INTERNATIONAL STANDARD

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AMENDMENT 1
2012-07-15

Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

Part 5: Injury indices and risk/benefit analysis

Amendment 1: Ground impact and injury costs

Motocycles — Méthodes d'essai et d'analyse de l'évaluation par la recherche des dispositifs, montés sur les motocycles, visant à la protection des motocyclistes contre les collisions —

Partie 5: Indices de blessure et analyse risque/bénéfice

Amendement 1: Impact au sol et coûts des blessures

Reference number
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Foreword

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

Amendment 1 to ISO 13232-5:2005 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 22, *Motorcycles*.

Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

Part 5:
Injury indices and risk/benefit analysis

Amendment 1: Ground impact and injury costs

IMPORTANT This Amendment may require re-interpretation by users of numerous directly related clauses among the eight parts of ISO 13232. It is expected that consequential amendments to these clauses would be part of any future revision of ISO 13232.

Page 2, Clause 3

Add the following terms:

— economic costs;

— comprehensive costs;

— quality adjusted life costs;

Page 23, 5.9

Insert the following at the beginning of the subclause and before the Note.

“The risk/benefit analysis for each collision shall include, at a minimum, the primary impact period, which shall be considered to be the time period until but not including ground impact, or 0,500 s after the first MC/OV contact, whichever is sooner.

The risk/benefit analysis for each collision should also include a separate analysis for the entire impact sequence, which shall be considered to be the time period from first MC/OV contact until at least 1 s and no longer than 3 s after the first MC/OV contact, and to the extent applicable, within this period, until the dummy’s head, spine, and pelvis centres-of-gravity resultant velocities are all less than 1 m/s, or until 500 ms after ground impact, whichever is sooner.

Ground impact shall be considered to be the first point in time when any portion of the dummy’s head or helmet shapes is in contact with the ground.”

Page 153, O.3.8

Insert the following at the beginning of O.3.8:

“Injuries resulting from ground contact are often a substantial portion of the total injuries in MC/OV crashes (e.g., ACEM, MAIDS Report, 2004). Advances in computational speeds have made it feasible to conduct computer simulation analyses that include ground contact. However, in order to place reasonable upper limits on the computational requirements for simulations that include the ground contact period, the simulation is considered to be complete when the dummy’s velocities are nearly zero or 500 ms after head or helmet to ground impact, whichever is sooner. In order to account for cases in which, during the first 3 s after MC/OV contact, the dummy’s key body region velocities are not reduced to nearly zero and the dummy’s head or helmet does not impact the ground, the simulation may be considered to be complete after 3 s.

These upper limits on the required duration of the computer simulation allow virtually all important injuries to be included in the risk/benefit analysis without requiring excessive computer time. Using typical contemporary (i.e., 2008 production) personal computers, simulations of the primary impact period for the 2 X 200 impact configurations using an example fully ISO-compliant multi-body model (Kebschull et al, 1998) can be run in approximately 8 CPU hours. Extending the simulation time to include the entire impact period as described in subclause 5.9 requires less than 48 CPU hours. In cases where the researcher wishes to model higher levels of detail, it is expected that finite element models would require less than 10 000 CPU hours to simulate the primary impact period for these 2 X 200 impact configurations and less than 60 000 CPU hours to simulate the entire impact period. Hybrid multi-body/FE models would require CPU hours somewhere between those for a pure multi-body model and for a pure finite element model. Another technological advance that enables such computational loads to be feasible is the increasingly popular usage of ”computer clusters” or “computer grids” for processing, i.e., involving many CPUs, running in parallel.”

Comment: Add a calculation for injury costs based on comprehensive costs in addition to the current calculation based on ancillary costs. Document changes are as follows:

Rename all occurrences of the following variables based on only medical and ancillary costs as given below.

Old Variable	Old Description	New Variable	New Description
CF	Cost of fatality	CF_{eco}	Economic cost of fatality
IC_{norm}	Injury cost, normalized	$IC_{norm,eco}$	Injury economic cost, normalized
CS_{norm}	Normalized cost of survival	$CS_{norm,eco}$	Normalized economic cost of survival

Page 18, 5.5.3

Renumber 5.5.3 on Fatality cost to 5.5.4.

Insert the following new subclause immediately above the newly numbered 5.5.4:

5.5.3 Quality adjusted life costs

Tabulate the injuries by body region and AIS injury severity level. Determine the quality adjusted life costs associated with each body region injury and each discrete AIS injury severity level, for each country in the cost data listed in Annex A. Calculate the total quality adjusted life cost associated with the injuries for each of the four body regions, including the head, neck, thorax, and abdomen, using the equation given below:

$$QC_{i,tot} = \sum_{j=1}^{5} P_{i,j} \times QC_{i,j}$$

where

$QC_{i,tot}$ is the total quality adjusted life cost associated with injuries sustained to the body region i;

$P_{i,j}$ is the probability of sustaining an injury of AIS injury severity level j to the body region i;

$QC_{i,j}$ is the quality adjusted life cost associated with an injury to the body region i of AIS injury severity level j.

Determine the total quality adjusted life cost associated with lower extremity injuries using the maximum PPI value, as determined in 5.4.2.3, and the respective cost data table given in Annex A.

Determine the overall quality adjusted life cost of injuries to the head, neck, thorax, abdomen, and lower extremities as given below:

$$QC = \max\left(QC_{i,tot}\right)$$

where

QC is the overall quality adjusted life cost;

$QC_{i,tot}$ is the total quality adjusted life cost associated with injuries sustained to the body region i.

Insert the following text at the end of 5.8:

"Calculate the normalized comprehensive cost of survival as shown in the equation below:

$$CS_{norm,co} = \frac{\left(\text{minimum of}\left(\left(MDC + AC + QC\right)\text{or } CF_{co}\right)\right)\left(1 - P_{fatal}\right)}{CF_{co}}$$

where

$CS_{norm,co}$ is the normalized comprehensive cost of survival;

MDC is the medical cost;

AC is the ancillary cost;

P_{fatal} is the probability of fatality;

CF_{co} is the comprehensive cost of fatality (medical, ancillary, and quality of life);

the maximum value of $CS_{norm,co}$ is $(1 - P_{fatal})$.

The normalized cost of fatality (CF_{norm}) is equal to the probability of fatality (P_{fatal}).

Calculate the total normalized injury comprehensive cost as shown in the equation below:

$$IC_{norm,co} = CS_{norm,co} + CF_{norm}$$

where

$IC_{norm,co}$ is the total normalized injury comprehensive cost;

$CS_{norm,co}$ is the normalized comprehensive cost of survival;

CF_{norm} is the normalized cost of fatality;

the maximum value of IC_{norm} is 1,0."

Page 23, 5.9

Insert the following at the beginning of the subclause and before the Note.

"The risk/benefit analysis for each collision shall, at a minimum, include the primary impact period, which is the time period up to but not including dummy to ground contact, or 0,500 s after the first MC/OV contact, whichever is sooner. The risk/benefit analysis for each collision should also include a separate analysis for the entire impact sequence, which is defined as the time period from first MC/OV contact until the dummy's head, spine, and pelvis velocities are all less than 1 m/s or until 500 ms after ground impact, whichever is sooner. Ground impact is defined as the first point in time when any portion of the dummy's head or helmet is in contact with the ground. The entire impact sequence shall be at least 1 s and shall be no longer than 3 s after the first MC/OV contact."

Page 26, 5.9.4.2

Replace the equation for "average risk" with the following:

$$\text{average risk } j = \text{ average increase in injury index } j = \frac{1}{N}\sum_{k=1}^{N_{risk}}\left(\Delta x_{k,j} \times FO_k\right)$$

Page 28, Annex A

Replace the first two paragraphs in Annex A with the following text:

“Use the tables in Annex A to determine the medical, ancillary, and quality of life costs for each body region and AIS injury severity level when calculating the overall costs in 5.5.1, 5.5.2, and 5.5.3, respectively.

Tables A.1, A.2, and A.3 list respective medical, ancillary, and quality of life costs in 2000 U.S. dollars.”

Replace Table A.1 with the following table:

Table A.1 — Medical costs

Body region	AIS injury severity level	Cost (USD)
Head	1	30 405
Head	2	31 323
Head	3	193 785
Head	4	206 592
Head	5	280 228
Neck	3	355 082
Neck	4	824 887
Neck	5	1 088 896
Thorax	1	1 248
Thorax	2	11 384
Thorax	3	32 692
Thorax	4	52 963
Thorax	5	62 967
Abdomen	1	1 248
Abdomen	2	11 384
Abdomen	3	32 692
Abdomen	4	52 963
Lower extremities	2	8 592
Lower extremities	3	31 258

Page 29, Annex A

Replace Table A.2 with the following table:

Table A.2 — Ancillary costs

Body region	AIS injury severity level	PPI	Cost (USD)
Head	1	-	10 225
Head	2	-	36 539
Head	3	-	121 644
Head	4	-	232 423
Head	5	-	943 054[a]
Neck	3	-	262 761
Neck	4	-	399 937
Neck	5	-	476 360
Thorax	1	-	3 058
Thorax	2	-	51 882
Thorax	3	-	86 592
Thorax	4	-	119 742
Thorax	5	-	240 645
Abdomen	1	-	3 058
Abdomen	2	-	51 882
Abdomen	3	-	86 592
Abdomen	4	-	119 742
Lower extremities	-	07	27 996
Lower extremities	-	15	59 991
Lower extremities	-	22	87 986
Lower extremities	-	27	107 983
Lower extremities	-	38	151 976

NOTE The medical and ancillary cost of fatality is 919 834 in 2000 U.S. dollars.

[a] Although the ancillary cost of a head AIS5 injury exceeds that of a fatality, the equations which calculate normalized injury costs do not produce normalized costs which exceed a value of 1

Update the costs in Annex D accordingly and prepare other consequential amendments.

Add the following Table A.3 based on Miller, et al. (2001) to the end of Annex A:

Table A.3 — Quality of life costs

Body region	AIS injury severity level	PPI	Cost (USD)
Head	1	-	46 102
Head	2	-	202 455
Head	3	-	315 330
Head	4	-	681 113
Head	5	-	1 695 212
Neck	3	-	174 066
Neck	4	-	1 520 370
Neck	5	-	2 164 209
Thorax	1	-	3 552
Thorax	2	-	53 310
Thorax	3	-	91 870
Thorax	4	-	156 950
Thorax	5	-	203 090
Abdomen	1	-	3 552
Abdomen	2	-	53 310
Abdomen	3	-	91 870
Abdomen	4	-	156 950
Lower extremities	-	07	106 426
Lower extremities	-	15	228 056
Lower extremities	-	22	334 481
Lower extremities	-	27	410 500
Lower extremities	-	38	577 741
NOTE The quality of life cost of fatality is 2 389 179 in 2000 U.S. dollars.			

Page 31, Annex C

Add the following variable definitions to Annex C:

Variable	Definition
CF_{co}	Comprehensive cost of fatality
$IC_{norm,co}$	Injury comprehensive cost, normalized
$CS_{norm,co}$	Normalized comprehensive cost of survival

Page 34, Annex D

Replace the computer code in Annex D with the following:

```
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c
c     This is the verison in ISO/DIS 13232-5 Annex D (2008)
c
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      subroutine icm2009(Idatin,Rdatin,Table,Datout,Ierr)
      implicit none
      integer Idatin(5), Ierr
      real Rdatin(6), Table(9,6), Datout(12)

c**************************************************************************
c
c     name
c
c       icm - Evaluate the Injury Cost Model
c
c     description
c
c       This subroutine evaluates the Injury Cost Model for the inputs
c       in arrays Idatin and Rdatin.  Output is returned in arrays Table
c       and Datout.
c
c     calling sequence
c
c       argument  i/o  description
c       --------  ---  -----------
c       Idatin     i   integer data input array, elements as follows:
c                      element  symbol  description
c                      -------  ------  -----------
c                         1      FF3    number of AIS 3 femur fractures
c                         2      TF2    number of AIS 2 tibia fractures
c                         3      TF3    number of AIS 3 tibia fractures
c                         4      KDI2   number of AIS 2 knee dislocated
c                                       injuries
c                         5      KDI3   number of AIS 3 knee dislocated
c                                       injuries
c
c       Rdatin     i   real data input array, elements as follows:
c                      element  symbol  units  description
c                      -------  ------  -----  -----------
c                         1      AP      mm    maximum abdomen
c                                              penetration
c                         2      Gmax     -    maximum GAMBIT
c                         3      Cmax     %    maximum normalized chest
c                                              compression
c                         4      VCmax   m/s   maximum chest viscous
c                                              criteria when V>3 m/s
c                         5      HIC      -    Head Injury Criteria
c                         6      NII      -    Neck Injury Index
c
c       Table      o   table 1 values
c
c       Datout     o   real data output array, elements as follows:
c                      element  symbol  units  description
c                      -------  ------  -----  -----------
c                         1      MAIS          maximum AIS
c                         2      TAIS          total AIS
c                         3      NICE     -    Normalized Injury
c                                              Economic Cost
c                         4      NCOSE    -    Normalized Economic Cost of
```

```
c                                          Survival
c                        5      NCOD     -    Normalized Economic Cost of
c                                          Dying
c                        6      POF      -    Probability of Fatality
c                        7      POF5     -    POF due to non AIS 6
c                                          injuries
c                        8      POF6     -    POF due to AIS 6 injuries
c                        9      PPI      -    Permanent Partial
c                                          Incapacity
c                       10      Prisk    %    Risk of life threatening
c                                          brain injury
c                       11      NICC     -    Normalized Injury
c                                          Comprehensive Cost
c                       12      NCOSC    -    Normalized Comprehensive
c                                          Cost of Survival
c
c       Ierr       o   error code
c                          0   - normal return
c                         1- 5 - index of out of range Idatin
c                        11-14 - index of out of range Rdatin
c
c     version history
c
c       - original version by RMV, DRI, March 1993
c       - first revision by RMV, DRI, April 1993
c          - AIS 3 knee dislocation injuries added
c          - Input range checking added
c       - second revision by RMV, DRI, March 1994
c          - changed model and subroutine name from Injury Cost Model II
c            (icm2) to Injury Cost Model (icm)
c          - changed hospital cost (HC) to medical cost (MDC)
c          - changed parameter names from AISmax to AIS6, AISsrv to AIS5
c       - third revision by RMV, DRI, August 1994
c          - added PPI to Datout output array
c          - added risk of life threatening brain injury calculation
c            based on HIC, HIC input was added to Rdatin and Prisk
c            output added to Datout arrays
c       - fourth revision by RMV, DRI, December 1994
c          - Corrected PPI for 1 leg injury
c          - include HIC ISP for to head AIS, revision by DPC, DRI, March 1998
c          - include Neck Injury Criteria, revision by KDW,RMV,SM, DRI, May 2001
c       - sixth revision by KDW, DRI, February 2002
c          - added new neck ISPn equation coefficients
c       - seventh revision by RMV, DRI, June 2004
c          - revised new neck ISPn equation coefficents
c       - revised 2009-12-16 by JK
c          - updated injury costs as per ISO 13232-5:2005/DAM 2
c          - added Quality of Life costs

c
c*******************************************************************************
c
c     local parameters
c
c     AIS6 - fatal AIS
c     AIS5 - maximum survivable AIS
c
      integer AIS6, AIS5, jhic
      parameter (AIS6=6, AIS5=5, jhic=15)
c
c     local variables
c
      real Beta1(AIS6), Gamma1(AIS6), Eta1(AIS6)
      real Beta2(AIS6), Gamma2(AIS6), Eta2(AIS6)
      real Gamma3(AIS6)
```

```
      real Gamma5(AIS6)
      real Gamma6(AIS6),Eta6(AIS6)
      real Alpha4(AIS6), Beta4(AIS6)
      integer FF3, KDI2, KDI3, TF2, TF3
      integer i, itmp, j, kais(5), kais1, kais2, kais3, kais4, kais5
      integer krow, nLAIS2, nLAIS3, ntot
      real AP, Cmax, Gmax, VCmax
      real AAC(AIS5), AACT, AAIS(0:AIS6), AMDC(AIS5), AMDCT
      real AQC(AIS5), AQCT
      real AISP(AIS6)
      real CAC(AIS5), CACT, CAIS(0:AIS6), CMDC(AIS5), CMDCT
      real CQC(AIS5), CQCT
      real CISP(AIS6)
      real HAC(AIS5), HACT, HAIS(0:AIS6), HMDC(AIS5), HMDCT
      real HQC(AIS5), HQCT
      real HISP(AIS6)
      real HGISP(AIS6), HHICISP(AIS6)
      real LAC07, LAC15, LAC22, LAC27, LAC38
      real LQC07, LQC15, LQC22, LQC27, LQC38
      real LACT, LAIS(0:AIS6), LMDC(AIS5), LMDCT, LQCT
      real NAC(AIS5), NACT, NAIS(0:AIS6), NMDC(AIS5), NMDCT
      real NQC(AIS5), NQCT
      real NISP(AIS6)
      real MR(0:AIS5,0:AIS5,0:AIS5)
      real AC, CCISP, CVCISP, MDC, POF, POF5, POF6, PPI, QC
      real APAIS, CPAIS, HPAIS, LPAIS, NPAIS
      integer IAPAIS, ICPAIS, IHPAIS, ILPAIS, INPAIS
      real COFE, MAIS, NCOD, NCOSE, NICE, TAIS, COFQ, COFC, NICC
      real NCOSC
      real curve(2,jhic), HIC, Prisk, NII
C
C     ****************************************************************
C     ***                                                          ***
C     ***  data                                                    ***
C     ***                                                          ***
C     ****************************************************************
C
C     Injury Severity Probability function coefficients
C
      data Gamma1/0.0,0.125,0.375,0.438,0.650,0.680/
      data Eta1/0.755,0.70,0.64,0.62,0.54,0.60/
      data Beta1/3.5,3.5,3.5,3.5,2.2,1.8/
      data Gamma2/0.0,0.0,0.0,0.4,1.0,1.5/
      data Eta2/0.3,0.68,1.40,1.291,0.995,0.78/
      data Beta2/0.99,1.46,2.85,3.10,3.10,3.10/
      data Gamma3/1.77,7.47,13.22,18.97,24.72,32.52/
      data Alpha4/0.0157,0.0123,0.000155,9.36e-13,0.0,0.0/
      data Beta4/1.0,1.0,2.0,6.5,1.0,1.0/
      data Gamma5/0.0,0.0,0.0,450.0,450.0,450.0/
      data Gamma6/1.06,1.86,2.29,4.73,4.73,6.13/
      data Eta6/4.38,4.38,4.38,4.38,4.38,4.38/
C
C     Medical Cost data in U.S. Dollars - Table A.1
C
      data HMDC/  30405.,  31323., 193785., 206592., 280228./
      data NMDC/      0.,      0., 355082., 824887.,1088896./
      data CMDC/   1248.,  11384.,  32692.,  52963.,  62967./
      data AMDC/   1248.,  11384.,  32692.,  52963.,      0./
      data LMDC/      0.,   8592.,  31258.,      0.,      0./
C
C     Ancillary Cost data in U.S. Dollars - Table A.2
C
      data HAC/ 10225., 36539.,121644.,232423.,943054./
      data NAC/     0.,     0.,262761.,399937.,476360./
      data CAC/  3058., 51882., 86592.,119742.,240645./
```

```
      data AAC/  3058., 51882., 86592.,119742.,     0./
      data LAC07/ 27996./, LAC15/ 59991./, LAC22/87986./
      data LAC27/107983./, LAC38/151976./
c
c     Quality of Life Cost data in U.S. Dollars - Table A.3
c
      data HQC/  46102., 202455., 315330., 681113.,1695212./
      data NQC/      0.,      0., 174066.,1520370.,2164209./
      data CQC/   3552.,  53310.,  91870., 156950., 203090./
      data AQC/   3552.,  53310.,  91870., 156950.,      0./
      data LQC07/106426./, LQC15/228056./, LQC22/334481./
      data LQC27/410500./, LQC38/577741./
c
c     Mortality Rate data
c
      data (((MR(kais1,kais2,kais3),
     &                    kais3=0,kais2),kais2=0,kais1),kais1=0,AIS5)/
     &     0.0000,  0.1502,  0.3481,  0.8068,  0.9379,  1.2140,  1.5713,
     &     2.0339,  2.6327,  3.4077,  1.8198,  2.0789,  2.3750,  2.7133,
     &     3.0997,  3.5412,  4.0456,  4.6218,  5.2800,  6.0320,  9.1459,
     &    10.3025, 11.6052, 13.0727, 14.7258, 16.5879, 18.6855, 21.0483,
     &    23.7099, 26.7080, 30.0853, 33.8896, 38.1750, 43.0022, 48.4399,
     &    24.5181, 25.8821, 27.3220, 28.8420, 30.4465, 32.1403, 33.9283,
     &    35.8158, 37.8083, 39.9117, 42.1321, 44.4759, 46.9502, 49.5622,
     &    52.3194, 55.2300, 58.0236, 61.5461, 64.9700, 68.5844, 72.3999/
c
c     Cost of Fatality in U.S. Dollars
c
      data COFE/ 919834./ ! Medical and ancillary cost of fatality
c                           (economic cost of fatality)
      data COFQ/2389179./ ! Quality of Life cost of fatality
c
c     Risk of life threatening brain injury vs HIC data
c
      data curve/  430.0,  1.0,
     &             550.0,  2.0,
     &             730.0,  5.0,
     &             890.0, 10.0,
     &            1080.0, 20.0,
     &            1220.0, 30.0,
     &            1340.0, 40.0,
     &            1450.0, 50.0,
     &            1560.0, 60.0,
     &            1680.0, 70.0,
     &            1820.0, 80.0,
     &            2010.0, 90.0,
     &            2170.0, 95.0,
     &            2350.0, 98.0,
     &            2470.0, 99.0/
c
c*******************************************************************************
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Extract input data from input arrays                    ***
c     ***                                                          ***
c     ****************************************************************
c
      FF3   = Idatin(1)
      TF2   = Idatin(2)
      TF3   = Idatin(3)
      KDI2  = Idatin(4)
      KDI3  = Idatin(5)

      AP    = Rdatin(1)
```

```
      Gmax  = Rdatin(2)
      Cmax  = Rdatin(3)
      VCmax = Rdatin(4)
      HIC   = Rdatin(5)
      NII   = Rdatin(6)
c
c     check inputs for allowable ranges
c
      do 2 i=1,5
        if( (Idatin(i).lt.0) .or. (Idatin(i).gt.2) ) then
          Ierr = i
          return
        end if
    2 continue
      do 5 i=1,6
        if( (Rdatin(i).lt.0.0) ) then
          Ierr = 10+i
          return
        end if
    5 continue
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate injury severity probabilities (ISP) for head,   ***
c     ***  neck, chest, and abdomen                                 ***
c     ***                                                          ***
c     ****************************************************************
c
c
c     begin loop through injury severity levels
c
      do 10 kais1=1,AIS6
c
c       calculate the head injury severity probability (ISP) based on
c       Gmax
c
        if(Gmax.ge.Gamma1(kais1)) then
          HGISP(kais1) =
     &      1.0-exp(-(((Gmax-Gamma1(kais1))/Eta1(kais1))**Beta1(kais1)))
        else
          HGISP(kais1) = 0.0
        end if
c
c       calculate the chest ISP based on VCmax
c
        if(VCmax.ge.Gamma2(kais1)) then
          CVCISP =
     &     1.0-exp(-(((VCmax-Gamma2(kais1))/Eta2(kais1))**Beta2(kais1)))
        else
          CVCISP = 0.0
        end if
c
c       calculate the chest ISP based on Cmax
c
        if(Cmax.ge.Gamma3(kais1)) then
          CCISP = 1.0-exp(-(((Cmax-Gamma3(kais1))/24.0)**6))
        else
          CCISP = 0.0
        end if
c
c       calculate the chest ISP based on the
c       of larger of the probabilities due to VCmax and Cmax
c
        CISP(kais1) = max(CVCISP,CCISP)
c
```

```
c       calculate the abdomen ISP based on penetration
c
        AISP(kais1) = Alpha4(kais1)*AP**Beta4(kais1)
c
c       calculate the neck ISP
c
        if(NII.ge.Gamma6(kais1)) then
          NISP(kais1) = 1.0 - exp(-1.0*(((NII-Gamma6(kais1))
     &                                    /Eta6(kais1))**3.5))
        else
          NISP(kais1) = 0.0
        endif

   10 continue

c
c     calculate ISP for head using HIC
c
      if(HIC.ge.Gamma5(1)) then
        HHICISP(1) = 1.0-(exp(-((HIC/560.0)**2.98)))
      else
        HHICISP(1) = 0.0
      endif

      if(HIC.gt.Gamma5(3)) then
        HHICISP(3) = 1.0-(exp(-(((HIC+500.0)/1990.0)**4.5)))
      else
        HHICISP(3) = 0.0
      endif

      if(HIC.ge.Gamma5(6)) then
        HHICISP(6) = 1.0-(exp(-(((HIC-450.0)/3275.0)**1.36)))
      else
        HHICISP(6) = 0.0
      endif

      if(HIC.ge.Gamma5(2)) then
        HHICISP(2) = HHICISP(3)+((HHICISP(1)-HHICISP(3))*55.0/123.0)
      else
        HHICISP(2) = 0.0
      endif

      if(HIC.ge.Gamma5(4)) then
        HHICISP(4) = HHICISP(6)+((HHICISP(3)-HHICISP(6))*24.0/41.0)
      else
        HHICISP(4) = 0.0
      endif

      if(HIC.ge.Gamma5(5)) then
        HHICISP(5) = HHICISP(6)+((HHICISP(3)-HHICISP(6))*14.0/41.0)
      else
        HHICISP(5) = 0.0
      endif
c
c     calculate the maximum head ISP between HIC & Gmaxc
c
      do 12 kais1 = 1,AIS6
        HISP(kais1) = max(HGISP(kais1),HHICISP(kais1))
   12 continue
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate the probability of discrete AIS injuries by   ***
c     ***  body region                                             ***
c     ***                                                          ***
```

```
c     ****************************************************************
c
      HAIS(0) = 1.0-HISP(1)
      CAIS(0) = 1.0-CISP(1)
      AAIS(0) = 1.0-AISP(1)
      NAIS(0) = 1.0-NISP(1)
      do 15 kais1=1,AIS5
        HAIS(kais1) = HISP(kais1)-HISP(kais1+1)
        CAIS(kais1) = CISP(kais1)-CISP(kais1+1)
        AAIS(kais1) = AISP(kais1)-AISP(kais1+1)
        NAIS(kais1) = NISP(kais1)-NISP(kais1+1)
   15 continue
      HAIS(AIS6) = HISP(AIS6)
      CAIS(AIS6) = CISP(AIS6)
      AAIS(AIS6) = AISP(AIS6)
      NAIS(AIS6) = NISP(AIS6)
c
c     calculate the leg AIS based on worst AIS injury
c
      do 20 kais1=0,AIS6
        LAIS(kais1) = 0.0
   20 continue
      if( (FF3.ne.0) .or. (TF3.ne.0) .or. (KDI3.ne.0) ) then
        LAIS(3) = 1.0
      else if( (TF2.ne.0) .or. (KDI2.ne.0) ) then
        LAIS(2) = 1.0
      else
        LAIS(0) = 1.0
      end if
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate the maximum lower extremity Permanent Partial  ***
c     ***  Incapacity (PPI) and leg ancillary cost                 ***
c     ***                                                          ***
c     ****************************************************************
c
c     count the number of leg injuries
c
      ntot = FF3 + TF2 + TF3 + KDI2 + KDI3

      if(ntot.ge.3) then
c
c       three or more leg injuries
c
        PPI = 0.38
        LACT = LAC38
        LQCT = LQC38

      else if(ntot.eq.2) then
c
c       two leg injuries
c
        PPI = 0.27
        LACT = LAC27
        LQCT = LQC27

      else if(ntot.eq.1) then

        if(FF3.eq.1) then
c
c         1 AIS 3 femur fracture
c
          PPI = 0.15
          LACT = LAC15
```

```
          LQCT = LQC15

        else if(KDI3.eq.1) then
c
c         1 AIS 3 knee dislocation injury
c
          PPI = 0.22
          LACT = LAC22
          LQCT = LQC22

        else if(KDI2.eq.1) then
c
c         1 AIS 2 knee dislocation injury
c
          PPI = 0.15
          LACT = LAC15
          LQCT = LQC15

        else if(TF3.eq.1) then
c
c         1 AIS 3 tibia fracture
c
          PPI = 0.15
          LACT = LAC15
          LQCT = LQC15

        else if(TF2.eq.1) then
c
c         1 AIS 2 tibia fracture
c
          PPI = 0.07
          LACT = LAC07
          LQCT = LQC07

        end if

      else
c
c       no leg injuries
c
        PPI = 0.0
        LACT = 0.0
        LQCT = 0.0

      end if
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate medical and ancillary costs                   ***
c     ***                                                          ***
c     ****************************************************************
c
      HMDCT = 0.0
      NMDCT = 0.0
      CMDCT = 0.0
      AMDCT = 0.0
      LMDCT = 0.0
      HACT = 0.0
      NACT = 0.0
      CACT = 0.0
      AACT = 0.0
      do 30 kais1=1,AIS5
        HMDCT = HMDCT + HAIS(kais1)*HMDC(kais1)
        NMDCT = NMDCT + NAIS(kais1)*NMDC(kais1)
        CMDCT = CMDCT + CAIS(kais1)*CMDC(kais1)
```

```
        AMDCT = AMDCT + AAIS(kais1)*AMDC(kais1)
        LMDCT = LMDCT + LAIS(kais1)*LMDC(kais1)
        HACT = HACT + HAIS(kais1)*HAC(kais1)
        NACT = NACT + NAIS(kais1)*NAC(kais1)
        CACT = CACT + CAIS(kais1)*CAC(kais1)
        AACT = AACT + AAIS(kais1)*AAC(kais1)
        HQCT = HQCT + HAIS(kais1)*HQC(kais1)
        NQCT = NQCT + NAIS(kais1)*NQC(kais1)
        CQCT = CQCT + CAIS(kais1)*CQC(kais1)
        AQCT = AQCT + AAIS(kais1)*AQC(kais1)
   30 continue
      MDC = max(HMDCT,NMDCT,CMDCT,AMDCT,LMDCT)
      AC = max(HACT,NACT,CACT,AACT,LACT)
      QC = max(HQCT,NQCT,CQCT,AQCT,LQCT)
c
c     ****************************************************************
c     ***                                                           ***
c     ***  probability of fatality (POF)                            ***
c     ***                                                           ***
c     ****************************************************************
c
c     POF due to AIS 6 injuries
c
      POF6 = 1.0 - (1.0-HAIS(6))*(1.0-NAIS(6))*(1.0-CAIS(6))
c
c     POF due to survivable AIS (AIS<6) injuries
c
      POF5 = 0.0
      do 50 kais1=0,AIS5
        do 50 kais2=0,AIS5
          do 50 kais3=0,AIS5
            do 50 kais4=0,AIS5
              do 50 kais5=0,AIS5
c
c             sort kais from largest to smallest
c
              kais(1) = kais1
              kais(2) = kais2
              kais(3) = kais3
              kais(4) = kais4
              kais(5) = kais5
              do 45 i=1,4
                do 45 j=i+1,5
                  if(kais(i).lt.kais(j)) then
                    itmp = kais(i)
                    kais(i) = kais(j)
                    kais(j) = itmp
                  end if
   45         continue
c
c             accumulate POF
c
c             the POF increment is probability of ais level combination
c             times the mortality rate based on 3 largest ais levels
c
              POF5 = POF5 + MR(kais(1),kais(2),kais(3))*HAIS(kais1)*
     &                   NAIS(kais2)*CAIS(kais3)*AAIS(kais4)*LAIS(kais5)

   50 continue
      POF5 = 0.01*POF5
c
c     overall probability
c
      POF = POF6 + POF5
c
```

```
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate expected AIS                                  ***
c     ***                                                          ***
c     ****************************************************************
c
      HPAIS = 0.0
      NPAIS = 0.0
      CPAIS = 0.0
      APAIS = 0.0
      LPAIS = 0.0
      do 55 kais1=1,AIS6
        HPAIS = HPAIS + kais1*HAIS(kais1)
        NPAIS = NPAIS + kais1*NAIS(kais1)
        CPAIS = CPAIS + kais1*CAIS(kais1)
        APAIS = APAIS + kais1*AAIS(kais1)
        LPAIS = LPAIS + kais1*LAIS(kais1)
   55 continue
c
c     round expected AIS to nearest integer
c
      IHPAIS = nint(HPAIS)
      INPAIS = nint(NPAIS)
      ICPAIS = nint(CPAIS)
      IAPAIS = nint(APAIS)
      ILPAIS = nint(LPAIS)
c
c     construct table
c
      do 60 kais1=0,AIS6
        krow = kais1+1
        Table(krow,1) = HAIS(kais1)
        Table(krow,2) = NAIS(kais1)
        Table(krow,3) = CAIS(kais1)
        Table(krow,4) = AAIS(kais1)
        Table(krow,5) = LAIS(kais1)
        Table(krow,6) = 0.0
   60 continue

      nLAIS2 = TF2 + KDI2
      nLAIS3 = FF3 + TF3 + KDI3
      Table(3,6) = nLAIS2
      Table(4,6) = nLAIS3

      krow = AIS6+2
      Table(krow,1) = HPAIS
      Table(krow,2) = NPAIS
      Table(krow,3) = CPAIS
      Table(krow,4) = APAIS
      Table(krow,5) = LPAIS
      Table(krow,6) = 0.0

      krow = AIS6+3
      Table(krow,1) = IHPAIS
      Table(krow,2) = INPAIS
      Table(krow,3) = ICPAIS
      Table(krow,4) = IAPAIS
      Table(krow,5) = ILPAIS
      Table(krow,6) = 0.0
c
c     calculate maximum AIS
c
      MAIS = max(IHPAIS, INPAIS, ICPAIS, IAPAIS, ILPAIS)
c
c     calculate total AIS
```

```
c
      TAIS = IHPAIS + INPAIS + ICPAIS + IAPAIS + 2*nLAIS2 + 3*nLAIS3
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate Normalized Injury Costs                       ***
c     ***                                                          ***
c     ****************************************************************
c
c     Economic Cost of Survival
c
      if((MDC+AC).le.COFE) then
        NCOSE = ( MDC + AC ) * ( 1.0 - POF ) / COFE
      else
        NCOSE = (1.0 - POF)
      endif
c
c
c     Quality Cost of Survival
c
      COFC = COFE + COFQ ! Comprehensive cost of fatality (medical,
c                          ancillary, and quality of life)
      if((MDC+AC+QC).le.COFC) then
        NCOSC = ( MDC + AC + QC) * ( 1.0 - POF ) / COFC
      else
        NCOSC = (1.0 - POF)
      endif
c
c     Cost of Dying
c
      NCOD = POF
c
c     Total injury cost
c
      NICE = NCOSE + NCOD
      NICC = NCOSC + NCOD
c
c     ****************************************************************
c     ***                                                          ***
c     ***  Calculate the Risk of Life Threatening Brain Injury     ***
c     ***                                                          ***
c     ****************************************************************
c
      if(HIC.lt.curve(1,1)) then
c
c       Risk is less than 1%, return 0%
c
        Prisk = 0.0

      else if(HIC.gt.curve(1,jhic)) then
c
c       Risk is greater than 99%, return 100%
c
        Prisk = 100.0

      else
c
c       interpolate risk from table
c
        do 70 i=1,jhic-1
          j = i+1
          if( (curve(1,i).le.HIC) .and. (HIC.le.curve(1,j)) ) then
            Prisk = curve(2,i) + (curve(2,j)-curve(2,i)) *
     &                         (HIC-curve(1,i)) / (curve(1,j)-curve(1,i))
          end if
```

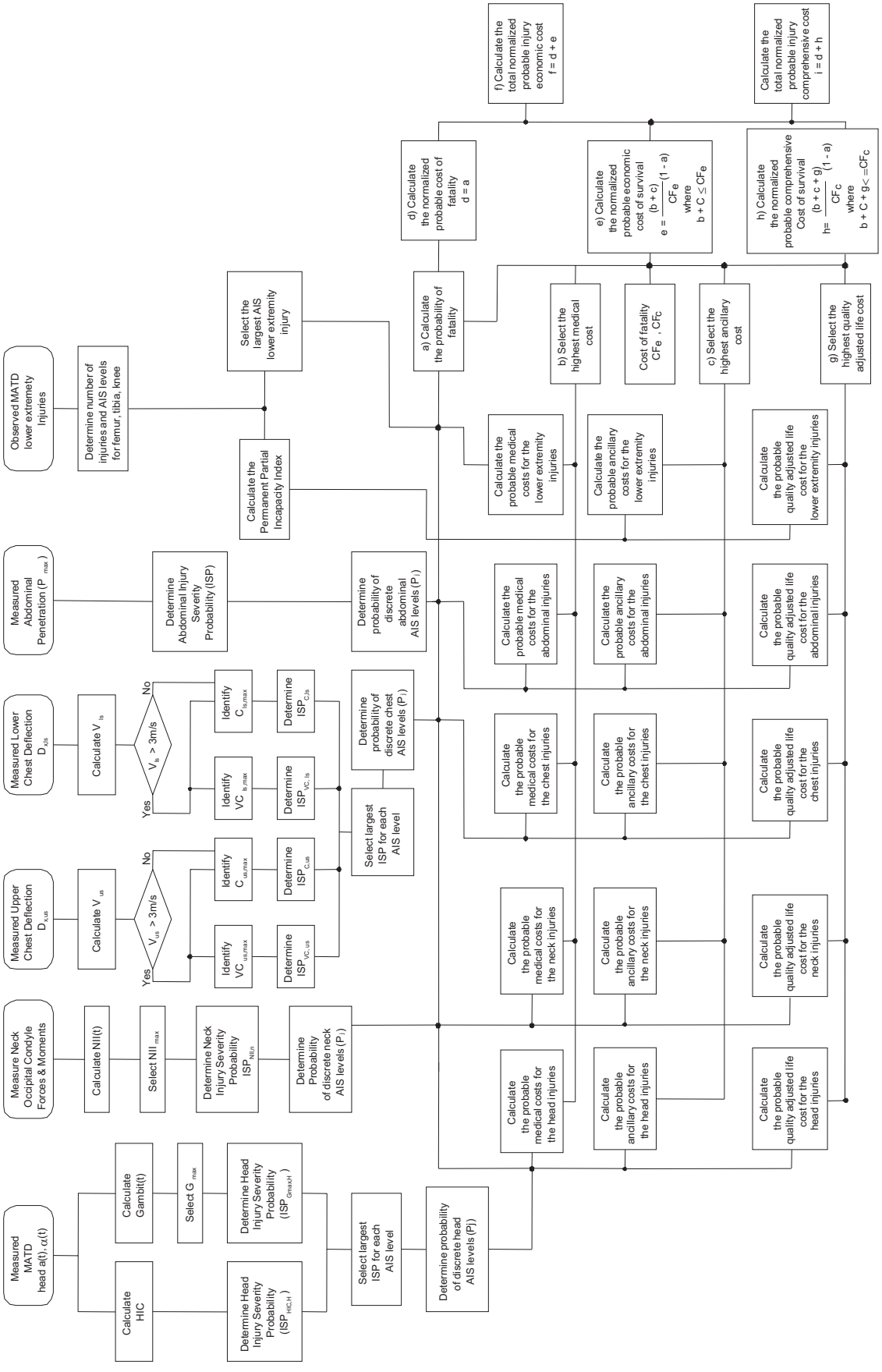
```
   70   continue

      end if
c
c     ****************************************************************
c     ***                                                          ***
c     ***  store output in output data array                       ***
c     ***                                                          ***
c     ****************************************************************
c
      Datout(1) = MAIS
      Datout(2) = TAIS
      Datout(3) = NICE
      Datout(4) = NCOSE
      Datout(5) = NCOD
      Datout(6) = POF
      Datout(7) = POF5
      Datout(8) = POF6
      Datout(9) = PPI
      Datout(10) = Prisk
      Datout(11) = NICC
      Datout(12) = NCOSC
c
c     done, normal return
c
      Ierr = 0
      return

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8

      subroutine wricm2009(Iout,Table)
      implicit none
      integer Iout
      real Table(9,6)

c*************************************************************************
c
c     name
c
c       wricm - Write the Injury Cost Model results
c
c     description
c
c       This subroutine writes the Injury Cost Model results for the
c       inputs in arrays Idatin and Rdatin and outputs in arrays Table
c       and Datout.
c
c     calling sequence
c
c       argument  i/o  description
c       --------  ---  -----------
c       Iout       i   output unit number
c       Idatin     i   integer data input array, elements as follows:
c                      element  symbol  description
c                      -------  ------  -----------
c                         1      FF3    number of AIS 3 femur fractures
c                         2      TF2    number of AIS 2 tibia fractures
c                         3      TF3    number of AIS 3 tibia fractures
c                         4      KDI2   number of AIS 2 knee dislocated
c                                       injuries
c                         5      KDI3   number of AIS 3 knee dislocated
c                                       injuries
```

```
c
c       Rdatin     i   real data input array, elements as follows:
c                      element  symbol  units  description
c                      -------  ------  -----  -----------
c                         1      AP      mm    maximum abdomen
c                                              penetration
c                         2      Gmax     -    maximum GAMBIT
c                         3      Cmax     %    maximum normalize chest
c                                              compression
c                         4      VCmax   m/s   maximum chest viscous
c                                              criteria when V>3 m/s
c                         5      HIC      -    Head Injury Criteria
c                         6      NII      -    Neck Injury Index
c
c       Table      o   table 1 values
c
c       Datout     o   real data output array, elements as follows:
c                      element  symbol  units  description
c                      -------  ------  -----  -----------
c                         1      MAIS          maximum AIS
c                         2      TAIS          total AIS
c                         3      NICE     -    Normalized Injury
c                                              Economic Cost
c                         4      NCOSE    -    Normalized Economic Cost of
c                                              Survival
c                         5      NCOD     -    Normalized Economic Cost of
c                                              Dying
c                         6      POF      -    Probability of Fatality
c                         7      POF5     -    POF due to non AIS 6
c                                              injuries
c                         8      POF6     -    POF due to AIS 6 injuries
c                         9      PPI      -    Permanent Partial
c                                              Incapacity
c                        10      Prisk    %    Risk of life threatening
c                                              brain injury
c                        11      NICC     -    Normalized Injury
c                                              Comprehensive Cost
c                        12      NCOSC    -    Normalized Comprehensive
c                                              Cost of Survival
c
c     version history
c
c       - original version by RMV, DRI, March 1993
c       - first revision by RMV, DRI, April 1993
c          - AIS 3 knee dislocation injuries added
c       - second revision by RMV, DRI, March 1994
c          - changed model and subroutine name from Injury Cost Model II
c            (wricm2) to Injury Cost Model (wricm)
c       - third revision by RMV, DRI, August 1994
c          - dimensions of Rdatin and Datout arrays changed
c       - version 2009 by JK, DRI, December 2009
c          - dimensions of Datout array changed
c          - new output added
c
c*******************************************************************************
c
c     local parameters
c
      integer kcol, krow
      character*69 blank, dline
c
c     data
c
      data blank/' '/
      data dline( 1:40)/'----------------------------------------'/
```

```
      data dline(41:69)/'-----------------------------'/
c
c*************************************************************************
c
c     write out Table
c
      write(Iout,101) dline,dline
      write(Iout,101) blank,
     & '                        BODY REGION                              '
      write(Iout,101) '  AIS ',dline
      write(Iout,102) blank,'    HEAD   ','    NECK    ','   CHEST   ',
     &                '  ABDOMEN  ','          LEG         '
      write(Iout,103) blank,('Probability',kcol=1,5),'# Injuries'
      write(Iout,103) (dline,kcol=1,7)
      do 10 krow=1,7
        write(Iout,104) krow-1,(Table(krow,kcol),kcol=1,5),
     &                        nint(Table(krow,6))
   10 continue
      write(Iout,103) (dline,kcol=1,7)
      krow=8
      write(Iout,105) ' PAIS ',(Table(krow,kcol),kcol=1,5)
      write(Iout,103) (dline,kcol=1,7)
      krow=9
      write(Iout,106) ' PAIS ',(nint(Table(krow,kcol)),kcol=1,5)
      write(Iout,103) (dline,kcol=1,7)

      return
c
c*************************************************************************
c
c     format statements
c
  101 format(1x,'|',a6,'|',a70,'|')
  102 format(1x,'|',a6,4('|',a11),'|',a22,'|')
  103 format(1x,'|',a6,5('|',a11),'|',a10,'|')
  104 format(1x,'|',3x,i1,2x,5('|',3x,f5.3,3x),'|',4x,i1,5x,'|')
  105 format(1x,'|',a6,5('|',3x,f5.3,3x),'|',10x,'|')
  106 format(1x,'|',a6,5('|',5x,i1,5x),'|',10x,'|')

      end

c...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
```

Page 55, Figure D.1

Replace Figure D.1 with the following new figure:



Page 151, O.3.4

Add the following to the end of O.3.4:

The medical and ancillary costs in Tables A.1 and A.2 were obtained from data in Appendix H of Blincoe, et al. (2002). The ancillary costs comprise market productivity, household productivity, workplace costs, travel delay, and legal costs. Separate costs for emergency services, insurance administration, and property damage reported in Blincoe, et al. (2002) are not included in these costs. Ancillary costs for the lower extremities were determined to be equal to the PPI x ancillary costs for a MAIS 4 spinal cord injury / 100 %, according to Newman, et al. (1991). The ancillary costs in 2000 U.S. dollars for a MAIS 4 spinal cord injury are $399 937.

The quality of life costs in Table A.3 were obtained from data in Table 3 of Miller et al. (2001) converted to 2000 U.S. dollars. It was assumed that quality of life costs for the lower extremities are equal to the PPI x quality of life costs for a MAIS 4 spinal cord injury / 100 %. This assumption is based on the same rationale used for ancillary costs. The quality of life cost in 1999 U.S. dollars for a MAIS 4 spinal cord injury is $1 487 956. The quality of life costs data were converted from 1999 U.S. dollars to 2000 U.S. dollars using the following conversion factor from the US Department of Commerce (2004):

97,868 USD1999 = 100 USD2000

The quality of life cost of fatality in 2000 U.S. dollars was obtained from Table A-1 of Blincoe et al. (2002).

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