based on ICDA and that based on AIS represent scales of the second type and first type, respectively, as discussed in the introduction. That is, the scale values of the ICDA scale (divided by 100) represent estimates of the unconditional probabilities that death results from the corresponding combinations of specific injury (ICDA code), age, and extent of injury. The scale values of the AIS scale (divided by 100) represent estimates of the conditional probabilities of death resulting from the corresponding combinations of injury severity, age, and extent of injury, given that death did not occur prior to the victim arriving at an initial care facility. These two types of estimates are based on slightly different data sets. In particular, all of the dead-on-arrival and dead-at-accident cases have been eliminated from the data set used for estimating the conditional probabilities. This results in generally smaller sample sizes and, consequently, somewhat larger standard deviations associated with the AIS scale. No attempt has been made to compare the two scales since they are of different types, and, in general, would be used in different situations.

Table 3.9 Subgroups of AIS levels.

	AIS	Age	Extent	Frequencies Survived	Died	Fatality Percentage
1	1	1-3	1	3079	13	.43
2	1	1-3	2	825	5	.60
3	1	1-3	3	227	11	4.62
4	1	4	1	200	5	2.44
5	1	4	2	43	6	12.24
6	1	4	3	15	3	16.67
7	2	1-3	1	5278	17	.32
8	2	1-3	2	1345	14	1.03
9	2	1-3	3	346	13	3.62
10	2	4	1	543	31	5.40
11	2	4	2	113	8	6.61
12	2	4	3	22	6	21.43
13	3	1	1	3569	18	.50
14	3	1	2	833	27	3.13
15	3	1	3	210	9	4.10
16	3	2	1	2640	21	.78
17	3	2	2	1063	30	2.74
18	3	2	3	309	20	6.07
19	3	3	1	1170	38	3.14
20	3	3	2	232	9	3.73
21	3	3	3	49	10	16.94
22	3	4	1	1927	160	7.66
23	3	4	2	163	12	6.85
24	3	4	3	27	4	12.90
25	4	-	1	271	12	4.24
26	4	-	2	106	11	9.40
27	4	-	3	48	10	17.24
28	5	1-2	1	292	44	13.10
29	5	1-2	2-3	153	44	22.34
30	5	3-4	1	26	15	35.59
31	5	3-4	2-3	9	14	60.87

- denotes that the variable was not used.

Table 3.10. Nine point threat-to-life scale.

	Fatality Percentage	Standard Deviation	Description
1.	.40	.06	$J_1A_{1-3}N_{1-2}$, $J_2A_{1-3}N_1$, $J_3A_1N_1$
2.	.86	.15	$J_2A_{1-3}N_2$, $J_3A_2N_1$
3.	3.19	.26	$J_1A_{1-3}N_3$, $J_1A_4N_1$, $J_2A_{1-3}N_3$, $J_3A_1N_{2-3}$, $J_3A_2N_2$, $J_3A_3N_{1-2}$, $J_4A_{1-4}N_1$
4.	5.73	.72	$J_2A_4N_{1-2}$, $J_3A_2N_3$
5.	7.67	.54	$J_3A_4N_{1-2}$, $J_4A_{1-4}N_2$
6.	13.81	1.47	$J_1A_4N_{2-3}$, $J_3A_3N_3$, $J_3A_4N_3$, $J_4A_{1-4}N_3$, $J_5A_{1-2}N_1$
7.	23.94	2.60	$J_2A_4N_3$, $J_5A_{1-2}N_{2-3}$, $J_5A_{3-4}N_1$
8.	60.87	10.18	$J_5A_{3-4}N_{2-3}$
9.	100.00	0.00	dead-at-accident dead-on-arrival

$J \equiv$ AIS class (J_1 : AIS-1, ..., J_5 : AIS-5)

$A \equiv$ Age (A_1:$\leq$20, A_2:21-55, A_3:56-70, A_4:>70).

$S \equiv$ Severe secondary injury (S_1 : no secondary injury with AIS as high as first, S_2 : one or more secondary injuries as severe as first).

$N \equiv$ Extent (or number) of injuries (N_1 : 1 or 2, N_2 : 3 or 4, N_3 : 5 or more).

Data Source: Illinois Trauma Registry.

Validation Studies

Two sets of comparisons using different data files were made in an attempt to validate the ICDA Threat-to-Life Scale. The primary validation was to have been done using the NCSS data file. Since, however, only a limited amount of NCSS data was available at the time the analyses were done, only rather rough comparisons can be made between the fatality percentages based on this data and those of the ICDA scale. The first two columns of Table 3.11 show these percentages for the ICDA scale and the NCSS data respectively. Along with the NCSS percentages the fractions from which they were computed are also shown. From these it can be seen that the sample sizes are generally quite small, and in particular there are only 51 fatalities distributed over the 14 categories. Another point to be noted is that a substantial part of the denominators (especially in the lower categories) arises from the weighting factors associated with the sampling scheme used in collecting the NCSS data. For example, the denominator 980 for category four is made up of 194 cases with weighting factor 1, 159 cases with weighting factor 4, and 15 cases with weighting factor 10. Differences of a few observations with a weighting factor of 10 can thus produce large differences in the fatality proportions.

Another difficulty encountered in using the NCSS data was the fact that injury information was retained for only the three most severe injuries. On the other hand, the variable (extent of injury) with a level corresponding to five or more injuries was used in defining the threat-to-life scales. Thus, some incorrect assignment of cases to categories with the NCSS data is quite possible. An examination of the NCSS fatal cases revealed that most of them had three injuries present. It seems likely, then, that some would have had as many as five. Since this possible misclassification could affect most of the middle threat-to-life categories (i.e. all of those including an N_2 or N_3 in Table 3.8), it is difficult to estimate exactly what the effect might be.

Standard deviations for the NCSS percentages are shown in the third column of Table 3.11. For the case of zero percentages, standard errors were estimated by adding one to both numerator and denominator of the corresponding fraction. While the two sets of percentages differ

Table 3.11 Validation comparisons for ICDA threat-to-life scale.

	ICDA Scale Value (Fatality Percentage)	NCSS Fatality Percentage & Fraction	Standard Deviation of NCSS Fatality Percentage	NCSS Avg. Length of Stay (Non-Fatals Only)	RSEP-Mean ISS (N)
1.	.35	.00 (0/66)	1.48	.61	1.72 (605)
2.	.65	.36 (1/280)	.36	1.04	1.99 (1743)
3.	1.25	1.06 (2/189)	.74	1.25	4.03 (745)
4.	2.13	.10 (1/980)	.10	.58	2.40 (3870)
5.	4.18	.00 (0/10)	8.67	.70	7.77 (318)
6.	6.55	.00 (0/8)	10.48	3.86	4.08 (205)
7.	8.30	.00 (0/79)	1.24	3.47	5.17 (597)
8.	15.47	30.43 (7/23)	9.59	18.85	8.86 (127)
9.	26.37	39.13 (9/23)	10.18	15.08	13.67 (48)
10.	31.97	61.90 (13/21)	10.60	6.67	19.80 (10)
11.	49.74	81.82 (9/11)	11.63	19.00	28.62 (13)
12.	57.88	66.67 (2/3)	27.22	12.00	34.75 (12)
13.	69.05	42.86 (6/14)	13.23	13.14	45.52 (29)
14.	82.24	25.00 (1/4)	21.65	37.00	18.00 (10)

considerably, these differences exceed two standard deviations for only five of the fourteen categories. The NCSS percentages are much lower than those of the ICDA scale for Categories 4, 7, and 14 and much higher for Categories 10 and 11. The fact that the NCSS percentages tend to be quite low for the first seven categories and quite high for Categories 8-13 may be an indication that some combining of categories within these ranges is appropriate. This should be examined further when more NCSS data becomes available.

In addition to the fatality percentages, an average length of hospital stay was computed for each threat-to-life category for the nonfatal cases using NCSS data. These are shown in column four of Table 3.11.

As an additional comparison with the ICDA threat-to-life scale, average ISS was computed, using the RSEP data file, for each of the fourteen categories. Since the RSEP file does not contain ICDA codes, a translation from OIC codes to the nine injury groups of Table 3.6 was necessary. This mapping is shown in Appendix D. These average values along with their sample sizes are shown in the last column of Table 3.11. It can be seen that they are generally increasing with increasing category number.

The fact that both mean ISS and the NCSS fatality percentages show a sharp decrease from the thirteenth to the fourteenth category may be an indication that the fourteenth category is not a valid category. This category consists of three ICDA codes corresponding to multiple and unspecified fractures and internal injuries. It seems possible that the high scale value for this category could have arisen as a result of these unspecified codes being used more heavily in the Illinois data when the victim was dead at the time the information was obtained.

No attempt was made to obtain any validity checks for the AIS scale. To estimate this scale it is necessary to separate the fatal cases into those who were dead at the accident or dead on arrival and those who died at a later time. Such a separation could not be made with the RSEP data. With the NCSS data it seemed that this separation might be possible by using the police rating of K to identify those dead at accident or on arrival. Since there were only 14 cases, however, with an NCSS classification of fatal and a police rating of something other than K it did not seem worthwhile to perform the estimation.

Application to RSEP Data

As an illustration of a potential use of a threat-to-life scale, measures of effectiveness of restraint systems were estimated from the RSEP data using the ICDA threat-to-life scale. The RSEP data was partitioned into several subpopulations defined by the variables -- occupant age, occupant sex, vehicle size and type of crash. For each subpopulation a mean threat-to-life value and restraint effectiveness measures of the form

$$\text{Effectiveness} = \frac{\text{Mean threat-to-life(unrestrained occupant)} - \text{Mean threat-to-life(restrained occupant)}}{\text{Mean threat-to-life(unrestrained occupant)}}$$

were computed for lap belts alone and for lap and shoulder belts combined. These quantities are shown in Table 3.12.

In general, the threat-to-life scale appears to behave as would be expected for the various sub-populations. Compact cars are involved in the least life threatening crashes. Rollovers, head-ons, and fixed object crashes are the most dangerous. Surprisingly, neither belt system is effective in reducing life-threatening injuries in head-on collisions. Lap only belts are ineffective in reducing such injuries in rear-end and rollover crashes. For the most part, however, the threat-to-life scale behaves appropriately and indicates that belt systems are effective in reducing life—threatening injuries.

Discussion

The threat-to-life scales presented in this chapter were calibrated using, basically, data from the Illinois Trauma Registry. It is not known to what extent this data is representative of accidents in general and of automobile accidents in particular. The fact that most cases were treated in trauma centers and, hence, may have received better-than-average initial care may have resulted in threat-to-life scale points that are biased downward to some extent.

The quantity of data used in the validation studies described previously was not sufficient to answer such questions, nor to provide much useful

Table 3.12 Restraint system effectiveness in terms of reduced threat-to-life.

Variable	Level	Mean Predicted Threat-to-Life	S.D. of Predicted Threat-to-Life	Lap Only Effectiveness	Lap & Shoulder Effectiveness
Age	<25	1.41	4.53	.19	.36
	25-55	1.64	5.03	.24	.39
	56 & up	2.63	5.95	.41	.41
Sex	Male	1.51	5.11	.23	.41
	Female	1.79	4.66	.26	.33
Vehicle Size	Subcompact	1.71	5.19	.07	.35
	Compact	1.50	4.46	.29	.37
	Intermediate	1.62	4.67	.23	.36
	Full-Sized	1.69	5.33	.42	.44
Crash Type	Head-On	2.78	6.67	-.01	-.09
	Rear Striking	1.03	2.85	.00	.52
	Rear Struck	1.39	3.95	.07	.27
	Angle Striking	1.39	3.53	.16	.37
	Angle Struck, Left	1.56	4.29	.31	.32
	Angle Struck, Right	1.69	5.56	.28	.47
	Rollover	2.67	7.54	.05	.56
	Sideswipe	1.38	7.17	.62	.53
	Head-On Fixed Object	2.07	5.46	.48	.24
	Side of Car Into Fixed Object	2.27	8.25	.29	.35

information concerning the general validity of the scales. While it is the opinion of the authors that these scales represent at least good relative rankings of injuries with respect to threat-to-life, it is hoped that when more data becomes available additional studies will be conducted to further validate and improve the scales.

IV. DEVELOPMENT OF A DISABILITY SCALE

Criteria for the Selection of a Disability Scale

The purpose of the proposed disability scale is to use data available at the time of the accident or shortly thereafter to predict societal costs of any resulting disabilities. In many ways, this purpose dictates the type of disability scale that can be developed. Some of the aspects of the scale that are defined by its purpose are the type of disability that is predicted, the criteria measures that can be used to calibrate the scale, and the data elements that can be used in the scale. Each of these considerations is discussed below.

Clearly only disabilities resulting from injuries are of interest. Other types of disabilities will not result from motor vehicle crashes--at least not directly (e.g., complications leading to pneumonia). Injury-related disabilities are called "acute." Measures of acute disability describe how an individual's usual activity is restricted (typically the number of days that an individual cannot perform his or her job). The severity of the disability within the time the individual is restricted is not measured. This is justifiable, however, since the number of workdays lost will have greater societal consequences than measures that reflect changes in subsequent disability status (e.g., a change from bedridden to restricted-to-the-home) as well as being more reliably quantified.

Two common measures of acute disability are lost workdays and compensation awards. Lost workdays, of course, count the number of days an individual cannot perform his or her regular job. Compensation awards are payments to these individuals which correspond to some portion of their lost salary. Several arguments suggest that compensation will correspond more closely with the purpose of the desired disability scale.

First, compensation more accurately reflects the societal consequences of injuries. The differences in salaries between various age and sex categories must be reflected in any attempted measurement of societal consequences. While lost workdays may reflect the differential speed at which these groups recover, it will not reflect these differential salaries. Second, cost/benefit analysis is one of the basic evaluation methods employed in this area. If the compensation associated with an injury is predicted, then assumptions concerning the relationship between lost workdays and salaries would not have to be made when cost/benefit analyses are carried out. However, in developing this "cost" disability model, the medical costs associated with a disabling injury will not be included in the measurement of disability as they can be more appropriately reflected in the overall cost scales. Third, lost workdays will reflect only the temporary effects of disability. They will not measure any long-term disability due to the loss or impairment of any body parts. Compensation awards will generally contain information concerning these long-term disabilities in the form of scheduled payments.

The most severe restriction that the purpose of the scale imposes is that the scale elements must be able to be determined relatively soon after the occurrence of the accident. If there were no time constraints, then compensation information could be collected from the hospitals, doctors and rehabilitation centers that attended to the occupants of each vehicle. This data would, of course, give excellent disability predictions. Unfortunately, data of this nature can only be collected long after the accident (particularly for more severe injuries). Long delays in data collection have been shown to increase the proportion of missing and incorrect data as well as increase the cost of the data collection. Thus, the elements of the proposed scale are restricted to data available shortly after the crash, namely, injury descriptions, age and sex.

The restriction on the possible scale elements has the added benefit that such a scale can be applied to a much broader range of data sets. For example, if length of hospital stay was a scale element, then the scale could be applied to only selected Level 2 data sets and most Level 3 data sets. If only injury descriptions, age and sex are scale elements, then the scale would be appropriate for any data set containing similar injury descriptions including some Level 1 data (such as New York State Police data). Disability could also be estimated for special data banks such as those concerning particular types of data (for instance, seat belt information) or certain subsets of crashes (such as alcohol-related crashes or those involving commercial drivers).

Data Set Used to Construct the Scale

The constraints outlined in the previous section provide a fairly precise definition of the ideal data base. On a case-by-case basis, the file should contain data concerning disabilities resulting from injuries. At the least, the file must report the number of lost workdays associated with each case; preferably it should have a measure of the compensation awarded to each individual. This compensation should reflect both short-term disabilities (lost workdays) and long term effects (permanent loss of body parts). Finally, the injury descriptions on the file should be comparable to either the ICDA or Occupant Injury Classification (OIC) injury codes.

Of the available data sets, the North Carolina Workmen's Compensation File (WCF) best met these requirements. It contained case-by-case disability data for a large number of cases. With a few exceptions concerning occupational diseases, it dealt with the consequences of work-related injuries and thus pertained to acute disabilities. The WCF contained two measures of disability: lost workdays and compensation. Finally, the WCF injury descriptions specified not only the part of body injured but also the nature of the injury. This dichotomy is very similar to the body part and lesion portions of the OIC which has been used in several NHTSA projects. Thus the WCF had the majority of the required data on a reasonably large number of cases.

The Workmen's Compensation File obtained in connection with this research consisted of 77,263 cases. These represent the closed cases computerized by the North Carolina Industrial Commission as of mid-May, 1977. Most of these cases were closed in 1976 or 1977. The actual number of cases used to develop the scale is somewhat smaller because two types of cases were identified which would not contribute to the modeling: cases involving fatalities and cases where no lost workdays and no compensation were recorded.

There were 178 fatality cases on the WCF; the estimation of disability for these cases is difficult at best. Most of the compensation actually awarded in these cases is a lump sum corresponding to the expected loss of salary. Relatively little compensation is due to lost workdays. In fact, about 90 percent of these cases reported no lost workdays. Estimating the expected salary loss for fatalities is complicated and estimates vary considerably. Rather than using the WCF estimate or arbitrarily selecting some other estimate, these cases were excluded from consideration in the development of the scale. If it becomes necessary to include fatalities in the scale at a later date, then the user can make a direct assignment of his own estimate to all fatalities. Allowing the disability scale to be used with a variety of fatality cost estimates will increase the generality of the scale.

The second subset of cases that were excluded were those cases where only medical payments were made. The Industrial Commission awards payments to workers for medical costs associated with the injury and salary losses where applicable. Only those cases with salary losses, however, contain information which is pertinent to the disability scale. The medical payments will be reflected more appropriately in Chapter V dealing with overall direct costs. Therefore, those cases which contained only medical payments were eliminated from consideration. As a result, the usable WCF contained 44,096 cases.

The WCF contains both measures of disability under consideration: lost workdays and compensation. For this file, a lost workday is defined to be any day for which an employee is unable to earn or is not paid a full day's wage as a result of a work-related injury. Lost workdays are counted on a calendar basis. The Industrial Commission uses this information to determine when an injured employee may begin to draw compensation.

Compensation, the second measure of disability, reflects the societal consequences of disabilities arising from accidents more adequately. Despite the fact that compensation is composed of two separate factors, both are based on the employee's average weekly salary at the time of the injury. Thus, compensation reflects any societal biases in salary.

The two components of compensation are salary payments and scheduled payments. Salary payments constitute the bulk of the compensation awards. These payments are based on a rate of two-thirds of the employee's average weekly salary at the time of the injury. The length of time that salary payments are made depends solely on the length of disablement. If an employee returns to work before a calendar week has passed, then no salary payments are made. If the employee is out between 8 and 28 days, then payments are made for only the time after one week that the employee is disabled. Only if the disability extends beyond 28 days are compensation payments made from the date of the injury. Employees are encouraged to return to work as quickly as possible even to the point of compensating an employee who returns to work early but at a lower-paying job. In such cases, he is compensated at a rate of two-thirds of the difference between the average weekly salary at the time of the accident and the average reduced salary. Thus, an employee will receive the salary associated with the less-demanding job and the compensation payments. The employee will earn more money this way than he would receive by staying at home until he has fully recovered.

Scheduled payments are added to the salary payments if the injury leaves scars which seriously disfigure the person or causes permanent injury or loss of an important organ of the body. These payments (up to $7,500) are based on an assigned number of weeks for various types of injury. The awards are calculated by multiplying the scheduled number of weeks associated with the injury by the employee's average weekly salary. The scheduled payments reflect the permanent consequences of the injury. They represent a measure of the severity of the disability in the sense that they differentiate between temporary and permanent injuries and partially rank the permanent injuries according to their severity.

Compensation, then, is a much more appropriate measure of disability than lost workdays. It reflects the societal biases in salaries for different age and sex groups and the severity as well as the duration of the disability. Unfortunately, the compensation data do not reflect the first week of disability for all but the most severe cases. Only if an employee is disabled for more than 28 days does he receive compensation for the first week of disability. In order to obtain an accurate estimate of disability, it was necessary to adjust the compensation to reflect the first week or portions thereof for all claimants.

The first step in making this adjustment involved isolating those cases in which only salary payments were made. The scheduled payments component is independent of the length of disablement and thus would only confound the salary estimates. Fortunately, the type of case codes indicate which cases involved temporary disabilities. Using this information, the mean payment for the actual number of days compensated was then calculated within various age and sex categories for the temporary cases. These amounts were then used to adjust the compensation data for workers out less than four weeks. Table 4.1 reports the data used in the adjustment. The adjusted compensation data was then used as the criterion variable in the scale development.

Note that these figures, representing two-thirds of the worker's daily wages, are consistently lower than might be expected. However, the relative compensation by age and sex is what is of greatest importance in the scale development.

Variables in the Model

Age, sex and injury information are the primary WCF data elements which are available at the time of the injury. Each represents data that NHTSA field teams can obtain at or about the time of an accident. Thus these variables were used to construct the disability scale.

Age and sex provide biographical information about the employee. Sex is a categorical variable with two levels: male, female. Age, on the other hand, is an interval measure which is reported in years. Both variables are used directly in the scale development.

Injury information is the critical factor in predicting disability. Without this information, it is obviously impossible to predict disability on a case-by-case basis. Three types of information describe an injury. The first is the extent of the injury. Multiple injuries are generally more serious than single injuries. Fortunately a WCF variable indicates whether an accident results in multiple injuries. Approximately 4.7 percent of the data were coded as multiple injury cases. An effort was made to obtain more detailed information on these cases, but only 859 hard copy files were accessible to provide the detailed additional data. This is not a sufficiently large data base upon which to reach any conclusions concerning the interaction between particular injuries and their effect on compensation.

Table 4.1 Mean daily compensation by age and sex.

Sex	Age	Mean Daily Compensation	S.D.	N
Male	<15	$ 9.21	$ 4.01	7
	15	7.44	3.85	12
	16-20	12.14	10.55	1585
	21-25	15.07	30.10	2216
	26-30	15.58	10.12	1985
	31-35	16.95	14.93	1541
	36-40	16.08	7.56	1355
	41-45	17.93	66.66	1142
	46-50	16.15	7.42	1087
	51-55	16.18	12.09	962
	56-60	15.90	11.74	684
	61-65	15.28	14.42	421
	>65	11.10	4.96	155
	Total[1]	$15.46	$24.58	13868
Female	<15	$ 8.78	$ 0.00	1
	15	8.86	4.44	2
	16-20	10.02	5.72	315
	21-25	13.48	22.42	462
	26-30	12.39	6.47	490
	31-35	11.98	5.70	426
	36-40	12.92	10.25	436
	41-45	11.83	5.48	373
	46-50	11.68	5.61	473
	51-55	12.37	10.44	454
	56-60	13.22	15.52	321
	61-65	10.72	7.33	173
	>65	8.43	6.35	47
	Total[1]	$12.14	$11.23	4136

[1]Includes cases missing age information

Data Source: North Carolina Workmen's Compensation File

However, in developing the disability scale, this information is utilized as a dichotomous variable with levels single vs. multiple injuries.

The second and third types of injury information describe the body region that is injured and the nature of injury that occurs. These data are coded on the WCF as body part and nature of injury and are listed in Table 4.2 The body part codings are quite similar to the body region portions of the OIC but are more detailed in certain areas such as the head and wrist-hand regions. The nature of injury codes are much more extensive than the lesion part of the OIC. Most of the additional types of injuries, however, represent occupational types of injuries which would not occur in vehicle crashes. The WCF injury descriptions are similar to the ICDA codes in that the severity of the injury is not indicated. In all, there are 526 specific injuries (combinations of body part and nature of injury) on the WCF.

Candidate Injury Groups

The large number of specific types of injuries presents a problem in constructing the disability scale. The final scale will assign a predicted compensation award to each combination of age, sex, extent of injury, and type of injury. The number of combinations that must be considered when there are 526 possible injuries, however, is so large that even with 44,096 cases there will be many combinations with only a few or no observations. In order to obtain a reliable estimate of compensation awarded for each combination, the number of combinations (and hence the number of types of injuries) must be reduced substantially so that the observations will be distributed over fewer combinations. Two options were explored in this effort. The various injury grouping schemes developed within each option will be defined first and then the schemes will be compared.

Definition of candidate injury groups.

Several injury category schemes that have been developed in connection with other projects were considered within the first option. These injury systems generally maintain the major body region and nature of injury distinctions but are not based on disability information. The candidate schemes were the 43 threat-to-life categories developed in

Table 4.2 WCF injury codes.

PART OF BODY

110..Brain
121..Ear (external)
124..Ear (internal)
130..Eye
141..Jaw (include chin)
144..Mouth (lips, teeth, tongue, throat)
146..Nose
148..Multiple parts (any combination above)
149..Face, NEC[1]
150..Scalp
160..Skull
198..Head, Multiple
199..Head, NEC
200..Neck

311..Upper Arm
313..Elbow
315..Forearm
318..Arm, Multiple
319..Arm, NEC
320..Wrist
330..Hand
340..Finger
398..Upper Extremities, Multiple
399..Upper Extremities, NEC

410..Abdomen (include internal organs)
420..Back
430..Chest (ribs, breast bone)
440..Hips (pelvis, pelvic organs, buttocks)
450..Shoulder
498..Trunk, Multiple
499..Trunk, NEC

511..Thigh
513..Knee
515..Lower Leg
518..Leg, Multiple
519..Leg, NEC
520..Ankle
530..Foot
540..Toe
598..Lower Extremities, Multiple
599..Lower Extremities, NEC

700..Multiple Injuries
801..Circulatory System
810..Digestive System
820..Excretory System
830..Musculo-Skeletal System
840..Nervous System
850..Respiratory System
880..Other Body System
900..Body Parts, NEC
999..Unclassified

NATURE OF INJURY

100..Amputation or Enucleation
140..Concussion-Brain
161..Bruise, Contusion
162..Crushing Injury
170..Cut, Laceration, Puncture
190..Dislocation
210..Fracture
251..Hernia (Abdominal) (=Rupture)
252..Hernia (Other)
260..Inflammation or Irritation of Joints
309..Scratches, Abrasions (superficial wounds)
310..Sprains, Strains
400..Multiple Injuries

110..Asphyxia, Strangulation, Drowning
121..Burns, Scalds
122..Electric Burns
130..Burn (Chemicals)
150..Contagious and Infectious Disease
180..Dermatitis
200..Electric Shock
220..Freezing, Frostbite
231..Hearing Loss (due to noise)
232..Hearing Loss (other)
240..Heat Stroke, Sunstroke, Heat Cramps, Heat Exhaustion, or Prostration
270..Poisoning Systemic
281..Asbestosis
282..Byssinosis (cotton or linen dust)
283..Silicosis
289..Pneumoconiosis, NEC (any)
290..Radiation Effects
301..Surface Irritations (not dermatitis)
990..Occupational Disease, NEC
995..Other Injury, NEC
999..Unclassified, Not Determined

[1]NEC = other, not specified

Chapter III, the 39 groups defined in the RSEP for the estimation of costs (Reinfurt, Silva and Seila, 1976), and the 22 groups used in the RSEP Factbook (Hall, 1976). The category definitions for each scheme were translated into WCF body part and nature of injury codes. The injury data for each case were then examined and categorized according to each scheme, respectively.

It should be more appropriate, however, to group injuries on the basis of disability information rather than some other type of injury consequence. This alternative then examined injury groups which were derived using the disability data on the WCF. Within this approach, two procedures were explored.

First, injuries were grouped according to their compensation awards regardless of their body part and nature of injury codes. For example, if concussions and foot contusions had similar disability consequences, they were classified together even though they would be placed in different groups by most injury classification schemes. Two problems resulted from this approach. First, injuries not occurring on the North Carolina WCF could not be automatically included in an injury category (e.g., there is no face laceration category). Second, no simple descriptions of the groups described all of the injuries that are included in the categories. These problems are discussed in later sections.

The empirical injury groups were derived using a hierarchical clustering analysis (see Johnson, 1967). A representative compensation award was assigned to each specific injury. The analysis identified groups of injuries which have similar awards yet which differ, as a group, from those associated with other injuries. Specifically, the analysis first designates each injury as a cluster. The two clusters having the most similar representative compensation awards are combined into (and replaced by) a new cluster. The compensation award assigned to the new cluster is the mean of the awards assigned to the two component clusters. From this new set of clusters, the two most similar awards are again determined, and the injuries associated with these awards are combined into a single cluster, and so forth until all injuries have been grouped together. Thus the 526 injuries can be divided into from 1 to 526 injury groups.

The compensation awards assigned to the injuries obviously determine the injury groups. Initially analyses were performed using the mean and median of the compensation distributions associated with each injury. BMD program P2M (Dixon, 1975) performed the analyses. The injury categories defined at the 40 group stage of the clustering analysis were compared to the other injury group schemes so that each scheme had approximately the same number of groups.

In contrast to the empirical groups developed above, an attempt was also made to exert some control over which injuries were grouped together. For example, grouping injuries such as sprained ankles and nose fractures together makes little intuitive sense. If injuries are grouped within either body part or nature of injury, then the categories may be more acceptable.

In exploring this possibility, the nature of the injury was controlled for rather than the body part since there are condiderably fewer nature of injury codes. Within each nature of injury category, multiple t-tests on the average compensation awards determined which body part injuries could be grouped together. For example, when the mean compensation awards associated with fractures of the hand and of the fingers were compared, there were no significant differences. Both of these fractures, however, differed significantly in their compensation awards from fractures of the wrist. Therefore, these two fractures constituted a separate group from other fractures of the arm. In this manner, 48 injury categories were developed which were significantly different in compensation awarded but maintained the major nature of injury distinctions.

Comparison of candidate injury groups.

The selection of an injury grouping scheme was based on the ability to differentiate between injury groups on the basis of disability. This ability was estimated using a series of one-way analyses of variance. In each analysis, a scheme's categorization was used to define injury group membership and the compensation awarded in each case was then used as the independent variable. Thus, if a scheme corresponded well with disability, then a significant difference should be obtained.

Table 4.3 reports the F-ratios derived in the analyses of variance. Not surprisingly the two empirically-derived schemes corresponded best with disability. They grouped injuries associated with low compensation awards together and separated them from groups of injuries with high awards. The threat-to-life and RSEP-cost schemes show roughly equivalent grouping ability (at least in terms of disability). The low F-ratio for the within-nature-of-injury groupings indicates that the nature of injury categories cannot act as a constraint in grouping injuries by disability.

Table 4.3 F-ratios calculated for one-way analyses of variance of adjusted compensation awards with group membership determined by injury categorization scheme.

Injury Categorization Scheme	F-Ratio
Cluster - mean	244.9
Cluster - median	232.3
Ad hoc grouping	74.7
Threat-to-life	130.1
RSEP Cost Analysis	99.9
RSEP Factbook	81.7

Data Source: North Carolina Workmen's Compensation File.

Even though the empirically-based schemes represented the best categorization of injuries, there were some problems. For example, a number of injury categories were obtained that were not intuitively consistent. One part of one cluster contained the following injuries:

brain concussion
lower leg burn - scald
abdominal hernia
foot dislocation
digestive system infectious disease

There is no obvious underlying reason for these injuries to be grouped together. Just examining the cluster, it is not at all clear that they should have similar disability consequences. The lack of intuitive consistency represents a definite weakness in the grouping procedure. The groups based on the mean compensation awards were particularly susceptible to this problem.

Final Injury Groups

The most predictive disability scale involves using injury groups that reflect differential compensation awards. The previous section described a series of one-way analyses of variance which estimated each candidate scheme's ability to differentiate on the basis of compensation awards. It was found that the two schemes based on the empirical clustering procedures were clearly superior to the other schemes in their differentiation of awards. Further, it was observed that the clusters derived using the median compensation award seemed to be more consistent in the types of injuries which were grouped together (e.g., most contusions were grouped together). Before defining the final injury groups, however, some modifications of the data file and the analysis procedures were implemented which improved the injury groupings considerably.

Since NHTSA does not need a scale that predicts the disability consequences of all injuries or diseases, a subset of the WCF was selected containing only those injuries that might result from vehicle crashes. Thus injuries or diseases such as dermatitis, frostbite, asbestosis, etc., were excluded from the final injury groups while fractures, lacerations, and so forth were retained. Eliminating these diseases and injuries reduced the number of specific combinations of body part and nature of injury to 379; however, this process only reduces the number of cases from 44,096 to 39,869. A large reduction in types of injuries was achieved at the loss of only a small number of cases that involved situations with which NHTSA will not be concerned.

In addition, since the within cell compensation awards had large variances and differing ranges, the clustering procedure was modified to use additional distributional information about the compensation awards for each injury. Since approximately half of the injury types had at most five observations, only the upper and lower quartiles and the median could be used to describe the compensation award distributions associated with each injury. Nevertheless, these three statistics were used to determine the two most similar injuries in the clustering analysis instead of only the median.

Using the median and the upper and lower quartiles of the distribution of compensation awards associated with each injury, the cluster analysis grouped those WCF injuries which might likewise have resulted from a vehicle crash. The injury categories defined at the 10-group stage were examined first. Table 4.4 reports the number of cases, mean compensation awarded, and the standard deviation of the awards of each of the 10 groups. Several of the categories (3, 5, 9 and 10) contained only a very small number of cases. With the exception of Category 10, the mean compensation awards associated with these groups do not vary a great deal from certain other groups. Thus, they could be combined with other groups without much overall loss of predictive power. In particular, Categories 3, 5 and 9 were combined with Categories 2, 4 and 8, respectively. These were their most similar categories according to the clustering analysis. The mean compensation award associated with Category 10 was considerably higher than any other category so it was kept as a distinct group. The lower portion of Table 4.4 reports the data on the final seven injury groups.

The seven injury groups cannot be simply described because of their empirical nature. The injuries constituting each group are given in Tables 4.5 to 4.9. Each combination of body part and nature of injury codes occurring in this subset of the WCF is assigned to one of the final seven injury categories in these tables. For ease of interpretation, each of the tables concerns only one of the five general body regions (head/neck, arm, trunk, leg, general). The same injury categories, however, apply to each body region and each table. The category numbers correspond to the rank ordering (lowest to highest) of the mean compensation awards for each category. Combinations of body parts and nature of injury codes that are not assigned to a category did not occur in the file.

In general, several trends were identified. For example, concussions, contusions, abrasions and lacerations were included mostly in the first or least disabling category. Head abrasions were an exception tending

Table 4.4 Number of cases, mean and standard deviation of compensation for the 10-group and 7-group stages of clusterings based on compensation distributions.

	Category	Mean	S.D.	N
Injury Groupings (10-group stage)	1	$286.37	$719.87	25,774
	2	361.28	642.94	5,135
	3	284.00	90.13	34
	4	664.10	1,062.39	4,278
	5	604.71	226.94	17
	6	1,137.85	1,656.52	2,214
	7	2,045.44	2,462.83	2,170
	8	3,530.89	4,252.39	209
	9	4,680.50	3,789.10	6
	10	11,928.81	6,636.40	32
Injury Groupings (7-group stage)	1	$286.37	$719.87	25,774
	2	360.77	642.94	5,169
	3	663.86	1,060.38	4,295
	4	1,137.85	1,656.52	2,214
	5	2,045.44	2,462.83	2,170
	6	3,562.98	4,236.42	215
	7	11,928.81	6,636.40	32

Data Source: North Carolina Workmen's Compensation File

able 4.5 Final injury categories assigned to <u>head/neck</u> body parts and nature of injury combinations obtained from the WCF.

Nature of Injury

Body Part	Concussion	Contusion	Abrasion	Laceration	Sprain	Dislocation	Burn: Scald	Burn: Elect.	Burn: Chem.	Fracture	Crush	Amputation	Multiple	Other	Unclassified
Brain	1	2		1											
Ear (external)		1		2			4		1						
Ear (Internal)		4	2	2			1			5				2	
Eye		1	1	1	1		1	1	1	2	7	7		2	1
Jaw		1		1		1				2					
Mouth		2		1			2		1	3				4	
Nose		1	1	1			1			1	2		2	1	
Scalp	1	1	2	1		5	2			4					
Skull	1	1	2	1						4					
Face,NEC		1	1	1	1					3			4		
Head,NEC	1	1	1	1	1					3			1	3	5
Mult. Face		1		1			1	1	1	4			1		
Mult. Head	1	2		1			1		1	3	6		1		
Neck		2	1	2	2	5	1			6				2	2

Table 4.6 Final injury categories assigned to arm body parts and nature of injury combinations obtained from the WCF.

	Nature of Injury														
							Burn								
Body Part	Concussion	Contusion	Abrasion	Laceration	Sprain	Dislocation	Scald	Elect.	Chem.	Fracture	Crush	Amputation	Multiple	Other	Unclassified
Upper Arm		2	1	2	2		2	1		5	6	7			
Elbow		1	1	1	1	4	1			4	3	7		2	
Forearm	1	1	1	1	1	1	1	1	1	4	3	7	3		1
Wrist		1	2	1	1	2	1	1	1	4	2			2	
Hand		1	1	1	1	1	1	1	2	3	4	7			
Finger		1	1	2	1	3	1	2	1	3	4	5	5	1	
Arm, NEC		1	1	1	2		1	1		5	3				
Mult. Arm		1	1	1	4		3		1	6		7	2		
Mult. Upper Ext.		1	1	3	1		1	4	2	5	4				

Table 4.7 Final injury categories assigned to <u>trunk</u> body parts and nature of injury combinations obtained from the WCF.

	Nature of Injury														
							Burn								
Body Part	Concussion	Contusion	Abrasion	Laceration	Sprain	Dislocation	Scald	Elect.	Chem.	Fracture	Crush	Amputation	Multiple	Other	Unclassified
Shoulder		1	1	1	1	4	1		1	4				5	4
Chest		1	1	2	1	1	1		1	2	3				2
Abdomen		1	1	1	1	2	3		1	1			1	3	
Hips		1	1	1	1	5	4		4	5	7			1	3
Back		1	1	2	1	4	2			5			2	4	4
Trunk, NEC		3	1	2			2								
Mult. Trunk		1	1	1	1		3		3	5					

Table 4.8 Final injury categories assigned to <u>leg</u> body parts and nature of injury combinations obtained from the WCF.

	Nature of Injury														
							Burn								
Body Part	Concussion	Contusion	Abrasion	Laceration	Sprain	Dislocation	Scald	Elect.	Chem.	Fracture	Crush	Amputation	Multiple	Other	Unclassified
Thigh		1	1	1	1		2		1	6	6				
Knee		1	1	1	3	4	1			5	4	7		5	1
Lower Leg		1	1	1	2	5	2	1	1	5	4	7			
Ankle		1	1	2	1	4	3		1	4	5			1	
Foot		1	1	1	1	3	2	2	2	3	3	6			2
Toe		1	1	1	1	1	1		2	1	2	6			
Leg, NEC		1	1	1	1	6	4		3	6	3		2		
Mult. Leg		1	1	2	1		3			6					
Lower Ext., NEC			1												
Mult. Lower Ext.		1	1	3	2		3		3	5	3		1		1

Table 4.9 Final injury categories assigned to general body parts and nature of injury combinations obtained from the WCF.

Body Part	Nature of Injury: Concussion	Contusion	Abrasion	Laceration	Sprain	Dislocation	Burn: Scald	Burn: Elect.	Burn: Chem.	Fracture	Crush	Amputation	Multiple	Other	Unclassified
Circulatory System					1									6	
Digestive System														1	
Excretory System		3		2										3	
Musculo-Skeletal System					2									2	
Nervous System		3												5	
Respiratory System										7					
Body Part, NEC		2			1		1		3	5				5	
Mult. Parts		1	1	2	2	1	3	4	4	6	5	1	5	6	
Unclassified		2			3									1	1

to be regarded as Category 2 injuries. Dislocations are associated with larger compensation awards. The dislocation of any major joint (but particularly trunk or leg joints) is placed in a high category. Not surprisingly, fracture and crushing injuries fall primarily into the very high disability categories. Amputations fall into the highest category reflecting the lump sum compensation award for the loss of a body part.

Scale Construction

Multiple regression techniques were used to construct the disability scale. Age, sex, extent of injury, and injury category were treated as independent variables predicting compensation awarded. Several regression models were investigated: a main effects model, a multiple interaction model, a two-way interaction model, and finally a reduced two-way interaction model. The evaluation of each model was based on its simplicity and the proportion of variability in the compensation awarded for which it accounted.

The simplest regression model examined was the main effects model. In this model, compensation awarded is predicted from a linear combination of the independent variables -- age, sex, extent, and injury category -- along with the overall mean. More specifically, the model is of the form:

$$E(Y) = \beta_0 X_0 + \sum_{i=1}^{6} \beta_i X_i + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 \qquad (4.1)$$

where $X_0 = 1$ for all observations

X_1	X_2	X_3	X_4	X_5	X_6	
1	0	0	0	0	0	for injury category 1
0	1	0	0	0	0	for injury category 2
0	0	1	0	0	0	for injury category 3
0	0	0	1	0	0	for injury category 4
0	0	0	0	1	0	for injury category 5
0	0	0	0	0	1	for injury category 6
0	0	0	0	0	0	for injury category 7

X_7 = age (in years)

X_8 = 0 if male
1 if female

X_9 = 0 if single injury
1 if multiple injury

and Y corresponds to disability as measured by compensation awarded.

The model was reasonably successful. The linear combination of the independent variables correlated 0.50 with the actual compensation awards. Thus, approximately 25 percent of the variance in compensation awards was accounted for by the variables in the model. The regression coefficients associated with each independent variable are shown in Table 4.10. The disability predictions are then made by replacing the β_i, $i = 0,1,2,\ldots,9$ in (4.1) by the b_i from Table 4.10. For example, a

Table 4.10 Regression coefficients and standard errors for the main effects model (4.1) and the same model using age as a categorical variable.

Variable (X_i)	Age (Continuous) Coefficient	Age (Continuous) Standard Error	Age (Categorical) Coefficient	Age (Categorical) Standard Error
Mean (X_0)	$ 12,082.56		$ 12,250.54	
Injury Category 1 (X_1)	-11,967.39	189.44	-11,961.23	189.67
Injury Category 2 (X_2)	-11,899.20	189.92	-11.894.57	190.15
Injury Category 3 (X_3)	-11,602.03	190.03	-11,595.27	190.26
Injury Category 4 (X_4)	-11,118.17	190.73	-11,106.90	190.96
Injury Category 5 (X_5)	-10,241.30	190.75	-10,229.22	190.98
Injury Category 6 (X_6)	- 8,818.93	203.78	- 8,803.60	204.02
Age (X_7)	6.23	.42	128.92	11.61
Sex (X_8)	- 209.73	13.48	- 202.47	13.48
Extent (X_9)	83.11	25.83	84.61	25.87
R^2	0.2464		0.2445	

Data Source: North Carolina Workmen's Compensation File.

48-year old male with one Category 3 injury would be predicted to have a compensation award of:

$$\underbrace{\$779.57}_{\text{compensation}} = \underbrace{\$12{,}082.56}_{\text{mean}} + \underbrace{[1 \times (-11{,}602.03)]}_{\text{category 3}} + \underbrace{[48 \times (6.23)]}_{\text{age}}$$

$$+ \underbrace{[0 \times (-209.73)]}_{\text{sex}} + \underbrace{[0 \times (83.11)]}_{\text{extent}}.$$

The overwhelming dominance of the injury categories in predicting compensation awards was surprising. The age, sex, and extent coefficients were comparatively small. When these variables were added to a regression model containing only the injury category indicator variables, the R^2 only increased from 0.238 to 0.246. This corresponds to an increase in prediction of only 0.8 percent. Thus, the injury category is clearly the most important predictor of compensation awards.

The regression formulation of the disability scale is similar to the other models developed in this project with the exception of the variable representing age. Because of the categorical nature of the analyses used to develop the threat-to-life and medical cost scales, age was treated as a categorical variable rather than an interval variable. The resulting scales predict mean scale values for various combinations of the independent variables. If age is treated as an interval measure, then there are too many possible combinations of independent variables for the scale to be presented in tabular form as is done in the threat-to-life and medical cost scales. If age is treated as a categorical variable, however, then comparable results could be obtained. Such a model would be preferable if it provided essentially an equivalent amount of prediction as the model described in (4.1).

Age restrictions within the data created some problems in the development of age categories. Because the data is drawn from the working population, there were very few employees that were either under 15 or over 65 years of age. Thus, a two-way partition of age (≤ 40, >40) was found to obtain the most reasonable distinct grouping of compensation by age.

When X_7 is redefined (1 if age > 40, 0 otherwise), then a main effects model including age as a categorical variable can be derived. The coefficients associated with this model are also shown in Table 4.10. With the expected exception of the age coefficient, there is very little difference in the estimated model coefficients (age continuous vs. age dichotomous). Further the R^2 term decreases very insignificantly (0.2464 to 0.2445) with the redefinition of age. Since there was almost no loss in prediction, models treating age categorically were used in subsequent investigations in order to define a scale similar in nature to the threat-to-life and medical cost scales.

Table 4.11 gives the predicted disability amounts for the age, sex, extent and injury group combinations for the model with age as a categorical variable.

It is possible, of course, that age, sex, and extent of injury will have a greater impact on compensation awards in their interaction with injury category than they have as main effects. For example, if sex reflects salary biases, then it may not have as much of an effect in those injury categories associated with lower compensation awards. On the other hand, in those injury categories with high compensation awards, the sex biases will be more evident. This possibility was pursued in several interaction models.

The following multiple interaction model was investigated:

$$E(Y) = \beta_0 X_0 + \sum_{i=1}^{9} \beta_i X_i + \sum_{i=1}^{8} \sum_{\substack{j=7 \\ j>i}}^{9} \beta_{ij} X_i X_j + \sum_{i=1}^{7} \sum_{\substack{j=7 \\ j>i}}^{8} \sum_{k=j+1}^{9} \beta_{ijk} X_i X_j X_k + \sum_{i=1}^{6} \beta_{i789} X_i X_7 X_8 X_9 \quad . \tag{4.2}$$

A two-way interaction model was also explored which took the form:

$$E(Y) = \beta_0 X_0 + \sum_{i=1}^{9} \beta_i X_i + \sum_{i=1}^{8} \sum_{\substack{j=7 \\ j>i}}^{9} \beta_{ij} X_i X_j \quad . \tag{4.3}$$

Table 4.11 Predicted disability amounts (in dollars) by sex, age, extent, and injury type combinations.

Sex[1]	Age[2]	Extent[3]	Injury Category 1	2	3	4	5	6	7
M	Y	1	$289.31	$355.97	$655.27	$1,143.64	$2,021.32	$3,446.94	$12,250.54
		>1	373.92	440.58	739.88	1,228.25	2.105.93	3,531.55	12,335.15
	0	1	418.23	484.89	784.19	1,272.56	2,150.24	3,575.86	12,379.46
		>1	502.84	569.50	868.80	1,357.17	2,234.85	3,660.47	12,464.07
F	Y	1	86.84	153.50	452.80	941.17	1,818.85	3,244.47	12,048.07
		>1	171.45	238.11	537.41	1,025.78	1,903.46	3,329.08	12,132.68
	0	1	215.76	282.42	581.72	1,070.09	1,947.77	3,373.39	12,176.99
		>1	300.37	367.03	666.33	1,154.70	2,032.38	3,458.00	12,261.60

[1] M = male
F = female

[2] Y = 40 and under
0 = over 40 years of age

[3] 1 = single injury
>1 = multiple injury

Data Source: North Carolina Workmen's Compensation File.

The model given in (4.2) includes all main effects and all interactions of injury groups with age, sex and extent. The interactions between injury categories are not of interest.

The multiple interaction model (4.2) is obviously much more complicated than the main effects model but, with an R^2 of 0.25, it contributes relatively little predictive power beyond the main effects model. In addition, this model is difficult to interpret. Therefore, a simpler two-way interaction model was explored in more detail which would still account for interaction effects but would be reasonably interpretable.

The two-way interaction model (4.3) predicted compensation awards essentially as effectively as the multiple interaction model (R^2 = .25). Since it is also more parsimonious, the two-way interaction model is preferred. Table 4.12 reports the regression coefficients (b_i's and b_{ij}'s) calculated for the model. The most striking observation about these coef-

Table 4.12 Main effects and interaction coefficients for the two-way interaction regression model (4.3) predicting compensation from age, sex, extent and injury category.

Variable	Coefficients			
	Main Effects (b_i)	Interactions (b_{ij})		
		Age	Sex	Extent
Category 1	$ -11,046.31	$ -2,850.08	$ 7,335.46	$ -6,643.76
Category 2	-10,992.12	-2,769.04	7,266.37	-6,605.95
Category 3	-10,672.99	-2,736.53	7,095.06	-6,621.87
Category 4	-10,174.22	-2,688.43	6,983.90	-6,619.84
Category 5	- 9,241.37	-2,615.75	6,384.14	-6,524.55
Category 6	- 8,008.40	-2,309.25	5,738.20	-6,348.07
Age	2,944.05			
Sex	- 7,390.57	- 78.16		
Extent	6,676.38	107.85	- 205.52	
Mean	11,323.62			

Data Source: North Carolina Workmen's Compensation File.

ficients is the difficulty in interpreting the coefficients associated with the age, sex and extent variables. Neither the main effect coefficients nor the interaction with injury categories coefficients can be interpreted separately to estimate their effect on compensation. This reduces the face validity of the model.

The models that have been investigated to this point have shown little variation in their ability to predict compensation awards. This suggests that interpretability should be an important factor in the selection of the final disability scale. The final scale must, however, include injury categories as a main effect. This variable consistently showed interpretable coefficients and accounted for most of the predictive power of the model. Including age, sex, and extent of injuries as main effects was less informative. These variables contributed little additional prediction in the main effects model and their main effect coefficients in the two-way interaction model could not be interpreted without examining the interaction coefficients. It is clear that these variables should be included in the final model, but it is not clear that they should be included as main effects. They might best be included only as interactive factors in conjunction with the injury categories.

To explore this possibility, a reduced interaction model was developed in which age, sex, and extent were included only as interaction terms -- they were not included as main effects. In addition, the coefficients obtained in the two-way interaction model indicated that, within the interaction effects associated with each variable, several injury categories could be grouped together. The coefficients were similar and the effects could be combined without loss of prediction. The age by injury interaction effects separated into three injury groups: 1; 2, 3, 4, and 5; and 6. Sex effects were similar in injury categories 1, 2; 3, 4; and 5, 6. Extent effects could be grouped together for injury categories 1 through 4; categories 5 and 6 had different interaction coefficients.

This reduced interaction model had an R^2 of 0.25. The coefficients calculated for this model are shown in Table 4.13. This model has similar predictive ability as the more complex interaction models that have been examined. It accounts for the interactive effects of age, sex, and extent yet is reasonably parsimonious. Thus, it was selected as the final disability scale.

Table 4.13 Regression coefficients for the reduced interaction regression model predicting compensation from age, sex, extent, and injury category.

Injury Category	Main Effects (b_i)	Interactions (b_{ij}) Age	Sex	Extent
1	-12,009.17	79.67	- 104.86	44.55
2	-11,984.79	212.73	- 104.86	44.55
3	-11,635.68	212.73	- 383.63	44.55
4	-11,141.19	212.73	- 383.63	44.55
5	-10,152.92	212.73	-1,097.17	179.53
6	- 9,037.15	529.68	-1,097.17	400.47

Mean = 12,294.26
Data Source: North Carolina Workmen's Compensation File.

Table 4.14 presents the predicted compensation awards for the various age, sex, extent, and injury category combinations. Several observations can be made from this table. Compensation awards increase with injury category. Males tend to be compensated at a greater rate than females and this difference increases with injury category. Older individuals are awarded more compensation than younger individuals. Multiple injury cases are assigned more compensation than single injuries. All of these effects were expected.

The compensation awards associated with Injury Category 7 require some explanation. First it should be noted that this category -- which represents amputations and other severely disabling injuries -- contains only 32 cases. This is not a sufficient number of cases to be able to reliably estimate the age, sex and extent effects on this category. Second, because of the way the model was originally defined (6 indicator variables for 7 injury categories), this category was calculated using only the mean and the age, sex, and extent main effects and their interactions. When these variables are not included (as in the reduced interaction model), no effects are left to act on Injury Category 7. Thus because of the small number of cases involving Category 7 injuries and the way the original model was constructed, the effects of age, sex and extent on Category 7 could not be estimated.

Table 4.14 Predicted disability amounts (in dollars) by the reduced interaction model for sex, age, extent and injury category combinations.

Sex[1]	Age[2]	Extent[3]	Injury Category 1	2	3	4	5	6	7[4]
M	Y	1	$285.09	$309.47	$658.58	$1,153.07	$2,141.34	$3,257.12	$12,294.26
		>1	329.64	354.02	703.13	1,197.62	2,316.87	3,657.59	12,294.26
	O	1	364.76	522.20	871.31	1,365.80	2,354.07	3,786.81	12,294.26
		>1	409.31	566.75	915.86	1,410.35	2,529.60	4,187.28	12,294.26
F	Y	1	180.23	204.61	274.95	769.44	1,044.17	2,159.95	12,294.26
		>1	224.78	249.16	319.50	813.99	1,219.70	2,560.42	12,294.26
	O	1	259.90	417.34	487.68	982.17	1,256.90	2,689.64	12,294.26
		>1	304.45	461.89	532.23	1,026.72	1,432.43	3,090.11	12,294.26

[1] M = male
F = female

[2] Y = 40 and under
O = over 40 years of age

[3] 1 = single injury
>1 = multiple injury

[4] Estimates cannot be made for the effects of age, sex, and extent on the compensation awards associated with Category 7 because of the small number of cases involving Category 7 injuries and because of the model formulation.

Data Source: North Carolina Workmen's Compensation File

Application to NCSS Data

The NCSS file provides an opportunity to validate the disability scale at an intermediate level by comparing the mean lost workdays for each injury category for the NCSS and the WCF. If, furthermore, similar relationships can be established between lost workdays and the different scale elements (age, sex, extent of injury and type of injury) for both data sets, then the prediction of compensation is probably valid--depending on the assignment of dollar values to lost workdays.

The critical variable in establishing a consistent relationship between the disability scale and lost workdays is the type of injury. Injury categories were found to account for almost all of the predictive ability of the independent variables. Table 4.15 reports the mean and standard deviation of the number of lost workdays as well as the number of cases in each injury category for both the NCSS and the WCF data sets. Clearly there will be difficulties in using the NCSS data to quasi-validate the disability scale due to the inadequate sample size of the NCSS data alone.

There are, however, two observations that are encouraging. First, the distribution of injuries among the seven injury categories is similar between the two data sets. With the exception of Category 3, the proportion of injuries in each category is roughly the same for both data sets. If it were found that the higher category injuries had proportionately more cases in the NCSS than the WCF, then the definitions of the injury categories would be suspect since less severe injuries are more frequent than severe injuries. This was not the case, however. Second, the relative size of the mean lost workdays was also similar between the two data sets again with the exception of Category 3. Thus the relationships between the injury categories in terms of their lost workdays is consistent between the two data sets. The exception of the third injury category to both of these relationships is not a great concern since only 7 NCSS cases had injuries that were in that category. Presumably with a larger sample the proportion of cases in this category would increase and the number of lost workdays associated with this injury category would stabilize at a lower figure.

In summary, the proportion of cases in each injury category and the relative number of lost workdays associated with each category were similar for the two data sets even though the data sets described two completely different populations of injuries. The NCSS data set was obtained from a sample of vehicle crashes. The WCF was obtained from a sample of industrial accidents. A larger number of cases is required if any further validity checking efforts are to be performed, however.

Table 4.15 Mean number (standard deviation) of lost work days and sample size by injury category for the WCF and the NCSS data files.

Data File / Injury Category	WCF			NCSS		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N
1	17.0	35.4	25,774	4.0	13.6	944
2	15.0	20.8	5,169	5.0	14.4	199
3	34.2	42.3	4,295	59.1	100.1	7
4	47.3	57.3	2,214	15.6	37.4	34
5	64.3	141.2	2,170	21.9	27.5	19
6	148.6	228.4	217	52.2	71.5	6
7	293.9	335.6	32	--	--	0

Application to RSEP Data

The disability scale was applied to the RSEP data for three reasons. First, because of the empirical nature of the final injury groups, the ability of these groups to accommodate a variety of injury classifications had to be ascertained. The scale's usefulness would be limited if injuries obtained from other data sets could not be categorized into body part and nature of injury combinations which were obtained on the WCF. Second, one aspect of the validity of any scale is the reasonableness of its assignments (i.e., is it face valid?) In this case, estimates of the effectiveness for various restraint systems are examined. If these estimates conform to expectations, then face validity is demonstrated. Finally, it is of interest to examine these estimates of restraint system effectiveness using disability estimates and compare them with estimates from other types of injury information (AIS or threat-to-life).

With respect to the first point, the conversion of the final disability injury categories into OIC codes was simpler than had been the case with the nine threat-to-life injury categories since there is a close correspondence between the body region and lesion portions of the OIC and the body part and nature of injury codes on the WCF. Some problems were encountered, however, with the wrist-hand code of the OIC, which was separated into two WCF codes, and therefore required combining. Also, the "unknown" or "other" codes on either file could not be matched since there is no way of ascertaining that they include similar types of injuries. Only 61 cases out of a total of 15,853 were not categorized into one of the seven injury groups. Each of these 61 cases contained an "unknown" or "other" value for either the body region or lesion portions of the OIC.

Regarding the second part, effectiveness estimates were calculated in the same fashion as in Chapter III using the threat-to-life estimates. They represent the proportional decrease in predicted compensation awards for the different restraint systems. The estimates are reported in Table 4.16. They appear reasonable except for some types of crash configurations. For example, the estimated effectiveness (-.43) of the lap belt vs no restraint in rollover crashes is suspect. However, it was based on only 14 crashes. On the whole, the disability scale appears reasonable in this particular countermeasure evaluation and offers additional insight into another aspect of injury consequences.

Discussion and Conclusions

The type of injury was by far the most important element of the disability scale. While it was anticipated that injury type would be a major factor in determining disability, the magnitude of the importance was unexpected. When only the injury types were included in the main effects model, an R^2 of 0.238 was obtained. Adding age, sex and extent to the model only increased the R^2 to 0.246. Including age, sex and extent in the model increased by less than one percent the proportion of variance in compensation awards accounted for by the model. Similar findings were obtained for every model that was explored.

Clearly for this data set, the injury groups define the basic compensation level and age, sex, and extent have only a minor effect on the

Table 4.16 Predicted compensation and restraint system effectiveness estimates using the RSEP data and the disability scale.

		Predicted Compensation for Unbelted Occupants	Effectiveness	
Variable	Level	Mean (Std. Dev.)	Lap Only	Lap & Shoulder
Sex	Male	209.84 (348.05)	.20	.27
	Female	193.51 (368.21)	.25	.30
Age	<25	178.83 (386.51)	.21	.28
	25-55	211.80 (319.68)	.22	.26
	>55	277.66 (359.57)	.33	.40
Car Size	Sub-Compact	213.97 (468.09)	.17	.28
	Compact	183.41 (256.31)	.24	.22
	Intermediate	206.42 (333.30)	.24	.28
	Full-Sized	206.27 (305.15)	.25	.39
Crash Configuration	Head-on	269.18 (310.31)	.23	.05
	Rear Striking	138.49 (198.71)	.20	.33
	Rear Struck	238.28 (271.40)	.02	.02
	Angle Striking	184.13 (280.16)	.10	.29
	Struck Left Side	226.65 (584.51)	.33	.34
	Struck Right Side	196.97 (287.99)	.38	.33
	Rollover	262.83 (505.69)	-.43	.40
	Sideswipe	137.98 (217.92)	.32	.16
	Head-on, Fixed object	240.55 (401.55)	.31	.39
	Side of car, Fixed object	211.66 (358.95)	.14	.21

predicted scale values. There were, however, some limitations on the age and extent distributions that may have reduced the effect of these variables.

Since the data used to construct the disability scale was obtained from a Workmen's Compensation File, only individuals who were in the work force were included in the sample. This clearly restricted the range of possible ages at both ends of the age distribution. Neither children nor persons beyond retirement age were included in the sample. This may have reduced the effect of age on disability.

The effect of the age restrictions, however, must be considered in light of the definition of disability. For this scale, disability was defined to be the compensation awarded to an individual who is unable to work because of an injury. Thus disability is directly associated with salary loss. Given this definition, the age restrictions on the sample may not be critical. Individuals who are not in the sample (under 15 and over 65 years of age) will typically suffer no loss of income because of their injury. Thus they should be assigned a disability scale value of zero. The disability scale for the individuals in the work force would remain unchanged.

If salary losses are interpreted more broadly, however, then these individuals should be assigned a non-zero disability value. For while the incoming salary of these persons may be unaffected, the injury may necessitate that home care be provided for these individuals. If a relative stays at home and cares for the individual, then clearly that individual loses income due to the disabling injury. Alternatively, any nursing care would have to be paid for. This could also be interpreted as a loss of income. Thus a broader and more meaningful interpretation of salary loss will require the assignment of a disability scale value to these individuals.

In applying the disability scale to the RSEP data file, disability was interpreted in the broad sense for individuals not in the work force. It was assumed that an injury that would lead to an individual not going to work for a certain number of days would also require additional home care for these individuals for the same number of days. In order to obtain an estimate for the salary losses associated with this home care, it was assumed that a parent (or child) cared for the injured child (or person of retirement age). Thus, a reasonable age assignment might be the age of the injured person plus (or minus) twenty-five years.

In addition to the age distribution restrictions, only 4.7 percent of the cases in the Workmen's Compensation File indicated that an individual suffered multiple injuries. This was a much smaller percentage than might be expected. For example, in the Illinois Trauma File approximately 90 percent of the file involved multiple injuries. Clearly, the effect of multiple injuries on compensation cannot be accurately estimated with this set of data.

In general, however, the disability scale has provided a reasonable estimate of the compensation awards associated with various combinations of injury type, age, sex and extent of injuries. If this scale was applied to similar data sets, then, at worst, the rank order of the compensation awards should be correct and with some confidence many of the ratios between assignments will be similar. The scale may require some additional refinement, however, if it is applied to data sets containing more frequent multiple injuries.

V. DEVELOPMENT OF A COST MODEL

Introduction

Chapters III and IV have described the development of threat-to-life and disability models for measuring the societal consequences of automobile accidents. However, one of the most effective measures for assessing the magnitude of these consequences and for evaluating the safety benefits of alternative countermeasures would be to determine total societal costs in dollars.

As mentioned in Chapter I, this measure has two basic components, direct and indirect costs or consequences.

After an extensive data search (described in Chapter II), it was possible to obtain reliable data on three significant cost components. They are: professional medical costs, hospital costs, and compensation for partial or total disability including workdays lost. No case-by-case data source was available for other cost components. Compensation for disability has been analyzed in Chapter IV. In the current analysis, professional medical costs and hospital costs were combined to obtain a total medical cost.

An important element in the direct cost component of an accident, not included here, is the damage to the accident vehicles. This damage is a function of the vehicle size, vehicle age, and some measure of the crash severity as indicated, for example, by the Vehicle Deformation Index. Unfortunately, existing accident data was found inadequate for predicting damage costs using crash severity ratings and other related variables. It is hoped that eventually NASS, with its accident severity indices, collision type, and vehicle make-model information, could provide some data for predicting vehicle damage costs.

The overall objective of the cost estimating procedures presented here was to derive medical cost tables for different injury types by place of treatment. This was necessary since it is widely recognized that the cost of treating an injury depends to a large extent on where the treatment is administered. In the current analysis three treatment locations were considered: hospital inpatient, emergency room, and doctor's office.

Thus, for a given case, if the injury type, age and sex of victim, and location of treatment were known, then the medical cost could be estimated from the appropriate table. The medical costs could then be added to the disability estimates provided in Chapter IV to provide an estimate of (direct) costs of injuries.

Figure 5.1 presents an overall flowchart for the procedures used in this chapter. The data adjustment details follow in the next several sections, while the estimation methods are described in the Procedure section.

Medical Cost Data

As mentioned in Chapter II, HSRC was able to acquire two medical cost data files, the North Carolina Workmen's Compensation File (WCF) and an insurance file from Blue Cross Blue Shield (BCBS) of North Carolina.

In the Workmen's Compensation File, a medical cost which includes both hospital and professional costs is available on a case-by-case basis. The Workmen's Compensation File had over 77,000 records covering 1969-1977 with about 99 percent of the cases from 1975 through 1977. Some of the records on the original Workmen's Compensation File contained cases with non-accident related claims such as asbesteosis or other occupational diseases, and some had no medical costs attached. These cases were excluded from the current analysis and a new file was created with about 72,000 records. Appendix C.3 shows the record contents for the Workmen's Compensation data.

Unlike the WCF which had a case-by-case record format, the original BCBS insurance file was claims-oriented. Thus, for one case there could be multiple claims submitted, representing different medical services. The file utilized (see Appendix C.4) is an extract of a larger BCBS claims file and contains only accident-related claims.

Since neither the WCF data nor the BCBS data satisfied all the cost model requirements independently, both were used. Thus, for example, the WCF data had no treatment location available, while, as discussed later in this chapter, the BCBS emergency room data was inadequate. The processing of the Workmen's Compensation File has been described in Chapter IV. The raw data was processed in two steps. In the first step, the data was recoded and, in the second step, records referring to the same injury for each individual were matched and grouped to form cases for that individual.

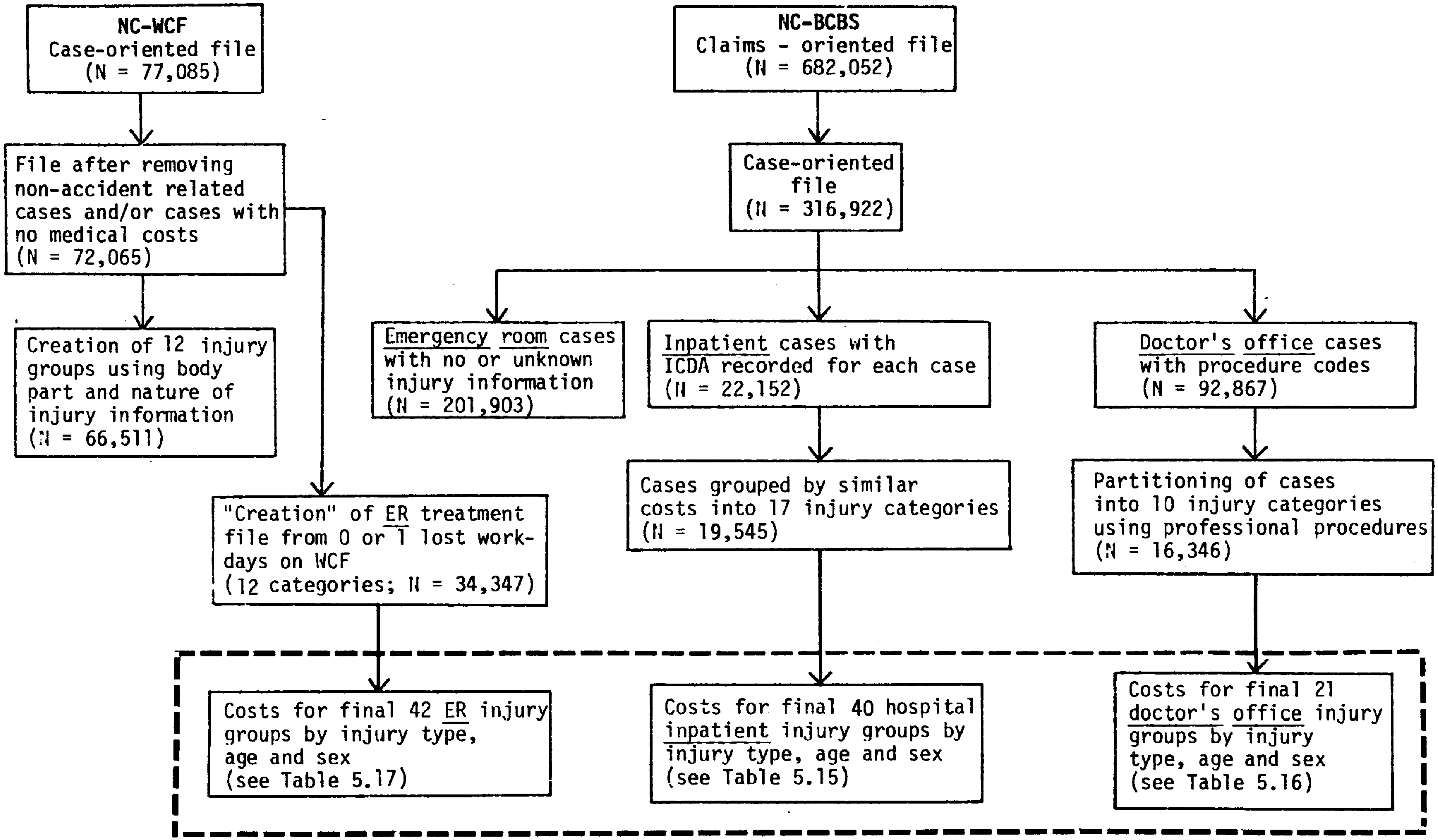


Figure 5.1 Overall scheme for determining medical cost consequences of injury by place of treatment, injury type, age and sex.

Recoding of BCBS data.

The raw data was recoded in order to create a file containing data which is relevant to the current application. The recoded file consisted of the following 13 items:

1. Identification key
2. Type record
3. Benefit code
4. Birth year
5. Age
6. Sex
7. Relationship to certificate holder
8. Diagnosis code
9. Treatment code
10. Number of days treatment
11. Beginning date of treatment
12. Ending date of treatment
13. Total charge

Age (Item 5) was computed from the year of birth as the age at the time of treatment (i.e., at the date given by Item 11), but rounded up to the next integer. The sex and relationship codes were separated for accessibility and usability. The number of days of treatment was computed as the number of days between the beginning date of service (Item 11) and the ending date of service (Item 12), including the first day but not including the last. The variable, "Days of service paid", provided no additional information, and therefore was not included in the recoded file. All other data items were left intact.

Matching BCBS records to form cases.

Each record in the BCBS file refers to one claim that was submitted to North Carolina Blue Cross Blue Shield for charges incurred for the treatment of an injury. Each claim represents some particular aspect of the treatment of the injury. Separate claims are submitted for hospital costs and professional fees. In addition, if a victim is treated by a physician several times over a period of days or weeks, several claims are often generated.

For the purpose of the present study, a case is defined to be the occurrence of an injury. From the above description, one can see that a number of claims may refer to the same injury. Therefore, claims must be matched in order to compute costs for the entire case.

The algorithm used to match claims was a heuristic procedure which was developed and tested on the first 3000 records on the file. Originally, the BCBS file was ordered according to the identification key, i.e., all records with the same identification (i.e., certificate number) key were grouped together on the file. However, two records with the same identification key could refer to the same case (i.e., the same injury and the same person), to different injuries for the same person, or to different persons covered by the same policy. To determine which of these possibilities was indeed the case, the following procedure was used:

1. If three of the following items -- birth year, sex, relationship, name -- matched for two records, then the two records were considered to refer to the same person; in addition,

2. If the beginning dates of service for the two records were within six weeks of one another, then the records were considered to refer to the same injury.

If <u>both</u> conditions are met, the records are considered to belong to the same case. The justification of this procedure is that it is unlikely that two different family members would have three out of the four variables identical, and it would seem fairly unlikely that the same person would suffer two different injuries requiring treatment by a doctor or hospital within six weeks.

The two possible errors that could occur in the matching process are: 1) to match records that refer to distinct persons or different injuries, and 2) to exclude records that refer to the same person and the same injury. There is no way, short of conducting a large scale investigation, to determine the extent of these errors; however, it is felt that the reasonableness of the matching criteria and the nature of the estimates of costs and days of treatment provide evidence that the matching process was substantially correct.

In the procedure discussed above to match BCBS claims to form cases, no satisfactory algorithm could be devised to identify cases with multiple injuries. This is because the original BCBS claims data had an injury code for the most severe injury only. Thus, when costs from claims are added to obtain case-costs, the cost data may be viewed as being total costs for the most severe injury, regardless of whether one or more injuries were sustained.

Hence, injury models based on this data may tend to overestimate injury costs. However, this overestimation would primarily affect the professional component of the injury cost since physician costs for treating injuries are basically additive. Hospital costs, on the other hand, are not as sensitive to the number of injuries. For example, number of days in hospital, an important hospital cost component, would depend primarily on the most severe injury being treated.

This case-oriented file has a total of nearly 317,000 records. For data analysis efficiency, however, this file was partitioned into three parts by place of treatment. The first data set contained slightly over 22,000 records referring to hospital inpatient cases. The second data set had approximately 200,000 records referring to emergency room cases, and the remaining nearly 93,000 records referring to doctor's office cases constituted the third data set. Appendix C.4 describes the contents for the case-oriented data file.

One difficulty with the BCBS file is that, for hospital records referring to emergency room treatment, an ICDA code is generally not given for the specific injury. Rather, a code is given which refers to "unspecified injuries." Thus it was necessary to create a substitute emergency room file from another data source. This is described in the section below.

Creation of an emergency room data set.

To derive cost estimates by place of treatment it was necessary to determine treatment location for each individual case. This has been described for the BCBS data in the previous section. The Workmen's Compensation data, however, had no information on place of treatment and therefore could not be correspondingly partitioned.

It was mentioned earlier that the approximately 200,000 emergency room cases from the BCBS generally had no diagnosis codes available, making this data per se essentially useless for cost modeling by injury type. Clearly, though, some estimates of emergency room treatment costs are necessary for an overall model of injury costs.

To overcome this deficiency, HSRC created an extract file containing over 35,000 records from the Workmen's Compensation data, by selecting only those cases where 0 or 1 workdays were lost. This restriction should exclude almost all inpatient cases but would include most of the emergency room-type WCF cases.

Table 5.1 presents the results of comparing the costs in the emergency room file created from the WCF data with costs in the approximately 36,000 cases from the BCBS emergency room data, using ridit analysis. The results show that a randomly selected case from the Workmen's Compensation emergency room file has a significantly higher cost than a randomly selected case from the BCBS emergency room data.

Table 5.1 Distribution of costs from BCBS emergency room data and "emergency room" extract from Workmen's Compensation file.

Cost $	Frequency of cases on emergency files BCBS	Derived from WCF
1-100	32,332	25,540
101-200	2,616	7,624
201-300	656	1,399
≥301	370	1,311
Mean ridit = 0.59		
Standard error of ridit = 0.0015		

Thus, by using the emergency room file extracted from the WCF data the medical cost would be overestimated. However, since no other injury cost data was available and since emergency room cases constitute a very significant fraction of automobile injury cases, this extracted file, with its known biases, was utilized in the cost analysis.

Note that, in this section, ridit analysis was used to compare the cost distribution instead of using the standard Chi-square procedure. This was done since, unlike Chi-square analysis, ridit analysis takes advantage of the natural ordering of the cost categories. In this application, the mean ridit for a group (WCF) may be interpreted as the probability that a randomly selected case from the group has a higher cost than a randomly selected individual from the standard group (BCBS). In this analysis no distribution assumptions are made. The only requirement is that the discrete categories represent intervals of an underlying continuous distribution.

Representativeness of cost data files.

The Workmen's Compensation File provides medical cost and compensation data for workers involved in accidents in primarily the manufacturing and construction industry in North Carolina. It therefore would exclude age groups that are unlikely to be in the working force, namely the very young and the very old.

About 35 percent of the North Carolina population is covered by some form of BCBS health insurance. According to BCBS of North Carolina, people of both sexes in the 20-29 and the 65 and over age groups are underrepresented. However, the under 20 and 30-64 age-sex groups follow the general population pattern.

The Industrial Commission of North Carolina, which administers the Workmen's Compensation Act, and Blue Cross Blue Shield of North Carolina both have schedules fixing fees that may be charged for medical and other costs. However, in spite of this upper limit, both the data files show large variances in costs within injury categories. In applying these injury costs to populations outside of North Carolina, the maximum fee schedules prescribed by the Industrial Commission and Blue Cross Blue Shield must be kept in mind. (See, e.g., DHEW Publication No. (HRA) 74-1766 for a discussion of medical cost differences by geographic region.)

Table 5.2 compares the age-sex distribution of the two cost data files with the North Carolina population (1970 census) and a 20 percent random sample from injured vehicle occupants in 1974. As expected, the WCF has males in the age group 25 through 54 overrepresented, while females are underrepresented across all age groups, when compared to both the accident and N.C. population distributions. In the BCBS data,

Table 5.2 Comparison of BCBS (inpatient and doctor's office data) and Workmen's Compensation data with the 1974 N.C. Accident File (20%) and the 1970 N.C. Census File.

Sex	Age	BCBS	WCF	'74 Accident File	'70 N.C. Population
Male	<25	33.7[1]	22.1	29.1	24.5
	25-54	20.1	50.0	31.1	17.1
	≥55	4.8	7.7	9.0	7.3
Female	<25	16.6	4.2	11.8	23.4
	25-54	17.6	13.1	15.3	18.2
	≥55	7.1	2.9	23.7	9.4
Total		38,498	68,800	39,271	5,082,059

[1]Column percent

the middle-aged males and females are adequately represented while as expected the older males and females are underrepresented. Surprisingly, young males are overrepresented while young females are underrepresented.

In developing a cost model, the independent variables included were age, sex and nature of injury (this could either be single ICDA codes or groups of ICDA codes combined together to form new injury classes). Hence, for a given case, the cost is not a function of the population from which this case was drawn, but depends only on its age, sex and injury classification. Therefore, for the cost model to be applicable to the population at risk, it is not necessary for the demographic characteristics of the risk population to be the same as the characteristics of the population from which the model was developed. The only requirement is that they be approximately similar and that for each age-sex combination in the cost model, the data files have adequate sample sizes in order that the model coefficients derived will be reasonably precise. Table 5.2 shows that the two cost files satisfy these requirements.

Procedure

As noted previously Figure 5.1 describes the overall scheme for determining medical costs for injuries from the BCBS file and the WCF. The initial steps in Figure 5.1 involved editing the Workmen's Compensation data and also creating case-oriented records from claims in the BCBS file.

The BCBS case-oriented file was partitioned into three segments by place of treatment -- the hospital inpatient file with about 22,000 cases, the emergency room file with over 200,000 records and the doctor's office file with nearly 93,000 cases. Next, since the emergency room file from the BCBS had no injury information available, it had to be replaced by an extract from the Workmen's Compensation file consisting of approximately 35,000 cases with 0 or 1 work days lost.

It has been mentioned previously that three different injury codes have been used on the two files available to HSRC for the cost scale modeling. The WCF has body part and nature of injury coded for each case, (see Table 4.2) while the BCBS file has ICDA codes for hospital inpatient cases and professional procedure codes for outpatients (doctor's office). Since the ICDA system is simpler than the professional procedure codes, and since the NCSS data has included ICDA as a data element, it was decided to first work with the BCBS inpatient data.

Table 5.3 shows the general trauma-related portions of the ICDA system while Table 5.4 displays, for example, the individual injury types included in Group 2 of Table 5.3, namely fracture of upper limb.

The overall strategy here was to combine those ICDA codes which had similar medical costs into more general injury groups. Thus, for example, it was possible to combine ICDA codes (900-907) into a single group as the medical costs for these eight ICDA codes were similar.

The optimal combinations of injury groups by cost were determined only for the BCBS inpatient data. This is because the ICDA coding system has but 200 possible trauma-related codes, whereas the Workmen's Compensation (Table 4.2) and the BCBS procedure codes have a vastly greater number of trauma-related codes. In addition, the procedure codes in the BCBS doctor's office cases are too detailed for a study of this nature. For

Table 5.3 ICDA codes for accidents.

Group	ICDA Codes	Injury Type
1	800-809	Fracture of skull, spine and trunk
2	810-819	Fracture of upper limb
3	820-829	Fracture of lower limb
4	830-839	Dislocation without fracture
5	840-848	Sprains and Strains of joints and adjacent muscles
6	850-854	Intracranial injury (excluding those with skull fracture)
7	860-869	Internal injury of chest
8	870-879	Laceration and open wound of head, neck, and trunk
9	880-887	Laceration and open wound of upper limb
10	890-897	Laceration and open wound of lower limb
11	900-907	Laceration and open wound of multiple location
12	910-918	Superficial injury
13	920-929	Contusion and crushing with intact skin surface
14	950-959	Injury to nerves and spinal cord
15	996	Injury, other and unspecified

Table 5.4 Injury types included in ICDA codes 810-819.

810	Fracture of clavicle
811	Fracture of scapula
812	Fracture of humerus
813	Fracture of radius and ulna
814	Fracture of carpal bone(s)
815	Fracture of metacarpal bone(s)
816	Fracture of one or more phalanges of hand
817	Multiple fractures of hand bones
818	Other, multiple, and ill-defined fractures of upper limb
819	Multiple fractures both upper limbs, and upper limb with rib(s) and sternum

example, code 0877 deals with the "fracture of femur neck with slipped epiphysis, no reduction, treatment by traction, bed rest, or cast application." On the other hand the coding system on the WCF is vague and too general for many of the injury types.

In order to use comparable injury classes for all treatment locations, it was necessary to determine which procedure codes for the BCBS doctor's office data and injury codes from the Workmen's Compensation data best describe the various injury classes formed from the inpatient ICDA codes. Since the number of injury classes was small (17 at most) for any of the injury files, the sample size of each class was adequate for examining effects of age and sex on medical costs. Also, the number of cells in the injury class by age by sex matrix was a manageable size for statistical analysis using standard programs.

Thus, for example, with the BCBS inpatient file, 17 injury classes by two sexes by three age groups yielded 102 cells. To test for differences in cost by injury class, age and sex, the GENCAT program (Landis, Stanish, Freeman, Koch, 1976) was used. Cells that had similar costs were combined, and final medical cost estimates were determined for each injury class by age and sex for the various treatment locations.

Determining injury classes from ICDA codes on BCBS inpatient data.

The ICDA coding system has, as shown in Table 5.3, almost 200 trauma-related codes. Ideally one would prefer a cost model that would provide injury costs for individual ICDA codes; however, because of data limitations, individual ICDA codes were combined to form more general injury groups.

In order to select ICDA codes to form injury groups with similar medical costs, various procedures were considered. Using standard clustering procedures on mean or median costs by ICDA would ignore the large sample variances (as shown in Table 5.5) which imply differing cost distributions across ICDA types. To overcome this problem, a two-step procedure was devised. First, for each group in Table 5.3, a distance matrix was constructed (see, for example, Table 5.6 for Group 2 involving fractures of the upper limb). Each element in the matrix represents the standardized distance between two ICDA groups, which takes into account

Table 5.5 Sample means ($\bar{X}$), standard deviations (s) sample sizes (N) for selected ICDA codes on the BCBS inpatient file.

ICDA	N	$\bar{X}$	s
810	198	$708.04	$638.41
811	39	842.57	841.80
812	417	1066.31	1097.25
813	776	874.16	1101.21
814	117	738.39	849.67
815	61	775.64	629.28
816	108	764.62	586.74
817	23	1191.02	1058.25
818	84	1466.68	2385.47
819	35	1542.36	1948.59

Table 5.6 Standardized distances[1] between ICDA codes included in Group 2, Table 5.3.

		ICDA (N)									
		810 (198)	811 (39)	812 (417)	813 (776)	814 (117)	815 (61)	816 (108)	817 (23)	818 (84)	819 (35)
ICDA	810	0.00	0.95	5.09	2.76	0.34	0.73	0.78	2.14	2.87	2.51
	811	0.95	0.00	1.54	0.23	0.67	0.43	0.53	1.35	2.13	1.97
	812	5.09	1.54	0.00	2.88	3.45	3.00	3.87	0.55	1.51	1.43
	813	2.76	0.23	2.88	0.00	1.54	1.10	1.59	1.41	2.25	2.01
	814	0.34	0.67	3.45	1.54	0.00	0.33	0.27	1.93	2.68	2.37
	815	0.73	0.43	3.00	1.10	0.33	0.00	0.11	1.77	2.54	2.26
	816	0.78	0.53	3.87	1.59	0.27	0.11	0.00	1.87	2.64	2.33
	817	2.14	1.35	0.55	1.41	1.93	1.77	1.87	0.00	0.81	0.89
	818	2.87	2.13	1.51	2.25	2.68	2.54	2.64	0.81	0.00	0.18
	819	2.51	1.97	1.43	2.01	2.37	2.26	2.33	0.89	0.18	0.00

[1]Standardized distance between groups i and j = $\dfrac{|\bar{X}_i - \bar{X}_j|}{\sqrt{\dfrac{s_i^2}{n_i} + \dfrac{s_j^2}{n_j}}}$

the sample sizes and variances of the two groups. Examination of these matrices suggest that some ICDA codes appear to have comparable medical costs and hence may be combined. Thus, for example, from Table 5.6, it appears that the ten ICDA codes could be collapsed into three classes as shown in Table 5.7.

Table 5.7 Comparable upper limb fracture ICDA codes.

Class	ICDA	N
1	810, 811, 813, 814, 815, 816	(1299)
2	812	(417)
3	817, 818, 819	(142)

In the second step, an analysis of variance was carried out to see if there were any significant differences within the combined groups as, for example, within each of the three classes in Table 5.7. To carry out this analysis, the General Linear Model Procedure from the 1976 version of the Statistical Analysis System (SAS) was used. Table 5.8, which presents the results of this comparison, shows that the hypothesis of equal means within Class 1 and within Class 3 may be accepted.

After several iterative applications of this procedure, including combining ICDA codes from different groups in Table 5.2, 17 injury classes, containing over 19,000 cases, were defined as shown in Table 5.9. The mean medical costs and standard errors from the BCBS inpatient data are also included in Table 5.9. This table shows that, for some injury classes such as Class 4 dealing with fractures of the spinal cord with lesion, there are few cases and the mean cost has a very high standard error. As a result, when models were fitted to these injury classes, the standard errors of the predicted costs were rather high.

Forming injury classes for Workmen's Compensation and BCBS doctor's office data.

For this portion of the study, the same injury classes developed in the previous section for categorizing injury data were utilized for the

Table 5.8 Sample comparison of mean costs within two injury classes.

Class 1. ICDA 810, 811, 813, 814, 815, 816				
Dependent Variable: Medical Cost.				
Source	d.f.	M.S.	F-Value	Pr>F
Model	5	1,200,729.30	1.3	0.26
Error	1293	921,408.06		
Total	1298			
Class 3. ICDA 817, 818, 819				
Source	d.f.	M.S.	F-Value	Pr>F
Model	2	926,109.19	0.21	0.81
Error	139	4,503,922.90		
Total	141			

Workmen's Compensation and the BCBS doctor's office files. This was necessary since the procedure used earlier on the ICDA codes could not be reliably used for the body part and nature of injury codes on the WCF or the procedure codes on the BCBS doctor's office file.

Table 5.10 shows the relationship between the 17 injury classes and the body part by nature of injury codes on WCF. Of the 17 classes, equivalent body part by nature of injury codes were available for 12 classes. Thus, for example, for injury Class 16, dealing with (internal) injuries to intra-abdominal and intrathoracic organs, no body part by nature of injury code exists. As shown in Figure 5.1, 66,511 cases covering 12 injury classes were coded on the WCF.

For coding the BCBS doctor's office data, (i.e., converting procedure codes to ICDA codes), considerable local medical consultation was required. Appendix D.4 contains a table which shows the derived relationship between the 17 injury classes and the professional procedure codes. Overall the professional procedure codes fell into 11 of the 17 injury classes. However, there were no actual cases involving injury

Table 5.9 Injury classification by ICDA; mean costs ($\bar{X}$), sample size (N) and standard errors (s.e.) as determined from BCBS inpatient data.

Injury Class	ICDA	Description	N	$\bar{X}$	s.e.
1	800-805,807,812 824-826	Fracture of skull and face bones, ribs, sternum, larynx, humerus, ankle, tarsal and metatarsal and toes	3,214	1,134.28	33.87
2	808,827,829,809, 817-819,860,861,866 874,875,877,879, 950-959	Fracture of pelvis, multp. lower limb, unspec. low. limb, mult. trunk, mult. upper limb, traumatic pneumothorax, inj. to heart & lung, kidney, open wound of neck, buttock, mult. & open wound of neck, inj. to nerves & spinal cord	1,078	1,597.13	81.27
3	810,811,813-816,840, 843,844,845,848 870-873,876,878	Fracture of clavicle, spacula radius, ulna, carpal & metacarpal, phalanges, sprains & strains of shoulder and upper arm, hip & thigh, knee & leg, ankle & foot, other sprains, eye injuries, other laceration of head, laceration of genital organs	2,459	805.65	25.55
4	806,828,852	Fracture of spinal cord with lesion mult. fractures of both limbs, subarchnoid, subdural & extradural hemorrhage without cerebral laceration or contusion	157	4,839.16	424.92
5	821,862-865,867	Fracture of femur (neck excld.), inj. to intrathoracic organ (excld. heart & lung), gastrointestinal tract, liver, spleen & pelvic organs	584	2,480.89	96.37
6	820	Fracture of neck of femur	559	2,189.82	82.63
7	880-884	Laceration & open wound of upper limb excld. amputation	578	861.61	36.96
8	822,823	Fracture of patella, tibia & fibula	1,003	1,296.67	44.98
9	830-834,837,838	Dislocation of jaw, shoulder, elbow, wrist, finger, ankle & foot	399	922.00	34.71
10	835,836,839, 900-907	Dislocation of hip, knee, others (excld. above). Laceration & open wound of multiple location	1,343	1,198.49	31.86
11	850,922,926-929	Concussion, contusion of trunk, finger, hip, thigh, leg & ankle, foot & toe(s), other (excld. face, eye, trunk, shoulder, elbow, etc.)	2,572	578.98	30.43
12	841,842,846,847, 910-918	Sprains & strains of elbow & forearm, wrist & hand, sacroilliac region, other parts of back, superficial injuries	2,905	646.98	11.71
13	890-894,996	Laceration & open wound of lower limb (except amputation), other injury	1,635	1,347.36	70.89
14	851,853,854	Cerebral laceration & contusion, intra-cranial hemorrhage, other intracranial inj.	358	1,898.45	245.79
15	885-887,895-897	Amputation of thumb, fingers, arm & hand, toes, feet & legs	159	1,255.62	159.24
16	868,869	Internal injury of intra-abdominal organs & intra-thoracic organs	141	3,435.03	382.75
17	920,921,923,924	Contusion of face, scalp & neck, eyes, shoulder & upper arm, elbow, forearm & wrist	381	404.04	23.16

Table 5.10 Relationship between ICDA codes and body part - nature of injury codes on Workmen's Compensation file.

Injury Class	Body Part	Injury Type
1	124, 130, 141, 146, 148, 149, 150, 160, 198, 199, 200, 311, 313, 410, 420, 430, 520, 530, 540	210
	130, 146, 149, 420, 520, 530, 540	162
2	440, 518, 519, 598, 318, 319, 398, 498	210
	440, 513, 515, 519, 900, 999, 598, 311, 313, 320, 330, 398, 315, 319, 340	162
	198, 200, 410, 430, 498, 499, 999	170
	840	995
	840	161
3	315, 320, 330, 340, 450, 144	210
	450	162
	130, 146, 149, 199, 311, 319, 410, 430, 440, 450, 511, 513, 515, 518, 519, 520, 530, 540, 598, 830, 900, 999	310
	121, 124, 130, 141, 144, 199, 146, 148, 149, 150, 160, 420	170
	121, 130	100
4	No equivalent codes	
5	No equivalent codes	
6	511	214
	511	162
7	311, 313, 315, 318, 319, 320, 330, 340, 450	170
8	513, 515	210
9	141, 313, 315, 320, 330, 340, 450, 520, 530, 540	190

Table 5.10 Continued.

Injury Class	Body Part	Injury Type
10	150, 200, 410, 420, 440, 513, 515, 519	190
	398, 598	170
11	110, 149, 150, 160, 198, 199	140
	330, 340, 398, 410, 420, 430, 440, 498, 499, 511, 513, 515, 518, 519, 520, 530, 540, 598, 900, 999	161
12	200, 313, 315, 318, 320, 330, 340, 398, 420, 498	310
	121, 124, 130, 141, 144, 146, 148, 149, 150, 160, 198, 199, 200, 311, 313, 315, 318, 319, 320, 330, 340, 398, 410, 420, 430, 440, 450, 498, 499, 511, 513, 515, 518, 519, 520, 530, 540, 598, 599	309
13	440, 511, 513, 515, 518, 519, 520, 530, 540	170
	900, 999	995
	900, 999	999
14	110	161
	198, 199	162
	110	170
15	311, 313, 315, 318, 320, 330, 340, 513, 515, 530, 540	100
16	No equivalent codes	
17	121, 124, 130, 141, 144, 146, 148, 149, 150, 160, 198, 199, 200, 311, 313, 315, 318, 319, 320, 450	161
	144, 330	140

Classes 4 and 15 on the BCBS doctor's office file. This was expected since, as shown in Table 5.9, these two groups deal with very severe injuries and hence are most likely to require hospitalization.

Using the scheme in Appendix D.4, only 7,350 of the nearly 93,000 cases on the BCBS doctor's office file were categorized into nine classes. Almost 67,000 cases were found to have no procedure codes! On checking this finding with BCBS personnel, this was said to be reasonable, since high volume - low claim cases are often processed as "0000", i.e., unknown. In addition, 8,996 cases on the BCBS doctor's office file involved lacerations, but these cases were excluded during the original matching since the procedure codes only distinguished lacerations by size (less than or greater than 2 inches), whereas the ICDA system has 28 codes for lacerations. In order to increase the number of effective cases in the doctor's office data set, a method was devised whereby these cases involving lacerations could be assigned an ICDA code and thus incorporated into the usable data pool. Essentially, this involved using the 2,361 laceration cases on the inpatient file as a basis for distributing the 8,996 laceration cases on the doctor's office file.

To accomplish this, the 28 ICDA codes on the inpatient file were ranked by their mean professional costs (see Table 5.11). Similarly, the laceration cases on the doctor's office file were ranked by their professional costs. It was then assumed that the distribution of laceration cases by ICDA was similar regardless of place of treatment. That is, if .64 percent of the laceration cases on the inpatient file were coded as ICDA 876, then .64 percent of the cases on the doctor's office file would have been assigned this same code. It was further assumed that the rankings by cost were similar. Thus, the 58 (.0064 × 8996) cases on the doctor's office file having the lowest professional costs were assigned ICDA 876 (ranked lowest on the basis of inpatient cost data), the next 130 cases assigned to ICDA 878 (ranked second lowest), etc. Using this approach, the number of cases available for the doctor's office cost modeling was expanded to 16,346, distributed among the ten injury classes.

Table 5.11 Ranking of ICDA codes involving laceration by mean professional cost from BCBS inpatient data for re-allocating the doctor's office laceration data.

ICDA for (lacerations)	Inpatient Inj. Group No.	N	Prop. of Total	Re-allocated Doctor's Office Lacerations
876	3	15	.0064	58
878	3	34	.0144	130
904	10	10	.0042	38
900	10	4	.0017	15
892	13	151	.0640	576
902	10	12	.0051	46
890	13	63	.0267	240
880	7	56	.0237	213
893	13	22	.0093	84
873	3	489	.2071	1862
870	3	120	.0508	457
879	2	199	.0843	758
894	13	26	.0110	99
877	2	15	.0064	58
874	2	36	.0152	137
891	13	249	.1055	949
882	7	121	.0512	461
884	7	22	.0093	84
907	10	148	.0627	564
871	3	25	.0106	95
901	10	14	.0059	53
875	2	87	.0368	331
881	7	149	.0631	568
905	10	10	.0042	38
883	7	231	.0978	880
872	3	34	.0144	130
906	10	17	.0072	65
903	10	2	.0008	7
Total		2361	1.0	8996

Comparison of BCBS and WCF costs.

In developing medical cost estimates in this chapter, both the BCBS and WCF data have been utilized. The BCBS data had treatment location information, but the emergency room data was essentially useless for cost modeling. To overcome this deficiency an "emergency room" file was created from the Workmen's Compensation data by extracting those cases where zero or one workdays were lost.

Thus as injury cost estimates have been derived from two independent data sources, it was of interest to compare the medical costs for similar injury classes from these sources. Accordingly, the combined BCBS inpatient and doctor's office data was compared to the WCF cost data, which does not distinguish place of treatment. (The emergency room component of the BCBS was not used because it did not have any injury information.)

Table 5.12 shows the mean ridits for the BCBS combined file when compared to the WCF data for various injury classes and age-sex combinations. The first column in Table 5.12 shows that the BCBS costs are higher overall. However, for some specific injury classes, (mostly fractures and lacerations of the extremities, Classes 2 and 7) the Workmen's Compensation file had higher costs. Part of this difference may be due to the fact that BCBS data is based on claims, while the Workmen's Compensation File represents actual medical expenses paid.

Development of a medical cost model.

After the common injury classes had been established for each of the data files, then (as shown in Figure 5.1) the inpatient file results in over 19,000 cases distributed among 17 injury classes, the doctor's office data set had 10 injury classes covering more than 16,000 cases and the emergency room file had over 34,000 cases with 12 injury types. This section describes the development of the final medical cost model for each of these treatment locations.

Since the number of injury classes was small, there were sufficiently many cases within each injury group to examine the effects of age and sex on medical cost for each treatment location. This was done by using a generalized categorical data analysis program called GENCAT.

Table 5.12 Mean ridits for BCBS costs when compared to Workmen's Compensation costs by age-sex and injury class.

Population Group	All Injuries	INJURY CLASS 1	2	3	6	7	8	9	10	11	12	13	14	15	17
MALES[1] 30-64	BCBS[2] 0.67[3]	BCBS 0.65	WC 0.48	BCBS 0.52	WC 0.41	WC 0.40	**[4] 0.51	BCBS 0.68	BCBS 0.63	BCBS 0.90	BCBS 0.86	BCBS 0.53	BCBS 0.76	BCBS 0.76	BCBS 0.84
ALL MALES	BCBS 0.60	BCBS 0.64	WC 0.39	WC 0.46	WC 0.36	WC 0.34	WC 0.48	BCBS 0.64	BCBS 0.54	BCBS 0.87	BCBS 0.88	WC 0.47	BCBS 0.65	BCBS 0.80	BCBS 0.86
ALL FEMALES	BCBS 0.64	BCBS 0.65	WC 0.39	** 0.50	** 0.47	WC 0.35	** 0.52	** 0.51	BCBS 0.57	BCBS 0.90	BCBS 0.89	** 0.49	** 0.48	BCBS 0.80	BCBS 0.89
TOTAL	BCBS 0.62	BCBS 0.63	WC 0.39	WC 0.48	WC 0.39	WC 0.34	WC 0.47	BCBS 0.60	BCBS 0.54	BCBS 0.88	BCBS 0.89	WC 0.47	BCBS 0.58	BCBS 0.81	BCBS 0.87

[1]This group was selected since it is the predominant group in the Workmen's Compensation file. (see Table 5.2)

[2]Indicates that a randomly selected case from BCBS data will have a higher cost than a randomly selected case from the Workmen's Compensation (WCF) data

[3]Mean ridit for BCBS data.

[4]No significant differences ($\alpha = 0.05$).

Thus, for example, the BCBS inpatient file with its 17 injury classes, two sex and three age (1-29, 30-64, 65 and over) groups had 102 cells. Table 5.13 shows these mean medical cost and standard errors by injury class, sex and age for inpatient cases. In Table 5.13, 13 cells were left blank because the number of observations in each of these cells was one or less and hence no reliable estimates could be obtained. The age-sex effects within each injury class were tested by setting up contrast matrices to investigate the following questions:

1) Was there a difference in cost by sex?

2) Was there a difference in cost between age groups 1 (1-29) and 2 (30-64) or between age groups 2 and 3 (65 and over)?

3) Same as 2 but within the same sex?

4) Was there a difference in cost between males age group 1 and females age group 1 or between males age group 2 and females age group 2 or between males age group 3 and females age group 3?

5) Was the age effect on cost dependent on sex?

If the resulting comparisons showed non-significant differences in the means, the cells being contrasted were able to be combined together for that particular injury class. Thus, for example the generic Table 5.14

Table 5.14 Illustrative interaction patterns for three injury classes.

Injury Class	Males			Females		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	A	B	C	A	B	C
7	D	D	D	D	D	No data
13	E	F	G	E	F	No data

shows that, for injury classes 1 and 13, sex had no effect on medical cost while age did. Thus cells for the corresponding age groups could be

Table 5.13 BCBS mean medical costs (standard errors) in dollars by injury class, sex and age for hospital inpatient cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	1092.17 (77.17)	1307.14 (72.69)	852.21 (401.70)	954.76 (47.07)	1186.95 (51.42)	545.92 (94.67)
2	1424.30 (128.21)	1859.26 (185.28)	673.60 (186.22)	1520.07 (153.20)	1585.73 (172.16)	2336.61 (1021.82)
3	789.56 (49.06)	967.96 (70.57)	436.69 (79.06)	666.95 (33.66)	809.42 (30.59)	578.87 (92.24)
4	7120.58 (1163.81)	4304.20 (538.30)	-	3235.32 (707.93)	3854.40 (638.90)	3292.01 (986.00)
5	2223.11 (130.53)	3098.99 (258.56)	-	2074.75 (191.82)	2728.22 (227.30)	2363.89 (726.93)
6	2064.31 (154.50)	2589.13 (236.54)	528.19 (261.81)	1775.73 (218.75)	2313.50 (123.72)	1931.07 (347.45)
7	892.09 (70.30)	855.44 (55.65)	1100.95 (424.93)	799.31 (63.60)	842.41 (95.22)	-
8	1165.86 (71.61)	1477.92 (99.72)	962.45 (342.09)	1130.82 (110.15)	1430.38 (91.64)	645.58 (120.72)
9	842.31 (36.20)	1011.21 (93.86)	-	927.58 (91.79)	1003.52 (87.35)	-
10	1046.84 (35.01)	1330.92 (87.46)	-	1179.64 (53.29)	1393.29 (88.11)	935.08 (441.95)
11	580.95 (63.32)	687.48 (59.08)	1002.38 (529.13)	463.57 (33.82)	603.47 (30.61)	454.29 (97.57)
12	502.02 (28.79)	623.39 (18.18)	351.10 (110.84)	636.12 (46.99)	708.82 (17.28)	409.81 (63.85)
13	1011.16 (116.46)	1104.79 (97.31)	712.06 394.20)	852.03 (93.61)	1093.14 (111.71)	-
14	2256.71 (438.88)	2039.00 (465.31)	-	1196.82 (321.32)	1388.63 (326.79)	530.60 (110.10)
15	1702.64 (322.39)	804.79 (97.44)	1231.98 (1159.98)	1611.32 (517.57)	571.41 (86.08)	-
16	3017.30 (613.30)	3871.50 (747.04)	-	3728.64 (997.64)	3137.77 (693.44)	-
17	369.25 (42.75)	471.04 (48.24)	-	346.38 (45.01)	472.68 (33.29)	-

- Indicates virtually no data available.

combined within each injury class (1 and 13). For injury category 7, age and sex had no effect on medical cost and hence all the cells in the second row in Table 5.14 could be combined.

Once the age-sex effects had been examined for all 17 injury classes, some comparisons were made to test for similarities in medical costs across injury classes. Thus, for those injury classes with comparable costs and similar age-sex effects, the corresponding cells were combined. For example, Table 5.14 showed that injury classes 1 and 13 had similar age-sex effects (i.e., an age effect but no sex effect). From Table 5.13, the cell means for these two injury classes for corresponding age groups appeared comparable and the significance test indicates that they could indeed be combined.

Table 5.15 shows the final mean medical costs and corresponding standard errors by injury class, sex and age for inpatient cases. The superscripts (ranging from 1 to 40) indicate the cells that were combined together.

Finally, an overall goodness-of-fit test was carried out to determine how well the 40 cell combinations predicted the cost for all injury classes by age and by sex categories. A Chi-square of 54.92 with 49 degrees of freedom and a p-value of 0.26 was obtained. This indicates that most of the medical cost variation in the 89 (=102-13) cells was accounted for by the 40 cell model.

Appendices E.1 and E.2 show the mean medical cost and standard errors by injury class, sex and age for doctor's office and emergency room cases. The procedure described above for inpatient cases was applied to these two treatment locations and the final results are shown in Tables 5.16 and 5.17.

Determination of "total" direct costs.

The two direct cost consequences of accidents that have been examined in this study are medical costs and disability payment, the latter including compensation costs for permanent bodily losses and lost wages. As mentioned previously, some other important cost consequences of accidents were not included because of data limitations. This section describes how the results of this study could be used to determine a "total" direct costs for a given injury.

Table 5.15 Medical cost estimates (standard errors) in dollars by injury class, sex and age for hospital inpatient cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	[1*] 1017.93 (44.42)	[2] 1209.29 (37.35)	[3] 662.78 (146.47)	[1] 1017.93 (44.42)	[2] 1209.29 (37.35)	[3] 662.78 (146.47)
2	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)
3	[7] 789.56 (49.06)	[8] 967.96 (70.57)	[11] 526.21 (65.42)	[9] 666.95 (33.66)	[10] 809.42 (30.59)	[11] 526.21 (65.42)
4	[12] 7120.58 (1163.81)	[14] 4099.95 (402.14)	-	[13] 3235.32 (707.93)	[14] 4099.95 (402.14)	[14] 4099.95 (402.14)
5	[15] 2184.44 (108.61)	[16] 2933.81 (174.52)	-	[15] 2184.44 (108.61)	[16] 2933.81 (174.52)	[16] 2933.81 (174.52)
6	[17] 1974.93 (126.39)	[18] 2408.11 (114.88)	[19] 528.19 (261.81)	[17] 1974.93 (126.39)	[18] 2408.11 (144.88)	[20] 1931.07 (347.45)
7	[21] 886.24 (26.07)	[21] 886.24 (26.07)	[21] 886.24 (26.07)	[21] 886.24 (26.07)	[21] 886.24 (26.07)	-
8	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)	[4] 1310.48 (59.96)	[5] 1602.93 (74.54)	[6] 1132.92 (300.70)
9	[21] 886.24 (26.07)	[21] 886.24 (26.07)	-	[21] 886.24 (26.07)	[21] 886.24 (26.07)	-
10	[22] 1046.84 (35.01)	[24] 1349.39 (64.82)	-	[23] 1179.64 (53.29)	[24] 1349.39 (64.82)	[24] 1349.39 (64.82)
11	[25] 541.66 (43.63)	[26] 645.15 (33.13)	[27] 697.89 (241.66)	[25] 541.66 (43.63)	[26] 645.15 (33.13)	[27] 697.89 (241.66)
12	[28] 502.02 (28.79)	[30] 623.39 (18.18)	[32] 388.28 (56.42)	[29] 636.12 (46.99)	[31] 708.82 (17.28)	[32] 388.28 (56.42)
13	[1] 1017.93 (44.42)	[2] 1209.29 (37.35)	[3] 662.78 (146.47)	[1] 1017.93 (44.42)	[2] 1209.29 (37.35)	-
14	[33] 1960.63 (329.80)	[34] 1782.43 (306.49)	-	[33] 1960.63 (329.80)	[34] 1782.43 (306.49)	[35] 530.60 (110.10)
15	[36] 1689.59 (285.11)	[37] 769.51 (81.38)	[37] 769.51 (81.38)	[36] 1689.59 (285.11)	[37] 769.51 (81.38)	-
16	[38] 3435.02 (382.75)	[38] 3435.02 (382.75)	-	[38] 3435.02 (382.75)	[38] 3435.02 (382.75)	-
17	[39] 362.27 (32.69)	[40] 471.87 (28.81)	-	[39] 362.27 (32.69)	[40] 471.87 (28.81)	-

* Superscripts indicate the cells that were combined in the modeling and thus have the same estimates.

\- Cells had virtually no data for reliable estimates. However, if medical cost estimates are required for these cells then the following approximation is recommended:

a) Use estimate from same age group from opposite sex, i.e., ignore sex effect.

b) If age group estimates missing in both sexes, use medical cost from next closest age category.

Data Source: BCBS inpatient file.

Table 5.16 Medical cost estimates (standard errors) in dollars by injury class, sex and age for doctor's office cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	[1]* 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)
2	[2] 26.45 (0.35)	[3] 28.58 (1.45)	[4] 23.50 (1.43)	[2] 26.45 (0.35)	[3] 28.58 (1.45)	[4] 23.50 (1.43)
3	[5] 58.51 (1.04)	[5] 58.51 (1.04)	[5] 58.51 (1.04)	[5] 58.51 (1.04)	[6] 91.64 (5.07)	[6] 91.64 (5.07)
5	[7] 192.70 (38.10)	[8] 57.00 (34.12)	-	[7] 192.70 (38.10)	[7] 192.70 (38.10)	-
6	[9] 200.24 (47.21)	[10] 703.00 (114.44)	[9] 200.24 (47.21)	[11] 483.44 (152.21)	[11] 483.44 (152.21)	[11] 483.44 (152.21)
7	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)	[12] 36.75 (0.26)
8	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)	[13] 109.75 (3.81)
9	[1] 79.82 (2.13)	[1] 79.82 (2.13)	-	[1] 79.82 (2.13)	[1] 79.82 (2.13)	[1] 79.82 (2.13)
10	[14] 51.77 (3.90)	[14] 51.77 (3.90)	[17] 29.50 (0.50)	[15] 41.97 (3.58)	[16] 75.16 (15.19)	[17] 29.50 (0.50)
13	[18] 21.67 (0.44)	[20] 24.85 (1.35)	[19] 20.56 (2.56)	[18] 21.67 (0.44)	[21] 29.89 (1.78)	[19] 20.56 (2.56)

* Superscripts indicate the cells that were combined in the modeling and thus have the same estimate.

\- Cells had virtually no data for reliable estimates. However, if medical cost estimates are required for these cells then the following approximation is recommended.

a) Use estimate from same age group from opposite sex, i.e., ignore sex effect.

b) If age-group estimates missing in both sexes, use medical cost from next closest age category.

Data Source: BCBS doctor's office file.

Table 5.17 Medical cost estimates (standard errors) in dollars by injury class, sex and age for emergency room cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	[1]*151.53 (38.32)	[3]217.98 (78.47)	[5] 89.00 (17.19)	[2] 96.25 (8.65)	[4]127.16 (18.42)	[6]257.00 (95.23)
2	[7] 87.60 (5.23)	[8]150.99 (17.81)	[8]150.99 (17.81)	[7] 87.60 (5.23)	[8]150.99 (17.81)	-
3	[9]112.83 (2.59)	[11]103.63 (33.72)	[12] 89.51 (9.80)	[10] 96.60 (7.68)	[11]103.63 (33.72)	[12] 89.51 (9.80)
7	[13] 84.41 (1.60)	[14] 97.38 (2.60)	[14] 97.38 (2.60)	[15] 67.02 (2.60)	[16] 79.50 (2.38)	[16] 79.50 (2.38)
8	[17]136.00 (21.54)	[18]171.01 (22.20)	-	-	[20]120.42 (15.99)	-
9	[17]136.00 (21.54)	[18]171.02 (22.20)	-	[19]179.45 (61.35)	[20]120.42 (15.99)	-
10	[21]146.00 (32.27)	[21]146.00 (32.27)	-	[22] 78.80 (9.69)	[23] 70.00 (16.95)	-
11	[24] 66.82 (1.68)	[26] 88.92 (5.63)	[25] 91.37 (9.80)	[24] 66.82 (1.68)	[27] 74.44 (2.82)	[25] 91.37 (9.80)
12	[28] 83.78 (3.14)	[29]117.09 (5.44)	[30]164.67 (65.44)	[28] 83.78 (3.14)	[29]117.09 (5.44)	[31] 70.75 (10.39)
13	[32] 69.59 (2.42)	[33] 93.60 (5.44)	[33] 93.60 (5.44)	[32] 69.59 (2.42)	[34] 76.76 (5.51)	[35]143.00 (19.44)
15	[36]168.95 (11.36)	[37]219.13 (20.25)	[38]115.44 (7.81)	[38]115.44 (7.81)	[39]165.52 (20.86)	-
17	[40] 70.91 (2.69)	[41] 94.80 (5.65)	[41] 94.80 (5.65)	[40] 70.91 (2.69)	[42] 82.49 (6.31)	[42] 82.49 (6.31)

* Superscripts indicate the cells that were combined in the modeling and thus have the same estimate.

\- Cells had virtually no data for reliable estimates. However, if medical cost estimates are required for these cells then the following approximation is recommended:

a) Use estimate from same age group from opposite sex, i.e. ignore sex effect.

b) If age group estimates missing in both sexes, use medical cost from next closest age category.

Data Source: WCF cases with zero or one workdays lost.

Table 4.13 presents the regression coefficients for determining disability costs given injury type, age, sex and extent of injury (multiple or single). Similarly Tables 5.15 - 5.17 present medical costs by injury type, age and sex for three treatment locations, inpatient, doctor's office, and emergency room.

To determine total costs for a given injury, the regression coefficients in Table 4.13 are used to derive disability costs and added to the medical cost determined from one of the three cost tables (Table 5.15, 5.16, or 5.17). Thus, for example, if the total cost were required for a case with ICDA 812 (fracture of the humerus), involving a 27 year-old female treated in a hospital, the following procedure would be used.

1. From Table 4.6 - injury type determined for disability model is 5
2. From Table 4.13 - age category is 0, sex category is 1 and extent is 0
3. From Table 5.9 injury category for medical cost model is 1
4. From Table 4.13:

Constant....................	$12,294.26
Injury effect...............	-10,152.92
Age effect (0) (212.73).....	0.00
Sex effect (1) (-1,097.17)...	- 1,097.17
Extent effect (0) (179.53)..	0.00

5. From Table 5.15 (for inpatient cases) medical cost.......................... 1,017.93

"Total" direct cost $ 2,062.10

The compensation cost for a case with multiple injuries may be determined by selecting the injury category (among those sustained by the individual) with the highest cost coefficient (lowest, if coefficients are negative) and by setting the extent variable equal to 1.

The medical cost for multiple injuries could be obtained similarly by selecting the injury with the highest medical cost. Another possibility is to add the medical cost for all injuries. It was mentioned earlier that the injury code on the BCBS data is given for the most serious injury and to some extent includes costs of other injuries. Hence, perhaps the most reasonable approximation would result from ignoring all lesser injuries. It is hoped that eventually a reliable set of medical cost data with information on multiple injuries would become available to study the sensitivity of the results using both procedures.

Thus, for example, to determine "total" direct costs for a 43-year old male with ICDA's 822 and 824 (fractures of the knee and ankle) and treated in a hospital, the following steps are required:

1. From Tables 4.6 and 4.8, injury type determined is 5 or 4.
2. From Table 4.13 age category is 1, sex category is 0 and extent is 1
3. From Table 5.9 injury category is 8 or 1
4. From Table 4.13:

Constant.....................	$12,294.26
Choose higher injury cost (lower if negative)	-10,152.92
Age effect (1) (212.73).......	212.73
Sex effect (0) (-1,097.17)....	0.00
Extent effect (1) (179.53)....	179.53

5. From Table 5.15 (for <u>inpatient</u> cases) medical cost from injury category 8 or 1 (select higher).................................... 1,602.93

"Total" direct cost	$ 4,136.53

The procedure used in the two examples in this section to determine "total" direct costs may be computerized. Thus, national cost estimates may be readily derived for single and multiple injuries for entire data files such as NASS and used to evaluate the effectiveness of various countermeasures.

Validation of Medical Cost Model

It was not possible to adequately validate the cost estimates developed in this chapter using the NCSS data that was made available to HSRC, since this data did not have <u>any</u> medical cost information. However, as hospital days were included in the NCSS data and since this variable has a major effect on the cost of treatment for <u>inpatient</u> cases, a comparison of hospital days on the BCBS <u>inpatient</u> file and the NCSS file by injury type constitutes a quasi-validation of the <u>inpatient</u> medical cost portion of the model. Lost workdays were also available and were investigated in Chapter IV.

It was mentioned earlier in Chapter III that the available NCSS file had 1320 accident records containing information on 2,795 occupants.

Unfortunately, for over 1,000 occupants no injury information was coded when, according to the police report, some level of injury was sustained. Table 5.18 shows the percentage distribution of occupants by injury

Table 5.18 Percentage distribution of NCSS cases (occupant orientation) by injury information, age and sex.[1]

Sex	Age	Injured-Injury Type Coded	Injured-No injury Type Coded	Not Injured	
Male	1-29	34.11	35.53	44.72	
	30-64	14.79	15.68	17.13	
	≥65	3.63	3.00	3.45	
Female	1-29	25.94	27.69	23.71	
	30-64	17.38	15.78	9.70	
	≥65	4.15	2.32	1.29	
Total		771	1,033	928	2,732

[1]63 cases had no sex or age information and have been excluded from this table.

information, age and sex. Although a major portion of the injured occupants have no injury-type information coded, Table 5.18 shows that there was no age or sex bias in recording injury type.

Table 5.19 presents the percentage distribution of the weighted NCSS and the BCBS <u>inpatient</u> cases by injury class. For some injury classes Table 5.19 shows that the NCSS data had very few cases. A comparison of the distribution of hospital days by injury class for the NCSS weighted data vs. the BCBS inpatient file showed that, except for injury classes 3 and 12, where BCBS <u>inpatient</u> cases had higher hospital days, there were no significant differences. Some comparisons were non-significant because of small sample sizes on the NCSS file. In addition, where all injuries were combined, the BCBS <u>inpatient</u> file had significantly higher hospital days.

In summary, because of the limited number of cases currently recorded on the NCSS file, no conclusive results could be derived from these quasi-validation procedures. However, it is hoped that eventually a reliable source of medical cost data will become available for further development and/or validation of the cost models presented in this chapter.

Table 5.19 Percentage distribution of NCSS and BCBS cases by injury class with mean ridits for NCSS hospital days when compared to BCBS inpatient hospital days by injury class.

Injury Class	Percentage Distribution NCSS	BCBS (inpt.)	Mean Ridit	Standard Error of Ridit	Significance
1	19.33	16.46	0.48	0.04	*[1]
2	8.55	5.52	0.55	0.06	*
3	24.91	12.59	0.41	0.04	BCBS[2]
4	1.12	0.80	0.33	0.17	*
5	8.18	2.99	0.51	0.06	*
6	1.12	2.86	0.63	0.17	*
7	0.37	2.96	0.23	0.29	*
8	2.97	5.14	0.49	0.10	*
9	2.23	2.04	0.33	0.12	*
10	1.86	6.88	0.58	0.13	*
11	17.47	13.17	0.41	0.05	*
12	4.46	14.88	0.23	0.08	BCBS
13	1.49	8.37	0.37	0.14	*
14	2.97	1.83	0.63	0.10	*
15	0.00	0.81	-[3]	-	-
16	0.00	0.72	-	-	-
17	2.97	1.95	0.43	0.10	*
Total	269	19,525	0.44	0.02	BCBS

[1]No significant difference (α=0.05) in distribution of hospital days.

[2]A randomly selected case from BCBS with injury category 3 will have longer hospital stay than a randomly selected case from NCSS data with injury category 3.

[3]No comparison possible.

Discussion

The medical cost estimates in Tables 5.15 - 5.17 are primarily affected by injury type, with age and sex having secondary effects. Thus, for those injury × sex × age combinations for which no cost estimates could be determined because of inadequate data, the approximations recommended at the bottom of the cost tables would seem reasonable.

Secondly, Tables 5.15 - 5.17 show that for many injury classes the medical cost estimates are lower for people 65 years old and over than for the two other age groups. The low estimates for this age group could be because BCBS receives only those portions of claims not covered by Medicare. In general, for people 65 and over covered by Medicare and also having a policy with BCBS, hospitals forward a claim first to Medicare and then subsequently to BCBS for supplemental coverage. Hence, cost estimates based on BCBS claims for this age group are generally underestimated.

The cost of medical treatment varies considerably with geographic region. Hence, the cost estimates developed in this study may not reflect actual costs for regions other than North Carolina; however, the relative costs would be expected to be retained. Thus, these estimates may be used to assess the safety benefits of alternative countermeasures regardless of geographic location.

Finally, it should be noted that a major limitation of the injury cost data used in this study is in the area of multiple injuries. This is because the data had an injury code for the most severe injury only, so that only this single most severe injury was incorporated in the scale. Nevertheless, the procedure recommended in the example illustrating the determination of "total" direct costs for cases with multiple injuries appears to be a reasonable approximation for such multiple injury cases. It is hoped that in the future additional medical cost data with information on multiple injuries would become available so that the cost model in this section could be refined to estimate costs for multiple injury cases with greater precision.

VI. SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

Summary

This research has been carried out to expand the usefulness of accident data for safety systems analyses. This improvement was sought by devising, calibrating and then validating several injury scales which will, in turn, reliably predict "societal" consequences of motor vehicle accidents. These scales were constrained to utilize field data elements that are easily obtainable in Level 2-type accident investigations, readily automated, and compatible with existing medical codes on non-accident data files. Finally, the research experience was documented in a form which should provide valuable injury-related input to NHTSA in their evolution of the National Accident Sampling System (NASS).

To begin the research, a detailed literature search was carried out covering over 100 articles dealing with scaling in general (i.e., properties of a reasonable scale, procedures for developing scales) as well as with specific scales developed in areas of traumatic injuries and diseases. In contrast to the current effort, the vast majority of existing scales are not based on actual case-by-case injury data -- in fact, many have resulted from medical concensus.

Three classes of scales were explored, each of which measured a different aspect of injury consequences. Specifically, the candidate scales were threat-to-life, disability (as measured by financial consequences rather than the more traditional activity limitations), and direct costs of injuries (eventually accounting for medical and disability costs).

The development of the corresponding models required case-by-case, automated data in as great a quantity as feasible on the following types of variables:

1. Type of accident
2. Injury description (ICDA, AIS, OIC)
3. Consequences (fatality or disability or medical costs)

4. Demographic characteristics of the victim (age, sex, previous medical condition)

An extensive search for data sets meeting the majority of these requirements led to the conclusion that no existing data sets even begin to approximate these stipulations. As a result, the research required a variety of assumptions using the most appropriate data sets that were available. (The alternative of a prospective study collecting all of the required data in sufficient quantity certainly was not realistic!)

With these caveats in mind, two threat-to-life scales were developed using data primarily from the Illinois Trauma Registry. The 14-point ICDA threat-to-life scale predicts the probability of a fatality prior to release from the hospital as a function of specific primary injury, age of occupant, and the extent (or number) and severity of secondary injuries. The estimation of these unconditional probabilities required additional information on dead-at-scene (DAS) and dead-on-arrival (DOA) cases. This information was obtained from data provided by the N.C. Medical Examiner's Office.

Briefly, the analysis procedure first involved grouping ICDA codes according to the following criteria: (1) Injuries within a group were of a similar medical nature; and (2) the proportions of people who died did not differ significantly among the ICDA codes within the group. Next, interactions of the resulting injury groups with each of three subsidiary injury variables (extent, pre-existing condition, and severe secondary injury) and with age of occupant were examined and the important ones accounted for. For example, if the proportion dying in a given injury group differed according to the age of occupant, then the age by injury interaction would be important to include in the scale. Finally, CHAID (automatic interaction detection program for categorical data) was utilized to provide the 14-point ICDA threat-to-life scale given in Table 3.8.

The 9-point AIS threat-to-life scale predicts the conditional probability that death will result given that the individual does not die before reaching an initial treatment facility. It is particularly useful with accident data since it is generally known if the occupant is DAS or

DOA. The scale is calibrated using the Illinois Trauma Registry data and is a function of the AIS severity score, the extent (or number) of injuries, and the age of the victim. The resulting 9-point AIS scale is given in Table 3.10.

The disability scale predicts compensation awards (i.e., compensation for lost workdays and permanent bodily loss such as through amputation) associated with acute or traumatic injuries. It is calibrated using data from the N.C. Workmen's Compensation File (WCF) and is a function of age and sex of accident victim along with the corresponding injury information in the form of body part by nature of injury.

A variety of approaches were investigated for grouping the various body part by nature of injury combinations on the basis of compensation paid. Of those examined, the preferred technique was a hierarchical clustering technique which clustered injury groups on the basis of similar compensation distributions as determined by the median and upper and lower quartiles. Seven injury clusters were selected which had similar compensation distributions within clusters but differing distributions among clusters.

The development of the disability scale was carried out by fitting various multiple regression models to the compensation data. The independent variables included the seven injury clusters, age and sex of occupant and extent of injury (single or multiple injuries). As the more general model with higher order interactions added little to the proportion of the compensation variability already accounted for by the model with main effects for injury category and various two-way interactions, the latter was selected as the preferred disability scale. See Table 4.14 for the components of this scale.

The goal of the final scale was to predict overall cost consequences of traumatic injuries. It became apparent all-too-soon that, at best, adequate case-by-case data was available to predict the major direct costs only. Thus, the cost scale predicts a combination of medical costs (by place of treatment) and disability consequences. The cost scale is calibrated using mainly data from Blue Cross Blue Shield (BCBS) of North Carolina with supplementary data from the N.C. Workmen's Compensation File. It is a function of the individual's primary injury along with his age and sex and the extent (or number) of his injuries.

Basically, starting with the hospital inpatient file where ICDA was available, injury types were grouped by costs first on the basis of standardized distance matrices and then by testing for similarities within groups using analyses of variance. Next, as age and sex clearly interact within injury groups to provide differing cost estimates, the final 102 cells, formed by the cross-classification of 17 ICDA groups and 6 age-sex groups, were examined to determine which cells, if any, could be combined. This investigation was carried out using a generalized weighted least squares procedure for categorical data (GENCAT). The final inpatient medical cost components of the scale are shown in Table 5.15. A similar procedure was followed for the doctor's office data and for the emergency room data (see Tables 5.16 and 5.17, respectively). In the latter case, extrapolations from the WCF were required as the BCBS emergency room cases generally lacked injury data.

The final cost scale then predicts a combination of disability compensation from Table 4.14 and the respective place of treatment medical costs from Tables 5.15, 5.16, or 5.17. The prediction of medical costs for multiple injuries is illustrated in the report.

Validation of the derived scales was carried out to the extent the data allowed. To examine face validity of the threat-to-life and disability scales, the predicted scale values were applied to the Restraint Systems Evaluation Program (RSEP) data in re-calculating belt effectiveness estimates. For the most part, the results were reasonable.

Finally, quasi-validation was carried out on the first 1320 accident cases of the National Crash Severity Study (NCSS) data. For example, the lost workdays by injury group distribution for the two files (WCF vs NCSS) were compared. Although severely limited by data quantity on the NCSS, the distributions appeared fairly similar; likewise for days of hospitalization. However, with the paucity of the data, conclusions regarding the validity of any of these scales are tenuous at best.

Recommendations

The major impediment to this study has been a lack of adequate medical and/or cost data in existing data sources in the United States. There appear, for example, to be no automated files which can provide case-by-case cost information together with age, sex, complete injury descriptions (using ICDA, AIS, or OIC), place of treatment, professional procedures used, and some measure of consequences (such as days in hospital, workdays lost or extent of disability). The data sources identified and used in this project had only subsets of these data elements. Even the various subsets included examples of all of the major injury classification schemes rather than a single, commonly-used classification scheme.

Coupled with these limitations is the fact that none of the data sets could be deemed to be nationally representative -- Workmen's Compensation data excluded the young people, elderly and housewives; the Illinois Trauma Registry included the generally more serious cases than those seen at non-trauma center hospitals.

Nevertheless, the study was carried out using these less-than-ideal data sets as they appeared to be the best available. Adjustments were made wherever possible to reduce these deficiencies in the data. However, the data required to more adequately carry out injury scaling research has yet to be collected.

Along these lines, it would appear that either the CSS (Continuous Sampling System) of the NASS (National Accident Sampling System) or an ambitious (longitudinal) Ancillary Study within NASS would hold the most promise for providing the required data on a national basis with sufficient case-by-case information using a common injury classification scheme. However, such a study should only be carried out after we have learned all we can from the RSEP, NCSS, and NASS I efforts.

As HSRC has been involved in the analysis of both RSEP and NCSS data and has followed the evolution of the NASS program over the past several years, we have seen numerous improvements made in a variety of areas. The following recommendations are offered in the spirit of hopefully continuing this improvement in the areas of overall system management, sampling, training, and data collection (with special emphasis on injury and its consequences).

Overall management of CSS program.

For maximum efficiency and leverage, having the accident investigation teams contract directly with their Zone Center rather than with the National Center for Statistics and Analysis (NCSA) should be considered.

The selection of a quality control contractor (CALSPAN) for NCSS was clearly an improvement over RSEP which had no quality control contractor. CALSPAN was to be responsible for making sure that:

1. Field data collection efforts were efficient and consistent with the overall experimental design and strategy of the data collection teams.

2. Field personnel adhered to a correct and consistent interpretation of field data elements.

3. The field data were accurately and completely coded using a common set of guidelines for definition and format.

To facilitate these tasks, the field and summary data forms were designed by CALSPAN.

From the monthly progress reports of CALSPAN, it appeared that these tasks could have been better carried out by having the seven teams directly responsible to CALSPAN. The same will likely be true of the current NASS I program where CALSPAN will be the Zone Center for six teams and Indiana University for four other teams. By the time the NASS program reaches the proposed 35 to 60 teams, it would seem impossible for NCSA to adequately supervise the individual teams. Instead, NCSA could contract with the Zone Centers to have them supervise the half dozen or so teams in their respective zones.

Sampling procedures for CSS investigations.

At the outset, the towaway threshold (as redefined in NCSS to mean that the vehicle could not be driven from the scene) provides a better-defined and a more reasonable sampling frame for candidate Level 2 investigations. The uniform sampling definition for all teams should guarantee consistency from team to team in their sampling procedures.

Secondly, serious consideration should be given to the weighted sampling scheme to be used in the eventual CSS. This is currently being done under contract to NHTSA. Of paramount importance is that teams do not arbitrarily deviate from the designated sampling strategy as happened in the RSEP. Likewise the sampling fractions to be used are of utmost importance since stratification is primarily useful for reducing the variance in the key statistics of interest -- generally in accident analysis the key statistics pertain to the more severe accidents. These considerations are certainly evident in the NCSS sampling scheme which is as follows:

1. 100 percent of those accidents involving the transport to a treatment facility and overnight hospitalization or death of at least one towaway - involved occupant;

2. 25 percent systematic random sample of accidents which involve transport of at least one towaway - involved automobile occupant to a treatment facility but not hospitalized overnight;

3. 10 percent systematic random sample of all other police-reported towaway accidents.

On the basis of the first 1320 acceptable NCSS cases, this stratification appears reasonable in that the investigations are fairly uniformly distributed over the three categories (38.8%, 25.6%, and 35.6%, respectively). If this trend continues, national estimates based on NCSS data will be reasonably valid. An unusually low percentage in any of the three groups could produce a dramatic effect on the corresponding estimates.

Perhaps the major recommendation here is that continued monitoring be carried out by NHTSA pertaining to the cases sampled by CSS. If gross deviations appear in any one of the three groups, a revision of the sampling scheme might then be in order.

Training and the overall data forms for the NASS I program.

Advanced planning along with team training has improved from RSEP to NCSS to NASS I. Fairly extensive training of the investigation teams is essential if there is to be reasonable intra- and inter-team consistency in the data provided. In the NCSS program, there was no formal training in investigation and reporting procedures until November 1977, long after accident investigations had begun. However, with NASS I, there was a five-week formal training session prior to the data collection phase. This was crucial since more than likely these same teams investigating accidents in the ten probabilistically-selected geographic regions will be retained as NASS continues to evolve.

In the area of data forms, there have also been noticeable improvements. Initially, RSEP teams had varying field forms from which data was transcribed (as well as possible) onto a common summary form. Although all of the field forms for the NCSS were identical from team to team, there was still a summary form which required the transcription (and loss) of data before submission to CALSPAN and eventually to NCSA. However, NASS I has eliminated the need for a summary form by designing the field form so that the data can be processed directly (as would be recommended by HSRC). This eliminates transcription errors in filling out the summary forms and allows for more data to be captured on computer for equivalent costs.

Data elements on the CSS field forms.

The final area of recommendations includes input to the current version of the CSS data collection efforts - particularly in the area of injury and disability data. The recommendations were based on a study of primarily the CSS Person Form, our work with the data bases when we developed the various scales (see Chapters III, IV, and V), and our efforts to validate the scales using the initial 1320 cases on the NCSS file.

The CALSPAN monthly reports and the initial NCSS data indicate that injury data is especially difficult to obtain. This is at least partly due to the fact that injury data obtained via interview has not in the past been recorded unless there is also a medical report from the hospital. Allegedly the hospitals are reluctant to release the information for fear of malpractice suits. Often the investigator is "unable" to track down the medical report from the treatment facility. Whatever the reason, this resulted in 39.7 percent of the 2795 occupants having no injury information (OIC, AIS, or ICDA) in the available NCSS file.

HSRC would recommend that injury information from the injured person be recorded regardless of whether or not a medical report was available, with an indication of the source of information. This is consistent with NHTSA's NASS I mode of operation. Obviously, the medical information would supercede the interviewee injury information. At some point, a study should be carried out comparing the reliability of the two sources of injury information.

Regarding the number of injuries recorded, HSRC would recommend that it is sufficient to record up to the three most serious injuries along with the total number of injuries. This information will more than suffice for utilizing the three types of scales developed in the present research. Costs along with coding and recording errors increase with the demand for additional information. In addition, the majority of the cases have indicated fewer than three injuries, so for these cases, there would not be any loss of information with the proposed cut-off.

Certain types of information required a waiting period before such information could become available. In the initial 1320 NCSS cases, 21.9 percent, 5.2 percent and 27.9 percent of the cases had an "unknown" code for lost workdays, hospital days and days restricted to bed, respectively. Evidently this follow-up data is difficult to obtain. It would seem that special emphasis by the Zone Centers in their training programs should be placed on the importance of obtaining this information. The "contract" leverage might also be of help here.

With respect to the Occupant Injury Classification, this injury scaling research has shown a need for splitting the "wrist-hand" code and the "ankle-foot" code (e.g., "wrist", "hand"). This need arose when using the body region-to-ICDA mapping in developing the disability and medical cost scales. Similarly, "eyes-ears" could be separated without essentially increasing the costs of computer storage.

A variety of levels within variables are not mutually exclusive. Examples of these pertaining to the injury variables include the following: head or neck vs face; upper extremities (arm) vs arm (upper); lower extremities (legs) vs leg (lower); right aspect vs anterior/front.

Although these are often used and established codes, they can cause unnecessary ambiguity for the investigators and can lead to inconsistency in the coding. However, they could easily be revised.

The list of specific recommendations in other areas could continue at length. In summary, however, many improvements have occurred in the evolution of NASS while some more are indicated. Certainly with the investment in this program -- past, current, and future -- careful appraisal and continual improvement of the program is a must.

Conclusions

In conclusion, acknowledging the limitations on the data used to calibrate the scales, it is felt that each of the scales provides at least a reasonably sound ranking of the corresponding societal consequences (threat-to-life, disability, medical cost) of various types of traumatic injuries. With an "ideal" data source, the scale values (or predicted societal consequences) might shift but the relative magnitudes would be expected to be retained. The injury effect in each scale played the dominant rôle in predicting the corresponding societal consequences. Particularly with the disability and medical cost scales, age and sex of occupant played lesser roles.

The scales are similar in that they all are functions of injury category and age; sex is utilized in the disability and medical cost scales, while extent (or number) of injuries is differentially important to each scale depending on the data source from which the scale was calibrated.

Biases and limitations in the scales derive primarily from the assortment of data sources used to calibrate the scales. The problem of multiple injuries remains unsolved with the disability and the medical cost scales since the data sources (WCF and BCBS) had little if any information on multiple injuries. To adequately account for the effects of combinations of injuries would require much larger, more detailed data sources than were available. Finally, as a variety of injury classifications (ICDA, AIS, OIC surgical and professional procedure, body part by nature of injury) were used, mappings between injury classifications became necessary. To the extent that these mappings assigned injuries to the "correct" combined injury groups, there would be no biases in this process. However, the extent of such biases is not known at present.

REFERENCES

American National Standards Institute. Manual on Classification of Motor Vehicle Traffic Accidents. National Safety Council, 1970.

Barr, A.J., Goodnight, J.H., Sall, J.P., and Helwig, J.T. A User's Guide to SAS-76. SAS Institute Inc., Raleigh, N.C., 1976.

Boyd, D.R., Lowe, R.J., Baker, J. and Nyhus, L.M. Trauma registry: New computer method for multifactorial evaluation of a major health problem. Journal of the American Medical Association, 1973, 223 (4), 422-428.

Commission on Professional and Hospital Activities. Hospital Adaptation of ICDA, v. 1, 1973.

Dixon, W.J. BMPD Biomedical Computer Programs. Los Angeles: University of California Press, 1975.

Hall, R.G. Fact Book: A Summary of Information about Towaway Accidents Involving 1973-1975 Model Cars. Final Report, NHTSA Contract No. DOT-HS-5-01255, 1976.

Johnson, S.C. Hierarchical clustering schemes. Psychometrika, 1967, 32, 241-254.

Joint Committee of the American Medical Association, The Society of Automotive Engineers, the American Association for Automotive Medicine. The Abbreviated Injury Scale (AIS), 1976 Revision.

Kass, G.V. Significance Testing in, and Some Extensions of Automatic Interaction Detection. Unpublished Ph.D. thesis, University of the Witwatersrand, 1975.

Landis, J.R., Stanish, W.M., Freeman, J.L., and Koch, G.G. A computer program for the generalized chi-square analysis of categorical data using weighted least squares (GENCAT). Documentation in the Department of Biostatistics, University of Michigan, Ann Arbor, Michigan, 1976.

Moien, M. Patient charges in short-stay hospitals. DHEW Publication No. (HRA) 74-1966. Vital and Health Statistics - Series 13 - No.15., 1974.

Reinfurt, D.W., Silva, C.Z., and Seila, A.F. A Statistical Analysis of Seat Belt Effectiveness in 1973-1975 Model Cars Involved in Towaway Crashes. Final Report, NHTSA Contract No. DOT-HS-5-01255, 1976.

U.S. Department of Transportation. Multidisciplinary Accident Investigation Data File Editing Manual and Reference Information. v.1, section 4, Editing Manual, 1976.

APPENDIX A

Literature Search Bibliography

Acton, J. Measuring the monetary value of lifesaving programs. Rand Publications, P-5675, 1976.

AD HOC Committee-Office of Science and Technology. Cumulative regulatory effects on the cost of automotive transportation (RECAT), February 28, 1972.

Akman, A., Brooks, M., Gordon, J. Use of work injury rate tables in estimating disabling work injuries. American Journal of Public Health, 1972, 62, 917-923.

Akpom, C. A., Katz, S. and Densen, P. M. Methods of classifying disability and severity of illness in ambulatory care patients. Medical Care, 1973, 11, (Supplement), 125-131.

AMA Committee on Rating of Mental and Physical Impairment. Guides to the evaluation of permanent impairment, 1971.

Baker, R. J. Newer tehniques in evaluation of injured patients. Surg. Clin. North Amer., 1975, 55, 31-42.

Baker, S. P., Haddon, W. Jr. Reducing injuries and their results: The scientific approach. Milbank Memorial Fund Quarterly, 1974, 52(4), 377-389.

Baker, S. P. and O'Neill, B. The injury severity score: An update. Journal of Trauma, 1976, 16(11), 882-885.

Baker, S. P., O'Neill, B., Haddon, W., Jr., and Long, W. B. The injury severity score: A method of describing patients with multiple injuries and evaluating emergency care. The Journal of Trauma, 1974, 14(3), 187-196.

Bergner, M., et al. The sickness impact profile: Validation of a health status measure. Medical Care, 1976, 14(1), 57-67.

Blischke, W. R., et al. Successive interval analysis of preference measures in a health status index. Health Service Research, 1975, 10(2), 181-198.

Boyd, D. R. A symposium on the Illinois trauma program: A systems approach to the care of the critically injured. The Journal of Trauma, 1973, 13(4), 275-284.

Boyd, D. R., Lowe, R. J., Baker, R. J., Nyhus, L. M. Trauma registry: New computer method for multifactorial evaluation of a major health problem. JAMA, 1973, 223, 422-428.

Boyd, D. R., Rappaport, D. M., Marbarger, J. P., Baker, R. J., Nyhus, L. M. Computerized trauma registry: A new method for categorizing physical injuries. Aerospace Medicine, 1971, 42(6), 607-615.

Brown, D. Cost benefit vs. total benefit in the implementation of safety standards. Proceedings, Fourth International Congress on Automotive Safety, 1975.

Bull, J. P. The injury severity score of road traffic casualties in relation to mortality, time of death, hospital treatment time and disability. Accident Analysis and Prevention, 1975, 7, 249-255.

Calabresi, G. The costs of accidents. Yale University Press, 1970.

Champion, H. R., Sacco, W., Ashman, W., Long, W. and Gill, W. An anatomical injury scale in multiple trauma victims. Proceedings of the 19th Conference of American Association for Automotive Medicine, San Diego, November, 1975.

Chiang, C. L., Cohen R. D. How to measure health: A stochastic model for an index of health. International Journal of Epidemiology, 1973, 2, 1-13.

Civetta, J. M. The inverse relationship between cost and survival. Journal of Surgical Research, 1973, 14, 265-269.

Committee on medical aspects of automotive safety. Rating the severity of tissue damage. I. The Abbreviated Scale. Journal of American Medical Association, 1971, 215, 277-280.

Committee on medical aspects of automotive safety. Rating the severity of tissue damage. II. The Comprehensive Scale. JAMA, 1972, 220, 717-720.

Comptroller General of the U.S. Need to improve cost benefit analyses in setting motor vehicle safety standards. Report to the Committee on Commerce, U.S. Senate, July 22, 1974.

Conrad, A. E., Morgan, J. N., Pratt, R. W., Jr., Voltz, C. E., and Bombaugh, R. L. Automobile accident costs and payments: Studies in the economics of injury reparation. University of Michigan, Ann Arbor, 1964.

Cowley, R. A., et al. Some significant biochemical parameters found in 300 shock patients. Journal of Trauma, 1969, 9, 926-938.

Cowley, R. A., et al. A prognostic index for severe trauma. Journal of Trauma, 1974, 14(12), 1029-1035.

Duran, B. S. and Lewis, T. O. Application of cluster analysis to the construction of a diagnostic classification. Computers in Biology and Medicine, 1974, 4(2), 183-188.

Dyson, R. B. Safety versus savings: An essay on the fallacy of economic costs of accidents, 1975.

Faigin, B. Societal costs of motor vehicle accidents for benefit cost analysis: A perspective on major issues and some recent findings. Proceedings Fourth International Congress on Automotive Safety, NHTSA, 1975.

Fanshel, S. A meaningful measure of health for epidemiology. International Journal of Epidemiology, 1972, 1, 319.

Fialkoff, R. Medical aspects of the disability program under social security. Connecticut Medicine, 1974, 38, 269-270.

Fleischer, G. A. and Jones, G. P. Cost benefit and cost effectiveness analyses in determining priorities among motor vehicle safety standards, programs, and projects. Fourth International Congress on Automotive Safety, 1975.

Flora, J. D., Bailey, J. and O'Day, J. The financial consequences of auto accidents. HIT LAB Reports, 1975, 5, No. 10.

Gallin, R. and Given, C. The concept and classification of disability in health interview surveys. Inquiry, 1976, 13(4), 395-407.

Garner, W. R. Rating scales, discriminability and information transmission. Psychological Review, 1960, 67(6), 343-352.

Gates, H. P., Jr. Review and critique of National Highway Traffic Safety Administration's revised restraints system cost benefit analysis. Fourth International Congress on Automotive Safety, 1975.

Gibson, B. S., Gibson, J. S., Bergner, M., Bobbitt, R., Kressel, S., Pollard, W., Vesselago, M. The sickness impact profile: Development of an outcome measure of health care. American Journal of Public Health, 1975, 65(12), 1304-1310.

Gibson, G. Guidelines for research and evaluation of emergency medical services. Health Services Reports, 1974, 89(2), 99-111.

Gibson, G. Indices of severity for emergency medical evaluative studies: Mythology and methodology. Presented at Annual Meetings of American College of Emergency Physicians, New Orleans, October, 1976.

Goldsmith, S. G. The status of health status indicators. Health Report, 1972, 87, 212-220.

Gonnella, J. S., Louis, D. Z. and McCord, J. J. The staging concept--An approach to the assessment of outcome of ambulatory care. Medical Care, 1976, 14(1), 13-21

Granger, C. V. and Greer, D. S. Functional status measurement and medical rehabilitation outcomes. Arch. Phys. Med. Rehab., 1976, 57(3), 103-109.

Greenberg, L. Comparison of three methods for evaluating injury disability. Journal of Occupational Medicine, 1972, 14, 673-678.

Grogono, A. W. Measurement of ill health: A comment. International Journal of Epidemiology, 1973, 2, 5-6.

Gustafson, D. H. and Holloway, D. C. A decision theory approach to measuring severity in illness. Health Service Research, 1975, 10, 97-106.

Haber, L. D. Identifying the disabled: Concepts and methods in the measurement of disability. From the Social Security Survey of the Disabled, Report #1, 1967.

Haber, L. D. Epidemiological factors in disability. I. Major disabling conditions. From the Social Security Survey of the Disabled, Report #6, 1969.

Haber, L. D. The epidemiology of disability. II: The measurement of functional capacity limitations. In publication by HEW entitled "Social Security survey of the disabled, 1966", Report #10.

Haber, L. D. Disabling effects of chronic disease and impairment. II. Functional capabity limitations. Journal of Chronic Disease, 1973, 26, 127-151.

Hutchinson, T. P. Statistical aspects of injury severity. Part I. Comparison of two populations when there are several grades of injury. Transportation Science, Vol. 10, No. 3, August 1976.

Hutchinson, T. P. Statistical aspects of injury severity. Part II: The case of several populations but only three grades of injury. Transportation Science, Vol. 10, No. 3, August 1976.

Joint committee on injury scaling of SAE, AMA, AAAM. The abbreviated injury scale. Proceedings of 19th AAAM Conference, 1975.

Joksch, H. C. A critical appraisal of the applicability of benefit cost analysis to highway traffic safety. Accident Analysis and Prevention, 1975, 7, 133-153.

Jones-Lee, M. Valuation of reduction in probability of death by road accident. Journal of Transport Economics and Policy, January 1969, 37-47.

Katz, S., Ford, A. B., Downs, J. D., Adams, M. Chronic disease classification in evaluation of medical care programs. Medical Care, 1969, 7, 139-143.

Keeler, E. B. Models of disease costs and their use in medical research resource allocations. Rand Publications, P-4537, December 1970.

Kessler, H., Manning, G. C., Jr. The effect of personal opinion on disability evaluation. Journal of Occupational Medicine, 1963, 5(9), 411-417.

Kessler, H. H. Disability: Determinants and Evaluation. Philadelphia: Lea and Sebiger, 1970.

Kirkpatrick, J. R. and Youmans, R. L. Trauma Index: An aide in the evaluation of injury victims. Journal of Trauma, 1971, 11(8), 711-714.

Krischer, J. P. Indexes of severity: Underlying concepts. Health Services Research, 1976, 143-157.

Lawson, John. Values of safety. Transport Canada, September, 1975.

Lawson, John. Cost of damage to vehicles and other property in road accidents. Transport Canada, February, 1976.

Lawson, John. Value of work efforts lost as a result of roadway accidents. Transport Canada, February, 1976.

Lee, M. L., Wallace, R. L. Classification of disease for hospital cost analysis. Inquiry, 1972, 9, 69-72.

Linn, B. S., Linn, M. W., Gurel, L. Cumulative illness rating scale. Journal of the American Geriatrics Society, 1968, 16(5), 622-626.

Little, A. D. Cost effectiveness in traffic safety. Praeger Publishers, 1969.

Longmoor, D. B., Rehahn, M. The cumulative cost of death. Lancet, 1975, 1023-1025.

MacNab, I. Pain and disability in degenerative disc disease. Clin. Neurosurg., 1973, 20, 193-196.

Maddox, G. L. Interventions and outcomes: Notes on designing and implementing on experiments in health care. International Journal of Epidemiology, 1972, 1, 339-345.

Mahoney, McCallum, Wood, and Barthel. Rehabilitation of the chronically ill in the state of Maryland. Southern Medical Journal, 1961.

Marsh, J. C., IV. Vehicle occupant injury classification. HIT Lab Reports, Vol. 4, No. 1, University of Michigan, Ann Arbor, September, 1973.

McBride, E. D. Disability evaluation and principles of treatment of compensable injuries, 1963.

The Medical Advisory Committee to the Social Security Administration. Disability evaluation under social security: A handbook for physicians. The American Medical Association.

Miller, L. F., Liebenson, H. A. Medical and legal evaluation of disability in personal injury cases, 1962.

Morganstein, D. The appropriate role of cost benefit studies in the formulation and evaluation of federal safety countermeasures. Fourth International Congress on Automotive Safety, 1975.

NHTSA. Societal costs of motor vehicle accidents: Preliminary Report. April, 1972.

NHTSA Motor Vehicle Programs. Amendment to - Analysis of effects of proposed changes to passenger car requirements of MVSS 208, Dec. 1974.

Nichols, P., Jr. The assessment of disability. Proc. Royal Soc. of Med., 1973, 66, 141-143.

Ogawa, M., Tsuyoshi, S. Rating severity of the injured by ambulance attendants: Field research of trauma index. J. Trauma, 1974, 14(11), 934-937.

O'Leary, et al. The relationship between Kisch Health Status Proxy and three direct measurements of health status. Minnesota Medicine, 1973, 56: supplement 2, 82-86.

O'Neill, B. and Kelley, A. B. Costs, benefits, effectiveness and safety: Setting the record straight. Automotive Engineering Meeting, Toronto, Canada, Oct. 21-25, 1974.

Patrick, D. L. Methods for measuring levels of well being for a health status index. Health Service Research, 1973, 8, 228-245.

Pollard, W. E., et al. The sickness impact profile: Reliability of a health status measure. Medical Care, 1976, 14(2), 146-155.

Rice, D.P. Estimating the cost of illness. Health Economics Series, Public Health Service Publication No. 947-6, May 1966.

Rice, D. The direct and indirect cost of illness. Federal progams for the development of human resources, 1968.

Rice, D. Measurement and application of illness costs. Public Health Reports, 1969, 84(2), 95-101.

Rice, D. and Cooper, B. The economic value of human life. American Journal of Public Health, 1967, 57, 1954-1966.

Robbins, D.H., Snyder, R.G. and Roberts, V.L. Injury criteria model for restraint systems effectiveness evaluation. NHTSA Final Report, April 1971.

Rosser, R.M. and Watts, V.C. The measurement of hospital output. International Journal of Epidemiology, 1968, 1, 361-368.

Sarno, J.E., Sarno, M.T. and Levita, E. The functional life scale. Arch. Phys. Med. Rehab., 1973, 54, 214-220.

Schelling, T.C. The life you save may be your own. In Problems in Public Expenditure Analysis, edited by S.B. Chase, the Brookings Institute, 1968, 127-177 (HJ2005 P7).

Schildt. Mortality rate in quantified combined injuries. Strahlentherapie, 1972, 144, 40-49.

Semmlow, J.L. and Cone, R. Utility of the injury severity score: A confirmation. Health Services Research, 1976, 11(1), 45-52.

Smith, J., Livetta, J., Lester III, J.L., Stephenson Jr., S.E. and Linn, B.S. A simple coding system of traumatic injuries. Presented at the American Public Health Meeting, October 1976.

Spence, E. A proposed injury code for automotive accident victims. Proceedings of 18th AAAM Conference, 1974.

Stalnaker, R., Mohan, D. and Melvin, J. Head injury evaluation: Criteria for assessment of field, clinical and laboratory data. Proceedings of 19th AAAM Conference, San Diego, November 1975.

Struble, D.E., Peterson, R., Wilcox, B. and Freidman, D. Societal costs, and their reduction by safety systems. Proceedings, Fourth International Congress on Automotive Safety, NHTSA, Washington, 1975.

Sullivan, D.F. A single index of mortality and morbidity. Health Report, 1971, 86, 347-359.

U.S. Department of Health, Education, and Welfare. Medical Care Expenditures, Prices and Costs: Background Book. September 1975. (SSA 75-11909).

Vital and Health Statistics. Conceptual problems in developing an index of health. Series 2, No. 17, May 1966.

Vital and Health Statistics. Disability components for an index of health. Series 2, No. 42.

Vital and Health Statistics. The prediction approach to finite population sampling theory: Application to the hospital discharge survey. Series 2, No. 55, April 1973.

Wakeland, H. Array of social values for analyzing safety regulations. Proceedings, Fourth International Congress on Automotive Safety, NHTSA, Washington, 1975.

Wax, H.W. Medical-legal concepts in the evaluation of the injured workman. California Medicine, 1973, 119, 69-75.

Weinstein, M., Shepard, D. and Pliskin, J. The economic value of changing mortality probabilities: A decision-theoretic approach, 1976.

Williams, A. The cost benefit approach. Br. Med. Bull., 1974, 30(3), 252-256.

APPENDIX B

Data Contacts

Personal Contacts

Dr. William Frazier and Dr. Donald Brand, Yale University School of Medicine

Dr. Bernard Linn, Veterans' Administration Hospital, Miami, Florida

Dr. Howard Champion, Washington Hospital Center, Washington, D.C.

Dr. Gene Cayton, University of Pennsylvania, Philadelphia

Dr. Geoffrey Gibson, Health Services Research and Development Center, Johns Hopkins University, Washington, D.C.

Dr. Lawrence Rose, Director, Division of Health Systems Design and Development, Health Services Research Center, Rockville, Maryland

Private Sources

Dr. J.T. Semmlow, University of Illinois, Chicago

Dr. Henry Gelfand, University of Illinois, Chicago

Dr. H.A. Muller, University of Illinois, Chicago

Ms. Doreene Bahr and Dr. Muhammad Ahtar, Illinois Department of Public Health, Springfield

Ms. Barbara Faigin, Office of Program Planning, NHTSA

Dr. Harold Fenner, Norte Vista Medical Center, Hobbs, New Mexico

Ms. Susan Baker, Office of the Chief Medical Examiner, Baltimore, Maryland

Dr. John States, University of Rochester School of Medicine, Rochester, New York

Systemetrics, Inc., Santa Barbara, California

The National Safety Council, Chicago, Illinois

Hospital and Related Sources

Commission on Professional and Hospital Activities, Ann Arbor, Michigan

Wake County Medical Center, Raleigh, N.C.

Wilson Memorial Hospital, Wilson, N.C.

Duke Medical Center, Durham, N.C.

Charity Hospital, New Orleans, L.A.

Humana Inc., Louisville, K.Y.

N.C. Hospital Association

Duke Endowment Office

Federal Government Sources

Workmen's Compensation, Washington, D.C.

The Consumer Product Safety Commission, Washington, D.C.

The Social Security Administration, Division of Health Insurance Services, Washington, D.C.

The Social Security Administration, Division of Disability Studies, Baltimore, Md.

The National Center for Health Statistics, Scientific and Technical Information Branch, Rockville, Md.

The Veterans' Administration, Washington, D.C.

State Government Sources

N.C. Department of Human Resources, Public Health Statistics Branch, Raleigh

N.C. Labor Department, Raleigh

Occupational Safety and Health Administration, Raleigh

N.C. Industrial Commission, Workmen's Compensation Division, Raleigh

California Labor Department, Division of Labor Statistics and Research, San Francisco

New York State Labor Department

N.C. Fire Insurance Rating Bureau, Raleigh

Office of the Insurance Commissioner, Consumer Insurance Information, Raleigh

N.C. Automobile Insurance Rating Bureau, Raleigh

N.C. Compensation Rating and Investigation Bureau, Raleigh

N.C. Building and Construction Trade Department, Charlotte

Insurance Sources

National Association of Independent Insurers, Desplaines, Illinois

National Council on Compensation Insurance, New York, New York

Insurance Services Offices, New York, New York

Insurance Information Institute, New York, New York

Insurance Institute for Highway Safety, Washington, D.C.

Hartford Insurance (Dr. Hertzler Knox)

Liberty Mutual of Massachusetts (Mr. Ned Pulley)

Kaiser Permanente Medical Care Program, Oregon Region, Portland

APPENDIX C

Data File Contents[1]

C.1 Contents of the Illinois Trauma Registry Extract

1. TYPE OF HOSPITAL (e.g., local)
2. UNIT (most specialized care a patient receives; e.g., burn)
3. PATIENT IDENTIFICATION
4. SEX OF PATIENT
5. RACE
6. MARITAL STATUS
7. SURVIVAL (e.g., death between 6 and 24 hours of admission)
8. AUTOPSY (e.g., routine necropsy, coroner)
9. EMERGENCY SURGERY (e.g., within one hour)
10. INSURANCE (e.g., Workmen's Compensation)
11. EDUCATION (highest grade attained)
12. BIRTHDATE
13. AGE
14. OCCUPATION (e.g., salesman)
15. LENGTH OF HOSPITAL STAY (in number of days)
16. ARRIVAL DATE
17. DISCHARGE DATE
18. BRAIN INJURY
19. FACIAL INJURY
20. CHEST INJURY
21. ABDOMINAL INJURY
22. BODILY SYSTEM WITH ACUTE POST-TRAUMATIC INJURY (e.g., circulatory system)
23. COMPLICATIONS (up to three late causes)
24. BLOOD ALCOHOL TEST RESULTS
25. MODE OF ALCOHOL TEST (e.g., blood alcohol)
26. DATE OF ACCIDENT
27. TIME OF ACCIDENT
28. TIME FROM INJURY TO INITIAL CARE FACILITY

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[1]A description of the levels of each variable is available from HSRC.

29. MODE OF TRANSPORTATION (e.g., private ambulance)
30. DISTANCE TO INITIAL CARE
31. TIME IN E.R. OR HOSPITAL ADMITTING AREA
32. TIME IN SPECIAL UNIT
33. MECHANISM(S) OF INJURY
34. TYPE OF ACCIDENT PRODUCING INJURY (e.g., pedestrian injured)
35. INJURY TYPE FOR INDUSTRIAL OR FARM ACCIDENTS (e.g., industrial explosion)
36. INJURY TYPE FOR HOME OR RECREATIONAL ACCIDENTS (e.g., home, fall from height)
37. INJURY DUE TO VIOLENT ACCIDENTS (e.g., stab, multiple)
38. LOCATION OF ACCIDENT (e.g., place of business)
39. INJURY CODES (includes diagnosis and AIS code for each injury, major complication, number of complications)

C.2 Contents of the North Carolina Medical Examiner's File

1. SEQUENCE NUMBER
2. SEX
3. AGE
4. DATE OF INJURY
5. HOUR OF INJURY
6. DATE OF DEATH
7. HOUR OF DEATH
8. PLACE OF DEATH (e.g., farm, highway, hospital)
9. MANNER OF DEATH (e.g., natural, homicide)
10. CAUSE OF DEATH ('E' codes)
11. RESULTS OF AUTOPSY: Diagnoses, AIS Codes, ICDA Codes, Larger Secondary AIS

C.3 Contents of the North Carolina Workmen's Compensation File

1. FILE NUMBER
2. TYPE OF CASE (e.g., permanent partial)
3. AGE
4. SEX
5. LOST WORKDAYS

6. COMPENSATION PAID
7. MEDICAL PAID
8. EXTENT OF INJURY (number of injuries)
9. ACCIDENT TYPE (e.g., fall, motor vehicle accident)
10. INJURY CODE: Body Part, Injury

C.4 Contents of the North Carolina Blue Cross Blue Shield Insurance File

1. INJURY CLASS (e.g., lacerations) AND SUBCLASSES
2. DIAGNOSIS/PROCEDURE CODES
3. AGE
4. SEX
5. PLACE OF TREATMENT (e.g., E.R.)
6. TOTAL DAYS IN HOSPITAL
7. TOTAL HOSPITAL COST
8. TOTAL PROFESSIONAL COST

APPENDIX D

Injury Mappings

D.1 Mapping of the ICDA injury codes onto the OIC injury codes

ICDA	Body Region	Aspect	Lesion	System/Organ
800	H	S	F	S
801	H	I	F	S
802	F	W	F	S
803	H	U	F	S
805.0, 805.1	N	W	F	S
805.2-805.5, 805.8, 805.9	B	W	F	S
805.6, 805.7	P	W	F	S
806.0, 806.1	N	W	F	S
806.2-806.5, 806.8, 806.9	B	W	F	S
806.6, 806.7	P	W	F	S
807	C	W	F	S
808	P	W	F	S
810	S	S	F	S
811	S	B	F	S
812	A	W	F	S
813	R	W	F	S
814	W	S	F	S
815	W	C	F	S
816	W	I	F	S
817	W	W	F	S
820	T	S	F	S
821	T	I	F	S
822	K	W	F	S
823	L	W	F	S
824	Q	S	F	S
825	Q	C	F	S
826	Q	I	F	S
827	Q	W	F	S
830	F	I	D	J
831	S	W	D	J
832	E	W	D	J
833	W	S	D	J
834	W	I	D	J

ICDA	Body Region	Aspect	Lesion	System/Organ
835	P	W	D	J
836	K	W	D	J
837	Q	S	D	J
838	Q	I	D	J
839	U	U	D	J
840	S	W	S	J
841	E	W	S	J
842	W	W	S	J
843	P	W	S	J
844	K	W	S	J
845	Q	W	S	J
846	B	I	S	J
847	B	W	S	V
848	U	U	S	U
850	H	W	K	B
851	H	S	L	B
852	H	W	H	I
853	H	U	H	I
854	H	U	U	B
860	C	W	L	U
861	C	W	U	P
862	C	W	U	U
863	M	I	U	D
864	M	P	U	L
865	M	A	U	Q
866	M	P	U	K
867	P	W	U	G
868	M	W	U	U
869	M	W	U	U
870	F	U	L	E
871	F	W	V	E
872	H	W	L	E
873	H	W	L	I
874	N	W	L	U
875	C	W	L	U
876	B	W	L	U

ICDA	Body Region	Aspect	Lesion	System/Organ
877	P	P	L	U
878	P	I	L	G
879	O	W	L	U
880	X	S	L	U
881	X	I	L	U
882	W	C	L	U
883	W	I	L	U
884	X	W	L	U
885	W	A	M	S
886	W	P	M	S
887	X	W	M	S
890	Y	S	L	M
891	Y	I	L	M
892	Q	C	L	M
893	Q	I	L	M
894	Y	W	L	M
895	Q	I	M	S
896	Q	C	M	S
897	Y	W	M	S
910	[H,F,N]	U	A	I
911	[C,B,M,P]	U	A	I
912	Y	S	A	I
913	Y	I	A	I
914	W	C	A	I
915	W	I	A	I
916	Y	W	A	I
917	Q	C	A	I
918	U	U	A	I
920	[H,F,N]	U	C	M
921	F	S	C	E
922	[C,B,M,P]	U	C	M
923	Y	S	C	M
924	Y	I	C	M
925	W	C	C	M
926	W	I	C	M
927	Y	W	C	M
928	Q	C	C	M
929	U	U	C	M

ICDA	Body Region	Aspect	Lesion	System/Organ
950	F	W	U	N
951	H	S	U	N
952	A	W	0	N
953	R	W	0	N
954	W	W	0	N
955	T	W	0	N
956	L	W	0	N
957	Q	W	0	N
958	B	W	0	N
959	U	W	0	N

D.2 Mapping of the WCF injury codes onto the OIC injury codes

Part I. Part of Body

Part of Body	OIC Body Region	OIC Aspect
110	H	W
121	H	W
124	H	W
130	F	W
141	F	I
144	F	I
146	F	C
148	F	W
149	F	U
150	H	S
160	H	S
198	H	W
199	H	U
200	N	S
311	A	W
313	E	W
315	R	W
318	X	W
319	X	U
320	W	S
330	W	C
340	W	L
398	X	W
399	X	U
410	M	W
420	B	W
430	C	W
440	P	W
450	S	W
498	O	W
499	O	W
511	T	W
513	K	W

Part of Body	Body Region	Aspect
515	L	W
518	Y	W
519	Y	W
520	Q	S
530	Q	C
540	Q	I
598	Y	W
599	Y	U
801	O	W
810	C	W
820	C	W
830	O	W
840	O	W
850	C	W
880	O	W
900	O	U
999	U	U
700	U	U

Part II. Nature of Injury

Nature of Injury	Lesion	System/Organ
100	M	S
121	B	I
122	B	I
130	B	I
140	K	B
161	C	I
162	N	S
170	L	M
190	D	J
210	F	S
309	A	I
310	S	J
400	O	U
995	O	U
999	U	U

D.3 Mapping of OIC codes onto the 9-point threat-to-life scale.*

Threat-to-Life Scale Value	Body Region	Lesion	System/ Organ	Aspect
9	H	F	S	U
	M	-	U	-
8	H	H	B	-
	C	-	P	-
7	U	U	-	-
6	H	L	B	-
	H	U	B	-
5	H	F	S	all except U
	O	B	-	-
	X	B	-	-
	-	-	C	-
4	C	L	P	-
	C	L	R	-
	-	-	Q	-
	-	-	L	-
	M	-	G	-
	M	-	K	-
	X	L	-	-
	Y	L	-	-
	O	L	-	-
	Y	C	-	-
	X	C	-	-
	O	C	-	-
3	C	F	-	-
	P	F	-	-
	M	F	S	-
	T	F	-	-
	-	-	D	-
	C	L	I	-
	C	L	M	-
	N	L	-	-
	-	M	-	-
	H	B	-	-
2	B	F	-	-
	N	F	-	-
	F	L	-	-
	H	L	-	-
	all except X,Y,O	C	-	-
1	anything else			
0	O	O	O	O

*A dash (-) indicates all possible values except O.

D.4 Mapping of surgical and anesthesia procedure codes onto cost injury classes.[1]

INJURY CLASS	PROCEDURE CODES
1	5018, 0681, 5022, 5024, 5020, 0685-0694, 0698, 0699, 0701-0706, 1255, 1256, 1262, 1264, 1267, 1270, 0720-0722, 0732, 0733, 0735, 0736, 0761, 0762, 0756, 0757, 2101, 0778, 0780-0795, 0932-0935, 0937, 0938, 0943-0946, 0940, 0941, 0954-0957, 0966-0968, 0970, 0975-0977, 0979, 0981, 0982
2	0767, 0768, 0771, 0772, 0773, 0775, 5330, 5320, 5322, 5323, 5325, 5326, 5332, 5328
3	0798-0810, 0811-0818, 0820-0824, 0740, 0741, 0742, 0743, 0747, 0748, 5421, 5431, 0827, 0830, 0840-0848, 0852-0858
4	5001-5004
5	0880-0887, 3481, 3081, 3083, 3141, 3220, 3221
6	0865-0879
7	No equivalent codes
8	0889, 0890, 0891, 0893-0910, 0914-0923, 0925-0930
9	1251, 1252, 1284-1286, 1273-1281, 1290-1292, 1295-1298, 1300, 1301, 1315-1317, 1326-1328, 1304-1306, 1354-1357, 1361-1363, 1371-1373, 1376-1378, 1385-1387, 1391-1393
10	1332, 1334, 1344-1346, 1350-1352
11	No equivalent codes
12	No equivalent codes
13	0351-0412
14	No equivalent codes
15	1701-1803
16	No equivalent codes
17	No equivalent codes

[1]See sample codes on following page.

Sample of surgical and anesthesia procedure codes and values for BCBS doctor's office data.

MUSCULOSKELETAL SYSTEM

Fractures

Skull

0681 Skull, non-operative..........
(Depressed with operation, see 5018, 5020.)

Facial Bones

0685 Nasal, simple or compound, no reduction.....................
0686 uncomplicated (digital) closed reduction..........
0687 complicated (instrumental) closed reduction.....
0688 open reduction, uncomplicated.......................
0689 complicated with either internal and/or external skeletal fixation.........
0690 with concomitant open reduction of fractured septum
0691 Malar, simple or compound, no reduction....................
0692 closed reduction (including towel clip technique).......
0693 depressed, open reduction...
0694 complicated, depressed, open reduction with internal skeletal fixation and multiple surgical approaches.........
0698 Maxilla, simple or compound,no reduction.....................
0699 closed reduction, with wiring of teeth...............
0701 open reduction, with wiring of teeth and/or local fixation........................
0702 complicated, open reduction, fixation by head cap, multiple surgical approaches, internal fixation, wiring teeth, etc., by report......
(For antral approach, see 1988.)
0703 Mandible, simple or compound, no reduction.................
0704 closed reduction and wiring of teeth..................
0705 open reduction with or without wiring of teeth.........
0706 skeletal pinning with external fixation................

Spine and Trunk

0720 Vertebral process, one or more
0721 Vertebral body, one or more not requiring reduction.......
0722 requiring reduction
0732 Sacrum, simple, not requiring reduction....................
0733 compound or complex, by report
0735 Coccyx, simple, not requiring reduction.....................
0736 compound or complicated, by report.....................
0740 Clavicle, simple, no reduction
0741 simple, closed reduction....
0742 compound, including uncomplicated soft tissue closure
0743 simple or compound, open reduction.....................
0747 Scapula, simple, no reduction.
0748 simple or compound, open reduction.....................
0756 Sternum, simple..............
0757 compound or complicated, by report.....................
0761 Ribs, simple.................
0762 compound or complicated, by report.....................

Pelvis (Ilium, Ischium, Pubis)

0767 Fracture, simple, no reduction
0768 complicated, closed reduction, by report............
0771 compound, open reduction....
0772 Acetabulum, with or without other fractures of pelvis, simple, no reduction..........
0773 central, with displacement, requiring closed reduction..
0775 simple or compound, open reduction...................

Upper Extremity

0778 Humerus, surgical neck, simple, not requiring reduction........
0780 requiring manipulative reduction..................
0781 compound, with uncomplicated soft tissue closure..
0782 simple or compound, open reduction..................
0783 shaft, simple, not requiring reduction.....................
0784 simple, closed reduction...
0785 compound, with uncomplicated soft tissue closure..
0786 simple or compound, open reduction..................
0787 simple or compound, open reduction, skeletal pinning with external fixation.....
0788 supracondylar or dicondylar, not requiring reduction......
0789 closed reduction...........
0790 compound with uncomplicated soft tissue closure........
0791 simple or compound, open reduction..................
0792 medial or lateral condyle, simple, not requiring reduction.........................
0793 closed reduction...........
0794 compound with uncomplicated soft tissue closure........
0795 simple or compound, open reduction..................
0796 Elbow, proximal end of ulna with dislocation of radial head, simple, (Monteggia fracture) closed reduction...............
0797 simple or compound, open reduction..................
(See also 1292.)
0798 Radius, head, simple, no reduction..........................
0799 closed reduction...........
0800 compound with uncomplicated soft tissue closure........
0801 simple or compound, open reduction or excision (See also 0556.)...............
0802 shaft, simple, no reduction..
0803 simple, closed reduction...
0804 compound, with uncomplicated soft tissue closure..
0805 simple or compound, open reduction..................
0806 distal end (e.g. Colle's type), simple, no reduction.........
0807 closed reduction...........
0808 with severe comminution and impaction, closed reduction...................
0809 simple or compound, open reduction..................
0810 skeletal pinning, with external fixation............
0811 Ulna, proximal end, olecranon process, simple, no reduction..
0812 compound with uncomplicated soft tissue closure........
0813 simple or compound, open reduction and/or resection.
0814 shaft, simple, no reduction..
0815 closed reduction...........
0816 compound, with uncomplicated soft tissue closure..
0817 simple or compound, open reduction..................
0818 skeletal pinning with external fixation...........
0820 Radius and ulna shaft, simple, no reduction..................
0821 simple, closed reduction.....
0822 compound, with uncomplicated soft tissue closure..........
0823 simple or compound, open reduction.....................
0824 skeletal pinning with external fixation................
(For Colle's fracture see 0806-0810.)
0827 Carpal bones, one or more, simple reduction.................
0830 simple or compound, open reduction.....................
0840 Metacarpal, simple, no reduction
0842 one, simple or compound, closed reduction with uncomplicated soft tissue closure.
0843 more than one, simple or compound, closed reduction, with uncomplicated soft tissue closure.................
0844 one or more, simple or compound, open reduction........
0848 skeletal pinning with external fixation................
(etc.)

APPENDIX E

Intermediate Cost Tables by Place of Treatment

Table E.1 BCBS mean medical costs (standard errors) in dollars by injury class, sex and age for doctor's office cases.

Sex	Male			Female		
Inj.Class \ Age	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	84.69 (3.94)	77.75 (5.84)	71.50 (13.91)	77.19 (4.89)	77.27 (3.33)	102.52 (20.25)
2	26.64 (0.47)	29.06 (2.00)	24.25 (2.93)	26.05 (0.46)	27.90 (2.07)	22.75 (0.75)
3	57.56 (1.27)	63.37 (4.03)	63.80 (12.09)	57.79 (1.64)	90.96 (5.19)	109.52 (21.45)
5	178.86 (47.62)	57.00 (34.12)	-	239.75 (101.97)	195.50 (34.50)	-
6	193.28 (54.55)	703.00 (114.44)	242.00 (57.00)	534.43 (296.26)	403.00 (274.01)	494.75 (163.55)
7	36.49 (0.36)	37.40 (0.63)	36.14 (4.86)	36.87 (0.56)	36.81 (0.80)	30.33 (5.44)
8	104.93 (4.29)	108.04 (8.45)	97.86 (26.64)	100.62 (6.91)	128.09 (11.51)	76.57 (22.13)
9	78.65 (11.39)	78.45 (9.67)	-	83.09 (25.14)	71.15 10.39	257.50 192.50
10	51.16 (4.75)	53.82 (5.99)	-	41.97 (3.58)	75.16 (15.19)	29.50 (0.50)
13	21.35 (0.55)	24.85 (1.35)	21.60 (3.84)	22.26 (0.72)	29.89 (1.78)	18.83 (2.70)

- Indicates virtually no data available.

Table E.2 WCF (cases with zero or one workdays lost) mean medical costs (standard errors) in dollars by injury class, sex, and age for emergency room cases.

Sex / Age / Inj.Class	Male			Female		
	1-29	30-64	65 & Over	1-29	30-64	65 & Over
1	151.53 (38.32)	217.98 (78.47)	89.00 (17.19)	96.25 (8.65)	127.16 (18.42)	257.00 (95.23)
2	87.70 (5.51)	146.38 (18.81)	288.00 (117.46)	86.85 (16.81)	158.83 (47.82)	-
3	112.83 (2.59)	102.89 (41.57)	89.96 (10.34)	96.60 (7.68)	106.78 (4.12)	87.22 (29.78)
7	84.41 (1.60)	97.33 (2.65)	99.47 (7.21)	67.02 (2.60)	79.68 (2.41)	66.50 (9.85)
8	135.05 (33.21)	194.16 (44.55)	-	-	117.18 (25.08)	-
9	136.33 (26.83)	161.15 (25.45)	-	179.45 (61.35)	124.88 (17.94)	-
10	205.69 (77.92)	106.20 (12.89)	-	78.80 (9.69)	70.00 (16.95)	-
11	67.51 (1.87)	88.92 (5.63)	83.14 (9.53)	64.06 (3.76)	74.44 (2.82)	104.29 (20.33)
12	82.18 (3.16)	116.79 (5.89)	164.68 (65.44)	92.65 (10.71)	118.18 (13.37)	70.75 (10.39)
13	70.35 (2.62)	93.76 (5.52)	82.54 (14.63)	63.41 (6.01)	76.76 (5.51)	143.00 (19.44)
15	168.95 (11.36)	219.13 (20.25)	121.00 (20.49)	114.05 (8.58)	165.52 (20.86)	-
17	70.93 (3.07)	93.81 (5.68)	138.38 (46.64)	70.84 (5.56)	82.28 (6.43)	92.20 (22.56)

- Indicates virtually no data available.