
**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

*Motorcycles — Méthodes d'essai et d'analyse de l'évaluation par la
recherche des dispositifs, montés sur les motos, 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





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Foreword

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

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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:

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

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:

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

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:

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

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

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                   5      KDI3     number of AIS 3 knee dislocated
c                   6      KDI3     injuries
c                   7      KDI3     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                   2      Gmax    -      penetration
c                   3      Cmax    %      maximum GAMBIT
c                   4      VCmax   m/s    maximum normalized chest
c                   5      HIC     -      compression
c                   6      NII     -      maximum chest viscous
c                   7      HIC     -      criteria when V>3 m/s
c                   8      NII     -      Head Injury Criteria
c                   9      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                   4      NCASE    -      Economic Cost
c                   5      NCASE    -      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

Ierr o error code

0 - normal return
 1- 5 - index of out of range Idatin
 11-14 - index of out of range Rdatin

version history

- original version by RMV, DRI, March 1993
- first revision by RMV, DRI, April 1993
 - AIS 3 knee dislocation injuries added
 - Input range checking added
- second revision by RMV, DRI, March 1994
 - changed model and subroutine name from Injury Cost Model II (icm2) to Injury Cost Model (icm)
 - changed hospital cost (HC) to medical cost (MDC)
 - changed parameter names from AISmax to AIS6, AISsrv to AIS5
- third revision by RMV, DRI, August 1994
 - added PPI to Datout output array
 - added risk of life threatening brain injury calculation based on HIC, HIC input was added to Rdatin and Prisk output added to Datout arrays
- fourth revision by RMV, DRI, December 1994
 - Corrected PPI for 1 leg injury
 - include HIC ISP for to head AIS, revision by DPC, DRI, March 1998
 - include Neck Injury Criteria, revision by KDW,RMV,SM, DRI, May 2001
- sixth revision by KDW, DRI, February 2002
 - added new neck ISPn equation coefficients
- seventh revision by RMV, DRI, June 2004
 - revised new neck ISPn equation coefficients
- revised 2009-12-16 by JK
 - updated injury costs as per ISO 13232-5:2005/DAM 2
 - added Quality of Life costs

local parameters

AIS6 - fatal AIS
 AIS5 - maximum survivable AIS

integer AIS6, AIS5, jhic
 parameter (AIS6=6, AIS5=5, jhic=15)

local variables

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, OC
real APAIS, CPAIS, HPAIS, LPAIS, NPAIS
integer IAP AIS, ICP AIS, IHP AIS, ILPAIS, INPAIS
real COFE, MAIS, NCOD, NCOSE, NICE, TAIS, COFO, 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
c data Gamma1/0.0,0.125,0.375,0.438,0.650,0.680/
c data Eta1/0.755,0.70,0.64,0.62,0.54,0.60/
c data Beta1/3.5,3.5,3.5,3.5,2.2,1.8/
c data Gamma2/0.0,0.0,0.0,0.4,1.0,1.5/
c data Eta2/0.3,0.68,1.40,1.291,0.995,0.78/
c data Beta2/0.99,1.46,2.85,3.10,3.10,3.10/
c data Gamma3/1.77,7.47,13.22,18.97,24.72,32.52/
c data Alpha4/0.0157,0.0123,0.000155,9.36e-13,0.0,0.0/
c data Beta4/1.0,1.0,2.0,6.5,1.0,1.0/
c data Gamma5/0.0,0.0,0.0,450.0,450.0,450.0/
c data Gamma6/1.06,1.86,2.29,4.73,4.73,6.13/
c 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
c data HMDC/ 30405., 31323., 193785., 206592., 280228./
c data NMDC/ 0., 0., 355082., 824887.,1088896./
c data CMDC/ 1248., 11384., 32692., 52963., 62967./
c data AMDC/ 1248., 11384., 32692., 52963., 0./
c data LMDC/ 0., 8592., 31258., 0., 0./
c
c Ancillary Cost data in U.S. Dollars - Table A.2
c
c data HAC/ 10225., 36539.,121644.,232423.,943054./
c data NAC/ 0., 0.,262761.,399937.,476360./
c 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./
```

Quality of Life Cost data in U.S. Dollars - Table A.3

```
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./
```

Mortality Rate data

```
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/
```

Cost of Fatality in U.S. Dollars

```
data COFE/ 919834./ ! Medical and ancillary cost of fatality
                  (economic cost of fatality)
data COFQ/2389179./ ! Quality of Life cost of fatality
```

Risk of life threatening brain injury vs HIC data

```
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/
```

```
***
*** Extract input data from input arrays ***
***
*****
```

```
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 begin loop through injury severity levels
c
do 10 kaisl=1,AIS6

c calculate the head injury severity probability (ISP) based on
c Gmax
c
  if(Gmax.ge.Gamma1(kaisl)) then
    HGISP(kaisl) =
& 1.0-exp(-(((Gmax-Gamma1(kaisl))/Eta1(kaisl))*Beta1(kaisl)))
  else
    HGISP(kaisl) = 0.0
  end if

c calculate the chest ISP based on VCmax
c
  if(VCmax.ge.Gamma2(kaisl)) then
    CVCISP =
& 1.0-exp(-(((VCmax-Gamma2(kaisl))/Eta2(kaisl))*Beta2(kaisl)))
  else
    CVCISP = 0.0
  end if

c calculate the chest ISP based on Cmax
c
  if(Cmax.ge.Gamma3(kaisl)) then
    CCISP = 1.0-exp(-(((Cmax-Gamma3(kaisl))/24.0)**6))
  else
    CCISP = 0.0
  end if

c calculate the chest ISP based on the
c of larger of the probabilities due to VCmax and Cmax
c
  CISP(kaisl) = max(CVCISP,CCISP)
c

```

```

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

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

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

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

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

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

c      if(HIC.ge.Gamma5(5)) then
c          HHICISP(5) = HHICISP(6)+((HHICISP(3)-HHICISP(6))*14.0/41.0)
c      else
c          HHICISP(5) = 0.0
c      endif

c
c      calculate the maximum head ISP between HIC & Gmaxc
c
c      do 12 kais1 = 1,AIS6
c          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
C      HAIS(0) = 1.0-HISP(1)
C      CAIS(0) = 1.0-CISP(1)
C      AAIS(0) = 1.0-AISP(1)
C      NAIS(0) = 1.0-NISP(1)
C      do 15 kais1=1,AIS5
C          HAIS(kais1) = HISP(kais1)-HISP(kais1+1)
C          CAIS(kais1) = CISP(kais1)-CISP(kais1+1)
C          AAIS(kais1) = AISP(kais1)-AISP(kais1+1)
C          NAIS(kais1) = NISP(kais1)-NISP(kais1+1)
15 continue
C      HAIS(AIS6) = HISP(AIS6)
C      CAIS(AIS6) = CISP(AIS6)
C      AAIS(AIS6) = AISP(AIS6)
C      NAIS(AIS6) = NISP(AIS6)
C
C      calculate the leg AIS based on worst AIS injury
C
C      do 20 kais1=0,AIS6
C          LAIS(kais1) = 0.0
20 continue
C      if( (FF3.ne.0) .or. (TF3.ne.0) .or. (KDI3.ne.0) ) then
C          LAIS(3) = 1.0
C      else if( (TF2.ne.0) .or. (KDI2.ne.0) ) then
C          LAIS(2) = 1.0
C      else
C          LAIS(0) = 1.0
C      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
C      ntot = FF3 + TF2 + TF3 + KDI2 + KDI3
C
C      if(ntot.ge.3) then
C
C          three or more leg injuries
C
C          PPI = 0.38
C          LACT = LAC38
C          LQCT = LQC38
C
C      else if(ntot.eq.2) then
C
C          two leg injuries
C
C          PPI = 0.27
C          LACT = LAC27
C          LQCT = LQC27
C
C      else if(ntot.eq.1) then
C
C          if(FF3.eq.1) then
C
C              1 AIS 3 femur fracture
C
C              PPI = 0.15
C              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 kaisl=1,AIS5
        HMDCT = HMDCT + H AIS(kaisl)*HMDCT(kaisl)
        NMDCT = NMDCT + N AIS(kaisl)*NMDCT(kaisl)
        CMDCT = CMDCT + C AIS(kaisl)*CMDCT(kaisl)

```

```

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
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
c POF5 = 0.0
c do 50 kais1=0,AIS5
c   do 50 kais2=0,AIS5
c     do 50 kais3=0,AIS5
c       do 50 kais4=0,AIS5
c         do 50 kais5=0,AIS5
c
c           sort kais from largest to smallest
c
c           kais(1) = kais1
c           kais(2) = kais2
c           kais(3) = kais3
c           kais(4) = kais4
c           kais(5) = kais5
c           do 45 i=1,4
c             do 45 j=i+1,5
c               if(kais(i).lt.kais(j)) then
c                 itmp = kais(i)
c                 kais(i) = kais(j)
c                 kais(j) = itmp
c               end if
c             end do
c           end do
c         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
c           POF5 = POF5 + MR(kais(1),kais(2),kais(3))*HAIS(kais1)*
&             NAIS(kais2)*CAIS(kais3)*AAIS(kais4)*LAIS(kais5)
c
c 50 continue
c POF5 = 0.01*POF5
c
c overall probability
c
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 kaisl=1,AIS6
    HPAIS = HPAIS + kaisl*HAIS(kaisl)
    NPAIS = NPAIS + kaisl*NAIS(kaisl)
    CPAIS = CPAIS + kaisl*CAIS(kaisl)
    APAIS = APAIS + kaisl*AAIS(kaisl)
    LPAIS = LPAIS + kaisl*LAIS(kaisl)
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 kaisl=0,AIS6
    krow = kaisl+1
    Table(krow,1) = HAIS(kaisl)
    Table(krow,2) = NAIS(kaisl)
    Table(krow,3) = CAIS(kaisl)
    Table(krow,4) = AAIS(kaisl)
    Table(krow,5) = LAIS(kaisl)
    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 + IAP AIS + 2*nLAIS2 + 3*nLAIS3
C
C      *****
C      ***
C      *** Calculate Normalized Injury Costs
C      ***
C      *****
C
C      Economic Cost of Survival
C
C      if((MDC+AC).le.COFE) then
C          NCOSE = ( MDC + AC ) * ( 1.0 - POF ) / COFE
C      else
C          NCOSE = (1.0 - POF)
C      endif
C
C      Quality Cost of Survival
C
C      COFC = COFE + COFQ ! Comprehensive cost of fatality (medical,
C                          ancillary, and quality of life)
C      if((MDC+AC+QC).le.COFC) then
C          NCOSC = ( MDC + AC + QC ) * ( 1.0 - POF ) / COFC
C      else
C          NCOSC = (1.0 - POF)
C      endif
C
C      Cost of Dying
C
C      NCOD = POF
C
C      Total injury cost
C
C      NICE = NCOSE + NCOD
C      NICC = NCOSC + NCOD
C
C      *****
C      ***
C      *** Calculate the Risk of Life Threatening Brain Injury
C      ***
C      *****
C
C      if(HIC.lt.curve(1,1)) then
C
C          Risk is less than 1%, return 0%
C
C          Prisk = 0.0
C
C      else if(HIC.gt.curve(1,jhic)) then
C
C          Risk is greater than 99%, return 100%
C
C          Prisk = 100.0
C
C      else
C
C          interpolate risk from table
C
C          do 70 i=1,jhic-1
C              j = i+1
C              if( (curve(1,i).le.HIC) .and. (HIC.le.curve(1,j)) ) then
C                  Prisk = curve(2,i) + (curve(2,j)-curve(2,i)) *
&                      (HIC-curve(1,i)) / (curve(1,j)-curve(1,i))
C              end if

```

70 continue

end if

```

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

```