

Appendix F

HAZUS INJURIES AND THE ABBREVIATED INJURY SCALE

F.1 Overview

To obtain monetary value for avoiding statistical injuries (including fatal injuries), the project team used the monetary values of avoided statistical injuries assigned by the Federal Highway Administration (FHWA 1994). That study attached values to the six-category Abbreviated Injury Scale (AIS). These values are comprehensive, in that they reflect pain and lost quality of life, medical and legal costs, lost earnings, lost household production, etc. Medical costs alone represent a relatively small portion of the comprehensive cost, typically 10% or less.

When actual injuries are coded in research studies, a single person does not necessarily receive a single code; each individual injury is coded. Thus, if the AIS scale is being used to code the injuries obtained, one can code each injury, record the maximum AIS level, or combine the injured person's AIS scores to produce a single number for further data processing and analysis.

Regardless of these issues, the AIS is a commonly used scale with equivalent monetary values assigned by agencies of the US government explicitly for use in cost-benefit analysis. The challenge for this project was to apply the AIS and its monetary values to HAZUS injuries. HAZUS's injury levels are not defined in terms of AIS injuries, and the HAZUS scale has four levels (1 through 4, where 4 is fatal) whereas AIS has six (1 through 6, where 6 is fatal).

This appendix describes the mapping between HAZUS injury severities to the AIS. Four references are examined here. The HAZUS Technical Manual (NIBS and FEMA, 2003a) provides a general description of each of four injury levels and provides 3 to 5 examples of each; see Table F-1, below. The AIS dictionary (AAAM, 2001) lists approximately 1,300 injuries, each provided with a distinct 7-digit numerical injury identifier, of which the last digit after the decimal place is the AIS level. The differences between HAZUS and AIS injury definitions virtually assure an ambiguous mapping between HAZUS and AIS levels.

In an attempt to reduce the ambiguity in mapping, two additional publications were examined. Peek-Asa et al. (1998) and Mahue-Giangreco et al. (2001) both studied large numbers of medical records of people injured in the 1994 Northridge earthquake. However, neither study includes transcriptions of the injuries studied as they were described in the medical records, prior to coding using AIS. In addition, neither the number of injuries nor the type of treatment by assigned AIS score was reported. No other readily available data were found about relative frequencies of AIS injury levels within HAZUS injury levels, based on data from the Northridge Earthquake or other natural disasters.

The method applied for this project was to quote the example injuries as given in the HAZUS Technical Manual Table 13.1 (duplicated in Table F-1 below), list several AIS injuries that appear to correspond to each HAZUS example, and note the range of possible AIS levels for each example. It is not defensible to infer relative frequencies with which injuries at a given AIS level occur simply by counting the number of distinct AIS injuries that correspond to a particular HAZUS level.

Only HAZUS levels 1, 2, and 3 were examined. HAZUS level 4 (fatal) was unequivocally mapped to AIS level 6 (maximum), so no detail was required to support this mapping.

Table F-1 HAZUS Injury Classification Scale

Injury Level	Injury Description
Severity 1	Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are: a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Injuries of lesser severity that could be self treated are not estimated by HAZUS.
Severity 2	Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration or exposure.
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.
Severity 4	Instantaneously killed or mortally injured

F.2 HAZUS Level 1

The project team assigned the monetary value of avoiding a HAZUS level-1 injury the geometric mean of the monetary values of avoiding injuries of AIS levels 1 and 2. (By geometric mean is meant the square root of the product, i.e., $cost = (cost_1 \times cost_2)^{1/2}$. It produced a result less than the simple arithmetic average, as if the lower value were somewhat more likely than the upper value.) From the HAZUS technical manual (see Table F-1), HAZUS injury level 1 is described as “Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are: a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness.” Table F-2 lists examples of AIS injuries that roughly correspond to example HAZUS level 1 injuries (i.e., include the words used in the HAZUS injury descriptions). Note that the last digit in the numeric identifier of each AIS coded injury is the AIS level for that injury. For example, “750620.1 Elbow joint sprain” is AIS level 1. The range of AIS levels in Table F-2 is 1 to 3.

F.3 HAZUS Level 2

The project team equated HAZUS level 2 and AIS level 3. From the HAZUS technical manual (see Table F-1), HAZUS injury level 2 is described as “Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness,

fractured bone, dehydration or exposure.” Table F-3 lists AIS injuries that roughly correspond to example HAZUS level 2 injuries (i.e., include the words used in the HAZUS injury descriptions). The range of AIS levels is very broad, ranging between 1 and 5.

F.4 HAZUS Level 3

The project team assigned the monetary value of a HAZUS level 3 injury the geometric mean of the monetary values of AIS 4 and 5. From the HAZUS technical manual (see Table F-1), HAZUS injury level 3 is described as “Injuries that pose an immediate life threatening condition if not treated adequately

Table F-2 HAZUS Level-1 injuries and related AIS-coded injuries

HAZUS example	Similar AIS-coded injuries, with numerical injury identifier. The last digit is the AIS level.	AIS
A sprain	The word “sprain” appears 14 times in the AIS dictionary. Some instances are: 750620.1 Elbow joint sprain 751020.1 Shoulder sprain 751420.1 Wrist sprain 850206.1 Ankle sprain 850404.1 Foot joint sprain 850826.2 Knee sprain	1 1 1 1 1 2
A severe cut requiring stitches	The AIS dictionary contains 179 instances of “laceration.” Here are 14 that could be called a severe cut, representing 2 kinds of injuries on each of 7 body sections. A third was identical to the first two, except with blood loss >20% by volume; this injury level is considered HAZUS level 3. 110602.1 Scalp laceration, minor 110604.2 Scalp laceration, major (> 10 cm long and into subcutaneous tissue) 210602.1 Face skin/subcutaneous/muscle laceration, minor, superficial 210604.2 Face skin/subcutaneous/muscle laceration, major (> 10 cm long on hand or 20 cm long on entire extremity and into subcutaneous tissue) 310602.1 Neck skin/subcutaneous/muscle laceration, minor, superficial 310604.2 Neck skin/subcutaneous/muscle laceration, major (> 10 cm long on hand or 20 cm long on entire extremity and into subcutaneous tissue) 410602.1 Thorax skin/subcutaneous/muscle laceration, minor, superficial 410604.2 Thorax skin/subcutaneous/muscle laceration, major (> 10 cm long on hand or 20 cm long on entire extremity and into subcutaneous tissue) 510602.1 Abdomen skin/subcutaneous/muscle laceration, minor, superficial 510604.2 Abdomen skin/subcutaneous/muscle laceration, major (> 10 cm long on hand or 20 cm long on entire extremity and into subcutaneous tissue) 710602.1 Upper extremity skin/subcutaneous/muscle laceration minor, superficial 710604.2 Upper extremity skin/subcutaneous/muscle laceration, major (> 10 cm long on hand or 20 cm long on entire extremity and into subcutaneous tissue) 810602.1 Lower extremity skin/subcutaneous/muscle laceration minor, superficial 810604.2 Lower extremity skin/subcutaneous/muscle laceration, major (> 10 cm long on hand or 20 cm long on entire extremity and into subcutaneous tissue)	1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2
A minor burn (first degree or second degree on a small part of the body)	The AIS dictionary contains 3 injuries that meet these criteria: 912002.1 Burn, 1°, > 1 yr old, any fraction of total body surface area 912004.2 Burn, 1°, ≤ 1 yr old, >50% of total body surface area 912006.1 Burn, 2°, <10% of body area	1 2 1
A bump on the head without loss of consciousness.	Aside from 110402.1, the AIS dictionary lists 4 injuries that explicitly exclude unconsciousness. 110402.1 Scalp contusion (includes subgaleal hematoma) 160402.1 No prior unconsciousness, but may have headache or dizziness known to be a result of head injury 160404.2 [Same as 160402.1] with neurological deficit 160602.2 Lethargic, stuporous, obtunded post resuscitation or on limited observation at scene (can be aroused by verbal or painful Stimuli; GCS* 914), no prior unconsciousness. 160604.3 [Same as 160602.2] with neurological deficit	1 1 2 2 3

and expeditiously. Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.” Table F-4 lists AIS injuries that roughly correspond to HAZUS level 3 injuries (i.e., include the words used in the HAZUS injury descriptions). The associated AIS levels range from 3 to 5.

F.5 Discussion

Peek-Asa et al. (1998) examined medical records of hospitalized injury victims of the 1994 Northridge Earthquake. They coded injuries according to the Abbreviated Injury Severity (AIS) scale. The Injury Severity Score (ISS) is also used, but it is calculated as a function of AIS (ISS is calculated as the sum of the squares of the highest AIS code in the three most severely injured body regions.) The authors report that injuries most commonly affected legs and arms, but at least some injuries were recorded to all other body regions except the neck. The paper does not provide raw injury data, so no inferences can be made as to the relative likelihood of various AIS coded injuries within a HAZUS level.

Table F-3 HAZUS Level-2 injuries and related AIS-coded injuries

HAZUS example	Similar AIS-coded injuries, with numerical injury identifier. The last digit is the AIS level.	AIS
3 rd degree burn, 2 nd degree burn over large parts of the body	The AIS dictionary lists 12 nonfatal burn injuries meeting these criteria. They are: 912007.1 Burn, 3° ≤ 100 cm ² (except face ≤ 25 cm) 912008.2 Burn, 3° > 100 cm ² (except face ≥ 25 cm) up to 10% of total body surface 912012.2 Burn, 2° or 3° (or full thickness) 10-19% of total body surface 912014.3 Burn, 2° or 3° (or full thickness) 10-19% of total body surface, < 5 years old 912016.3 Burn, 2° or 3° (or full thickness) 10-19% of total body surface, face/hand/genitalia involvement 912018.3 Burn, 2° or 3° (or full thickness) 20-29% of total body surface 912020.4 Burn, 2° or 3° (or full thickness) 20-29% of total body surface, < 5 years old 912022.4 Burn, 2° or 3° (or full thickness) 20-29% of total body surface, face/hand/genitalia involvement 912024.4 Burn, 2° or 3° (or full thickness) 30-39% of total body surface 912026.5 Burn, 2° or 3° (or full thickness) 30-39% of total body surface, < 5 years old 912028.5 Burn, 2° or 3° (or full thickness) 30-39% of total body surface, face/hand/genitalia involvement 912030.5 Burn, 2° or 3° (or full thickness) 40-89% of total body surface	1 2 2 3 3 3 4 4 4 4 5 5 5
A bump on the head that causes loss of consciousness	The AIS dictionary lists 27 injuries with explicit reference to unconsciousness. Some are: 160202.2 Head injury, unconscious < 1 hr 160204.3 Head injury, unconscious < 1 hr, with neurological deficit 160206.3 Head injury, 1-6 hr unconsciousness 160208.4 Head injury, 1-6 hr unconsciousness, with neurological deficit 160210.4 Head injury, 6-24 hr unconsciousness 160212.5 Head injury, 6-24 hr unconsciousness, with neurological deficit 160214.5 Head injury, >24 hr unconsciousness	2 3 3 4 4 5 5
Fractured bone	There are approximately 181 instances of the word “fracture” in the AIS dictionary. Here is a sample of 8. 450212.1 One rib fracture 450220.2 Two to three ribs fractured or multiple fractures of a single rib 450230.3 Three ribs on one side and no more than 3 ribs on other side, stable chest 450240.4 More than three ribs on each of two sides, with stable chest 752602.2 Humerus fracture, closed/undisplaced 752604.3 Humerus fracture open, displaced, or comminuted 851606.2 Fibula fracture, head, neck, shaft 851801.3 Femur fracture, open, displaced, or comminuted	1 2 3 4 2 3 2 3
Dehydration	The word “dehydration” does not appear in the AIS dictionary	
Exposure	The word “exposure” does not appear in the AIS dictionary	

Mahue-Giangreco et al. (2001) similarly examined medical records and other emergency-department records, addressing a larger population of injury victims than Peek-Asa et al. (1998), because they included non-hospitalized injury victims as well as hospitalized injuries. As with Peek-Asa et al. (1998), Mahue-Giangreco et al. (2001) do not provide raw injury data, so no inferences can be made as to the relative likelihood of various AIS coded injuries within a HAZUS level.

F.6 Summary

Table F-5 lists AIS injury levels that are possible under each HAZUS level and shows the mapping used in the present study (Mapping 1), as well as an alternative mapping (Mapping 2).

The table shows that, considering the examples given for each HAZUS injury level, both the original and alternative mapping can be defended solely on the basis of the examples and the definitions of some of the 1,300 AIS-coded injuries in the AIS dictionary (AAAM, 2001).

Table F-4 HAZUS Level-3 injuries and related AIS-coded injuries

HAZUS example	Similar AIS-coded injuries, with numerical injury identifier. The last digit is the AIS level.	AIS
Uncontrolled bleeding	<p>Neither the phrase “uncontrolled bleeding” nor just the word “uncontrolled” appear in the AIS dictionary. However, many injuries are qualified by amount of blood lost. The expression “blood loss >20%” appears approximately 31 times. Some examples follow.</p> <p>110606.3 Scalp laceration, blood loss > 20% by volume</p> <p>216006.3 Face penetrating injury, blood loss > 20% by volume</p> <p>320212.4 Carotid (common, internal) artery, laceration, major (blood loss > 20% by volume)</p> <p>320214.5 Carotid (common, internal) artery, laceration, major (blood loss > 20% by volume), with neurological deficit (stroke) not head injury related</p> <p>416006.3 Thorax penetrating injury with blood loss > 20% by volume</p> <p>716006.3 Upper extremity penetrating injury with blood loss > 20% by volume</p> <p>816006.3 Lower extremity penetrating injury with blood loss > 20% by volume</p>	<p>3</p> <p>3</p> <p>4</p> <p>5</p> <p>3</p> <p>3</p> <p>3</p>
Punctured organ	<p>The word “puncture” appears approximately 42 times in the AIS dictionary, but always in relation to blood vessels, never organs. Some examples of internal-organ lacerations include the following.</p> <p>441012.5 Heart laceration, perforation</p> <p>441420.4 Lung laceration, with blood loss > 20% by volume</p> <p>441422.5 Lung laceration, with tension pneumothorax</p> <p>540624.4 Bladder laceration, perforation; full thickness but not complete transection</p> <p>541826.4 Liver laceration, parenchymal disruption of ≤ 75% of hepatic lobe or 1-3 Couinaud's segments within a single lobe; multiple lacerations > 3 cm deep; "burst" injury; major</p> <p>542824.3 Pancreas laceration, moderate, with major vessel or major duct involvement</p>	<p>5</p> <p>4</p> <p>5</p> <p>4</p> <p>4</p> <p>3</p>
Spinal column injuries	<p>The AIS dictionary lists approximately 80 spinal injuries, ranging from AIS 2 to 6. Some nonfatal examples:</p> <p>630212.2 Cervical spine, brachial plexus injury, incomplete plexus injury, contusion (stretch injury)</p> <p>630604.3 Lumbar spine, cauda equina contusion, with transient neurological signs, with fracture</p> <p>630632.4 Lumbar spine, complete cauda equina contusion, with no fracture or dislocation</p> <p>640224.5 Cervical spine, cord contusion, complete cord syndrome, C4 or lower, with no fracture or dislocation</p>	<p>2</p> <p>3</p> <p>4</p> <p>5</p>
Crush syndrome	<p>The phrase “crush syndrome” does not appear in the AIS dictionary. There are approximately 27 instances of the word “crush” in the AIS dictionary. Some nonfatal examples are:</p> <p>340212.5 Larynx, laceration, puncture, avulsion, crush, rupture; transection; massive destruction</p> <p>340610.5 Pharynx or Retropharyngeal area, laceration, puncture, avulsion, crush, rupture; transection; massive destruction</p> <p>640240.5 Cervical spine cord laceration (includes transection and crush)</p> <p>640640.5 Lumbar spine cord laceration (includes transection and crush)</p> <p>713000.3 Upper extremity massive destruction of bone and of muscles/nervous system/vascular system of part or entire extremity (crush)</p>	<p>5</p> <p>5</p> <p>5</p> <p>5</p> <p>3</p>

Table F-5. Two options for mapping from HAZUS to AIS Injury levels

HAZUS level	AIS in Tables F-2 through F-4	AIS mapping 1		AIS mapping 2	
		AIS levels	Cost	AIS levels	Cost
1	1-3	1-2	\$17,000	1	\$6,000
2	1-5	3	\$180,000	2-3	\$114,000
3	3-5	4-5	\$1,200,000	4-5	\$1,500,000
4	Not addressed	6	\$3,000,000	6	\$3,000,000

No statistical data from natural disasters were readily available that might improve the mapping by providing actual rates of various AIS-coded injuries by HAZUS level.

The table also shows the equivalent monetary value of avoiding one such statistical injury, using government-endorsed values of avoiding statistical injuries, as listed in Table 4-3. It bears repeating that the costs in Table 4-3 and Table F-5 are comprehensive, reflecting medical costs, lost earnings, lost household production, emergency services, vocational rehabilitation, workplace costs, administrative, legal, pain and lost quality of life, and other factors. Medical costs alone represent a relatively small portion of the comprehensive cost, typically 10% or less.

Note that, where two AIS levels are applied to a single HAZUS injury level in Table F-5, the average of the two amounts is used. In the mapping for this project, where two AIS levels apply, the cost given in the table is the geometric mean, i.e., $\text{cost} = (\text{cost}_1 \times \text{cost}_2)^{1/2}$. This method reflects the notion that the lower level is more likely than the higher one. This approach may be considered overly complicated, and in the alternative mapping, the more common, easily-understood, simple arithmetic mean is applied, i.e., $\text{cost} = \frac{1}{2} (\text{cost}_1 + \text{cost}_2)$

F.7 Conclusion

The definitions of HAZUS injury levels in the HAZUS Technical Manual (NIBS and FEMA, 2003a) are somewhat vague and cannot be mapped uniquely to particular AIS levels using the AIS dictionary (AAAM, 2001). Empirical data are lacking to reduce or eliminate the ambiguity in mapping from HAZUS to AIS. As a result, the mapping is subject to judgment and disagreement. Either the mapping used for this project (“Mapping 1” in Table F-5), or an alternative examined here (“Mapping 2” in Table F-5), can be defended solely on the basis of a strict reading of the HAZUS Technical Manual and of the AIS dictionary.

