Informal Group on GTR9 Phase2 (IG GTR9-PH2) 2nd Meeting

Technical Discussion – Benefit

Updated Version of GTR9-1-07r1

March 28-29, 2012

Japan Automobile Standards Internationalization Center (JASIC)[1]

Outline

1. Anticipated Factors for Enhanced Injury Mitigation
2. Estimation of Cost Reduction due to Tibia Fracture Mitigation
3. Summary

1. Anticipated Factors for Enhanced Injury Mitigation

GTR9-1-07r1

- Improved Biofidelity -

Component Level

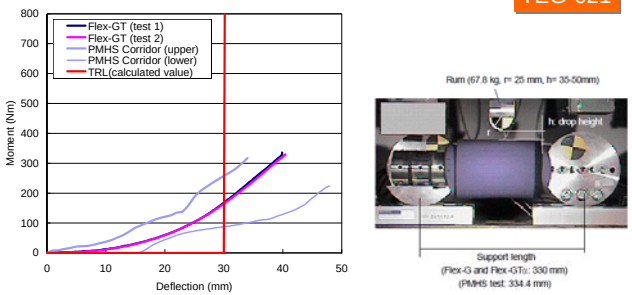
Assembly Level

Tibia

4. Comparison of Component Responses

- Tibia Bending -

TEG-021



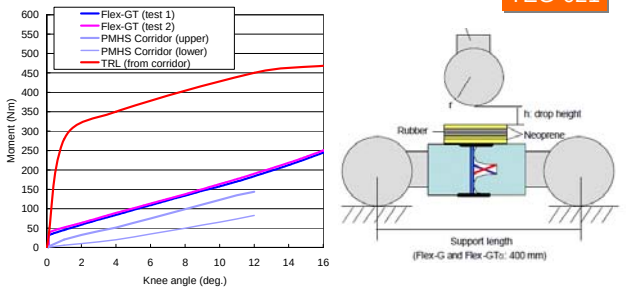
Flex-PLI tibia response characteristics are much closer to those of human compared to TRL legform

Knee

4. Comparison of Component Responses

- Knee Bending -

TEG-021



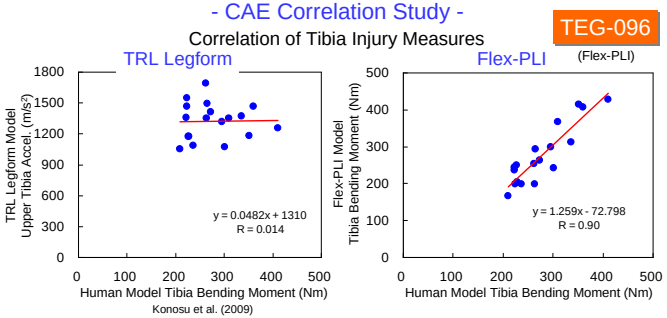
- **Flex-PLI knee joint is stiffer than that of human**
- **Flex-PLI stiffness is much more comparable to human stiffness than TRL legform**

Tibia

5. Correlation of Assembly Impact Responses

- CAE Correlation Study -

TEG-096



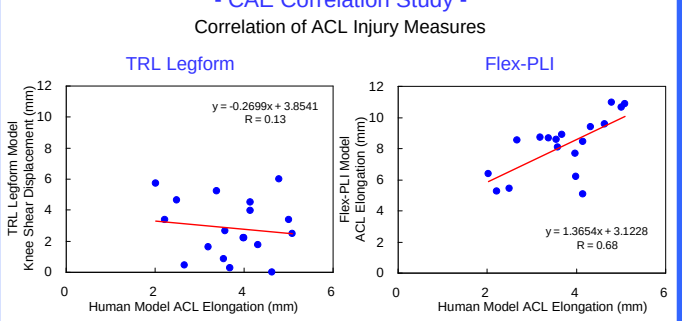
- **No correlation between TRL legform upper tibia acceleration and human tibia bending moment**
- **Good correlation between Flex-PLI and human tibia bending moment**

Reference : Konosu, A. et al., Evaluation of the Validity of the Tibia Fracture Assessment Using the Upper Tibia Acceleration Employed in the TRL Legform Impactor, IRCOBI Conference (2009)

Knee (ACL)

5. Correlation of Assembly Impact Responses

- CAE Correlation Study -



- **No correlation between TRL legform knee shear displacement and human ACL elongation**
- **Good correlation between Flex-PLI and human ACL elongation**

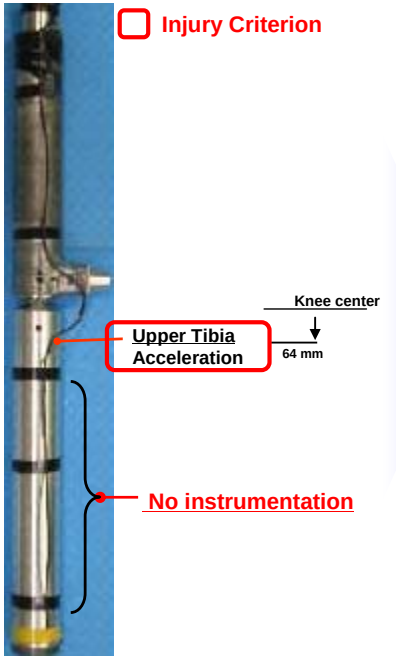
1. Anticipated Factors for Enhanced Injury Mitigation

GTR9-1-07r1

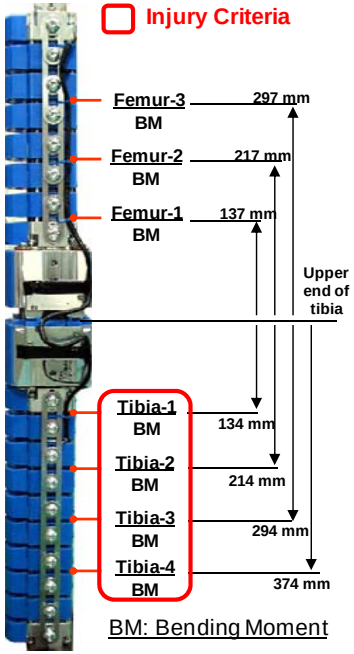
- Enhanced Injury Assessment Capabilities -

Tibia

TRL Legform



Flex-PLI



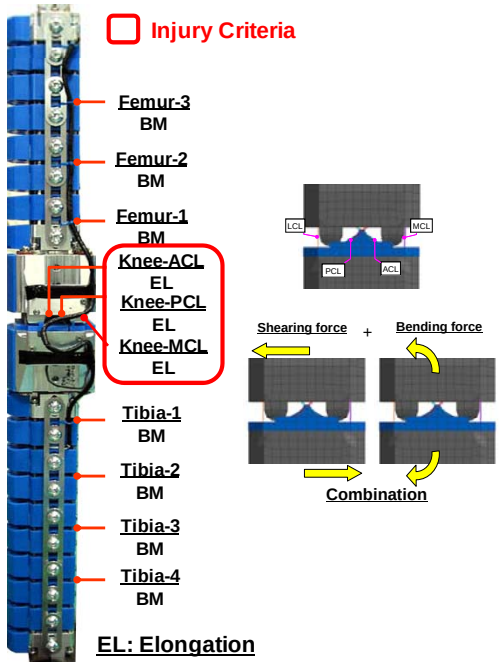
- Wider coverage of tibia fracture
- Use of bending moment that best describes human tibia fracture

Knee

Individual Measurement

Bending Angle

Shear Disp.



- Flex-PLI ligaments elongate due to combined knee loading
- Use of ligament elongation provides better correlation with human injuries

1. Anticipated Factors for Enhanced Injury Mitigation

GTR9-1-07r1

- Otte et al. (2007) -

CHARACTERISTICS ON FRACTURES OF TIBIA AND FIBULA IN CAR IMPACTS TO PEDESTRIANS – INFLUENCES OF CAR BUMPER HEIGHT AND SHAPE

Otte, D.*; Haasper, C. **
* Accident Research Unit
** Trauma Department
Medical University Hanover, Germany

ABSTRACT

This study deals with the analysis of lower leg fractures in pedestrians after collisions with passenger cars and examines to what extent the shape and location of the factures in the lower leg changed, following alterations in the shape and height of bumpers. It can be assumed that the bumpers changed in form and effective impact height, not least due to the realization of the developments of vehicle safety tests as in the context of the European Union Directive 2003/102/EC. In addition, consumer protection tests, EuroNCAP, accomplished a change of the injury situation.

For the study, traffic accidents from GIDAS (German in-Depth-Accident Study) were selected, which had been documented in the years 1995 to 2004 by scientific teams in Hannover and Dresden areas and for which there is detailed information regarding injury patterns and collision speeds. The

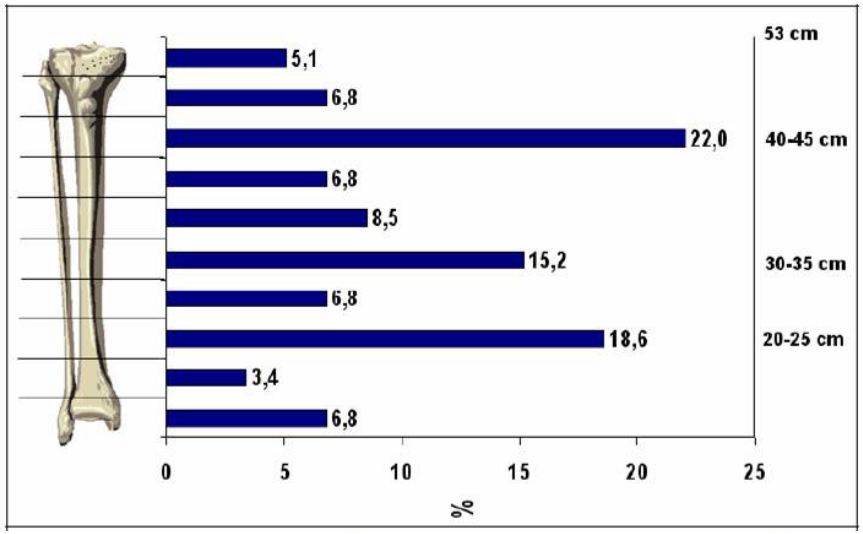
- 1995 – 2004 GIDAS data
- 143 pedestrians with leg fractures (tibia/fibula) documented by X-rays

Reference: Otte, D., Haasper, C., Characteristics on Fractures of Tibia and Fibula in Car Impacts to Pedestrians – Influences of Car Bumper Height and Shape, IRCOBI Conference (2007)

1. Anticipated Factors for Enhanced Injury Mitigation

GTR9-1-07r1

- Otte et al. (2007) -



If the heights of the fractures are correlated to the effective dynamic heights of the bumpers, it turns out that 80% of all fractures are located between 19 and 46 cm, whereas 80% of the impact forces are transferred at heights of 32 to 44 cm of the lower leg (Figure 4). Thus the cause of the fractures is frequently located above the fracture itself. Fracture height and bumper height were only identical in 17.5% of the cases, in 47.5% fracture was above the bumper and 35% fracture below the bumper.

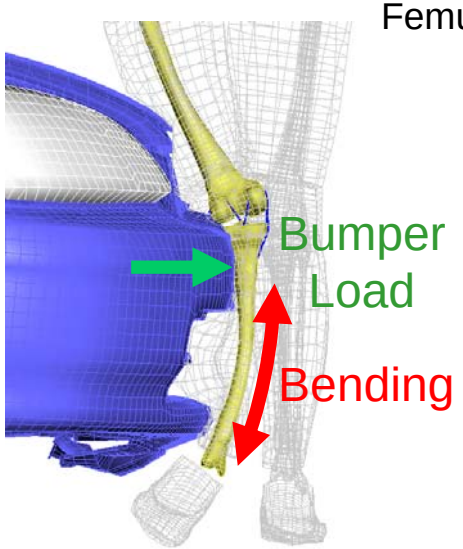
- Fracture location was identical to the bumper height only in 17.5 % of the cases
- 82.5% of fractures are presumed to be due to indirect loading

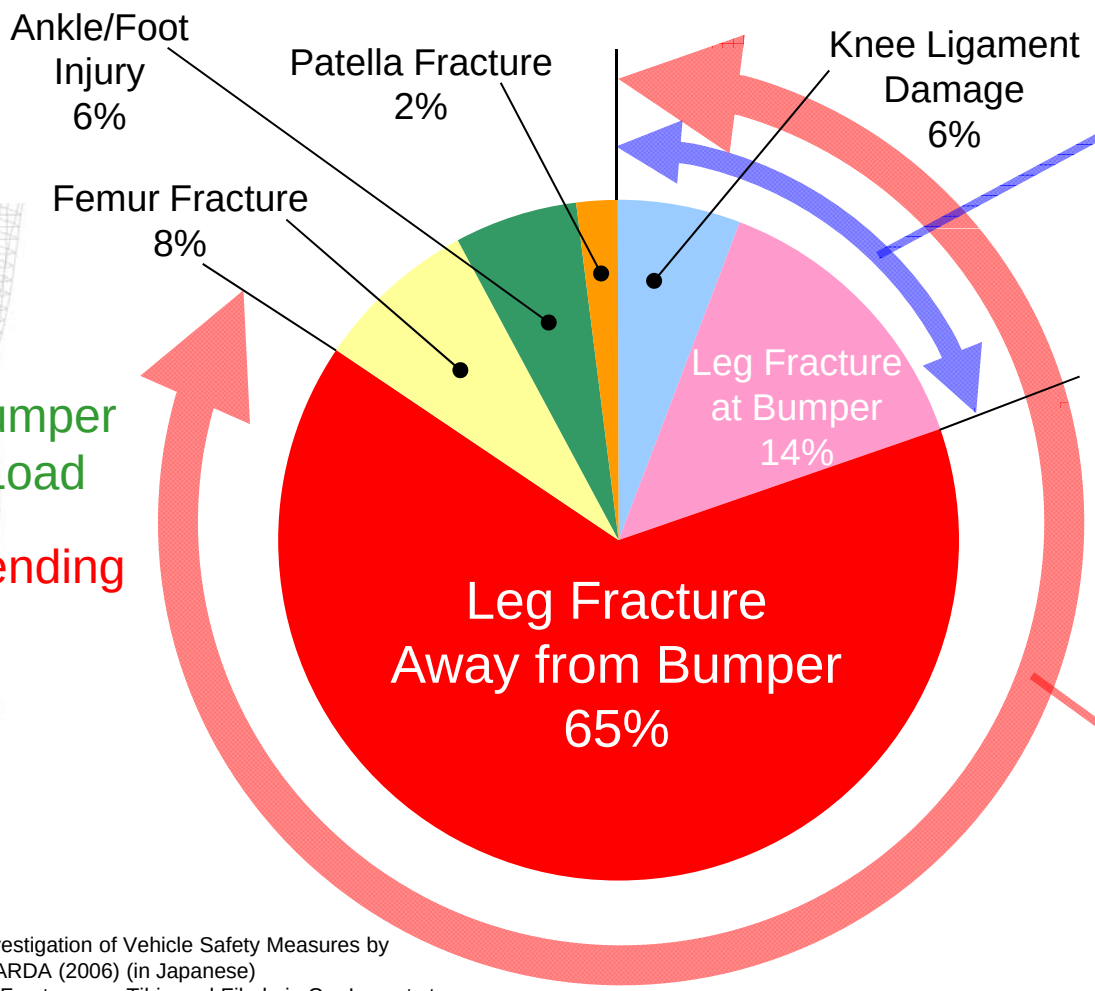
Reference: Otte, D., Haasper, C., Characteristics on Fractures of Tibia and Fibula in Car Impacts to Pedestrians – Influences of Car Bumper Height and Shape, IRCOBI Conference (2007)

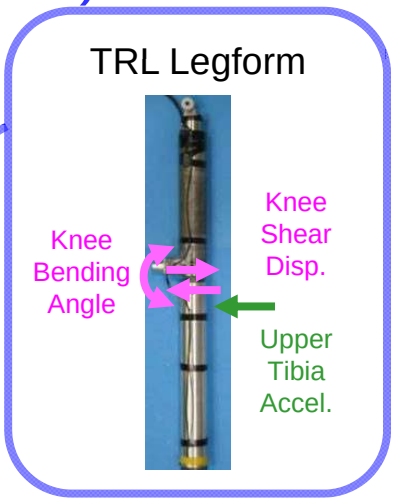
1. Anticipated Factors for Enhanced Injury Mitigation

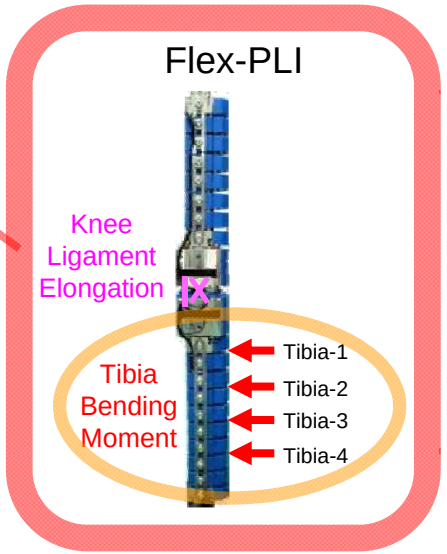
GTR9-1-07r1

- Japanese In-depth Accident Data (ITARDA) -









References:
(1) "FY2005 ITARDA Report : Investigation of Vehicle Safety Measures by Accident Reconstruction", ITARDA (2006) (in Japanese)
(2) Otte et al., Characteristics on Fractures on Tibia and Fibula in Car Impacts to Pedestrians – Influence of Car Bumper Height and Shape, IRCOBI (2007)

Most significant improvement is with leg fracture mitigation

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

GTR9-1-07r1

- Estimated Reduction in Annual Medical Cost (US, JPN) -

Number of Pedestrians Sustaining Tibia Fracture by MAIS

PCDS, age > 15

MAIS	Total	with Tibia Fracture	without Tibia Fracture
1	165	0	165
2	74	4	70
3	70	25	45
4	31	8	23
5	49	17	32
6	18	6	12

Fatality Ratio by MAIS

MAIS	Fatality Ratio
2	1.0%
3	5.3%
4	22.5%
5	47.6%
6	99.0%

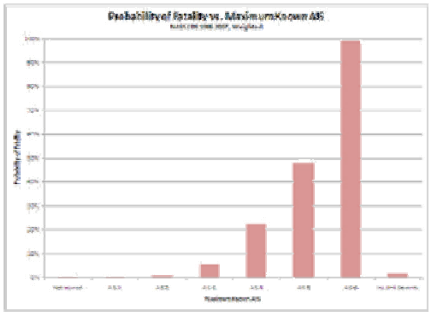


Figure 14. Probability of Fatality vs. Maximum Known AIS

Reference : Goertz A., Accident Statistical Distributions from NAS CDS, SAE Paper #2010-01-0139 (2010)

Percentage of Tibia Fracture by Injury Severity

Injury Severity	With Tibia Fracture (%)	Without Tibia Fracture (%)
Fatal	32.7%	67.3%
Severe	22.6%	77.4%
Minor	0.0%	100.0%

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

GTR9-1-07r1

- Estimated Reduction in Annual Medical Cost (US, JPN) -

Percentage of Tibia Fracture by Injury Severity

Injury Severity	With Tibia Fracture (%)	Without Tibia Fracture (%)
Fatal	32.7%	67.3%
Severe	22.6%	77.4%
Minor	0.0%	100.0%

×

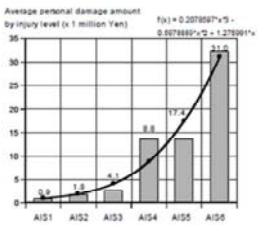
Number of Pedestrians by Injury Severity

Injury Severity	16YO and older		0-15YO	
	US	JPN	US	JPN
Fatal	3816	1372	276	29
Severe	11501	6730	2357	1277
Minor	31112	36517	11399	8974

US Fatal : FARS
US Non-fatal : NASS-PCDS (Weighed)
JPN : ITARDA

×

Average Medical Cost per Case



Tibia AIS	count
2	13
3	47

Weighed Cost For Tibia Fracture = $44,684

($1 = \80)

Annual Medical Cost due to Tibia Fracture

Country	Cost
US	$ 171,901,940
JPN	$ 88,010,679

×

0.825 (coverage increase)

×

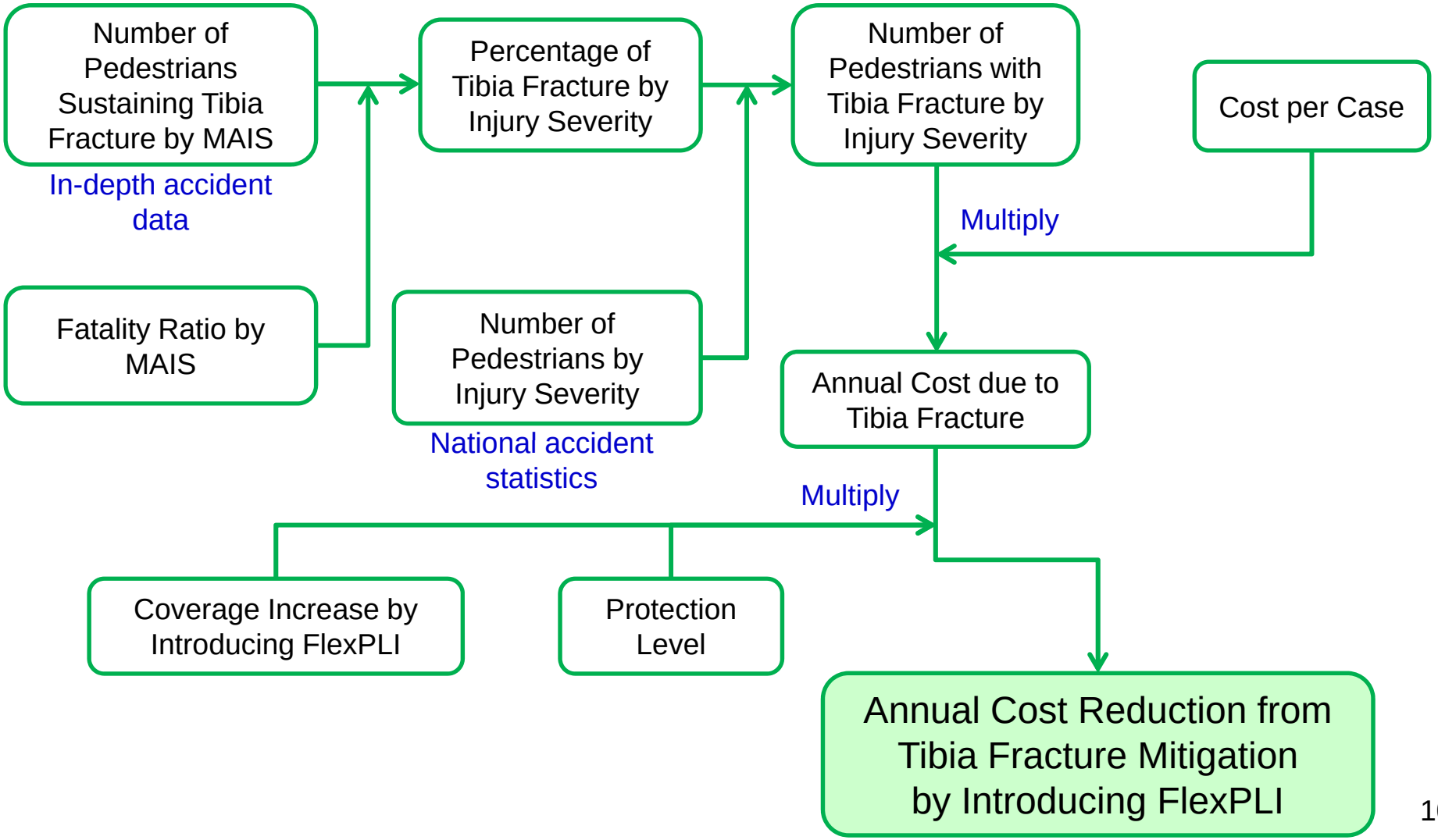
0.7 (Protection Level)

Annual Medical Cost Reduction from Tibia Fracture Mitigation

Country	Cost
US	**$ 99,273,370**
JPN	**$ 50,826,167**

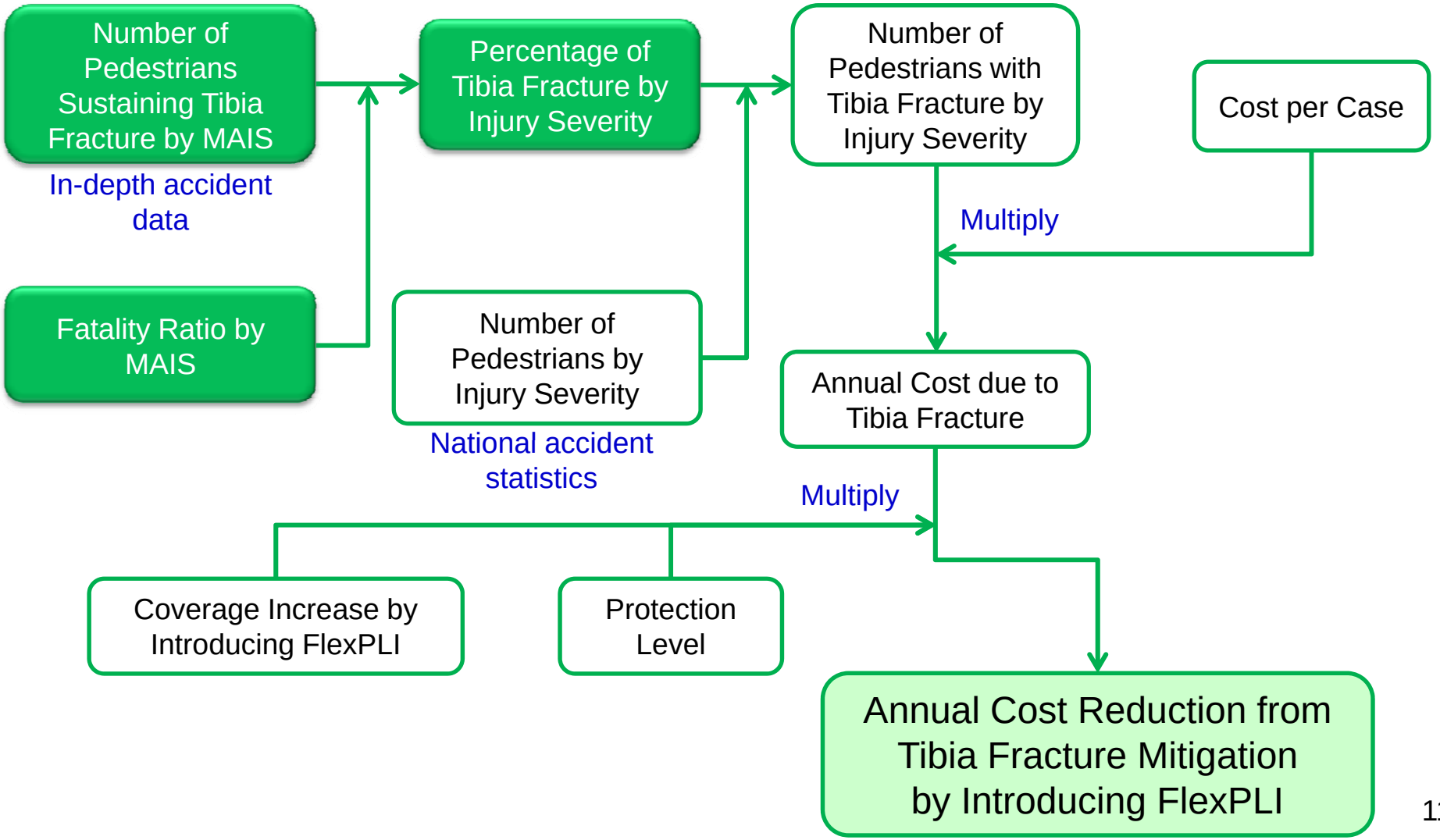
2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Estimation of Percentage of Tibia Fracture by Injury Severity -

FX: fracture

Number of Pedestrians Sustaining Tibia FX by MAIS

MAIS	with Tibia FX	without Tibia FX
1	0	n_1
2	N_2	n_2
3	N_3	n_3
4	N_4	n_4
5	N_5	n_5
6	N_6	n_6

Fatality Ratio by MAIS

MAIS	Ratio
1	R_1
2	R_2
3	R_3
4	R_4
5	R_5
6	R_6

Number of Pedestrians Sustaining Tibia FX by Injury Severity

MAIS	with Tibia FX			without Tibia FX		
	Fatal	Severe	Minor	Fatal	Severe	Minor
1	0	0	0	0	0	n_1
2	N_2xR_2	$N_2x(1-R_2)$	0	n_2xR_2	$n_2x(1-R_2)$	0
3	N_3xR_3	$N_3x(1-R_3)$	0	n_3xR_3	$n_3x(1-R_3)$	0
4	N_4xR_4	$N_4x(1-R_4)$	0	n_4xR_4	$n_4x(1-R_4)$	0
5	N_5xR_5	$N_5x(1-R_5)$	0	n_5xR_5	$n_5x(1-R_5)$	0
6	N_6xR_6	$N_6x(1-R_6)$	0	n_6xR_6	$n_6x(1-R_6)$	0
SUM	N_f	N_s	N_m	n_f	n_s	n_m

Percentage of Tibia Fracture by Injury Severity

Injury Severity	with Tibia Fracture	without Tibia Fracture
Fatal	$N_f / (N_f + n_f)$	$n_f / (N_f + n_f)$
Severe	$N_s / (N_s + n_s)$	$n_s / (N_s + n_s)$
Minor	$N_m / (N_m + n_m)$	$n_m / (N_m + n_m)$

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

Number of Pedestrians Sustaining Tibia Fracture by MAIS

MAIS	US (NASS-PCDS)			JPN (ITARDA)		
	Numbers			Numbers		
	total	with Tibia FX	without Tibia FX	total	with Tibia FX	without Tibia FX
1	165	0	165	77	0	77
2	74	4	70	45	12	33
3	70	25	45	36	7	29
4	31	8	23	26	4	22
5	49	17	32	45	4	41
6	18	6	12	27	4	23

US (NASS-PCDS)
age>15

JPN (ITARDA)
age>15, collision with passenger car or wagon

FX: fracture

Fatality Ratio by MAIS

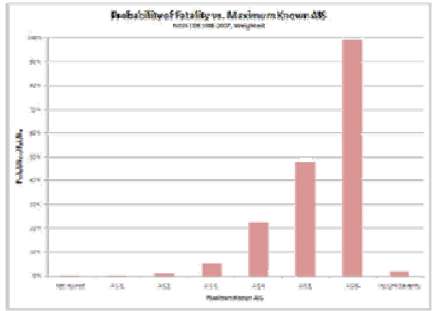


Figure 14. Probability of Fatality vs. Maximum Known AIS

Reference : Goertz A., Accident Statistical Distributions from NAS CDS, SAE Paper #2010-01-0139 (2010)

MAIS	Non-fatal		Fatal		Fatality Ratio	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
1	83974	31378428.0	345	20144.0	0.4%	0.1%-> 0.0%
2	22562	4148494.0	621	42577.7	2.7%	1.0%
3	13252	1358201.0	1217	76251.3	8.4%	5.3%
4	3457	305362.3	1677	88814.0	32.7%	22.5%
5	1709	119922.9	2414	109091.8	58.5%	47.6%
6	17	838.9	1886	79165.8	99.1%	99.0%

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Estimated Percentage of Tibia Fracture by Injury Severity -

Number of Pedestrians Sustaining Tibia Fracture by MAIS

age > 15

MAIS	US (NASS-PCDS) Total	US (NASS-PCDS) with Tibia Fracture	US (NASS-PCDS) without Tibia Fracture	JPN (ITARDA) Total	JPN (ITARDA) with Tibia Fracture	JPN (ITARDA) without Tibia Fracture
1	165	0	165	77	0	77
2	74	4	70	45	12	33
3	70	25	45	36	7	29
4	31	8	23	26	4	22
5	49	17	32	45	4	41
6	18	6	12	27	4	23

Fatality Ratio by MAIS

MAIS	Fatality Ratio
2	1.0%
3	5.3%
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5	47.6%
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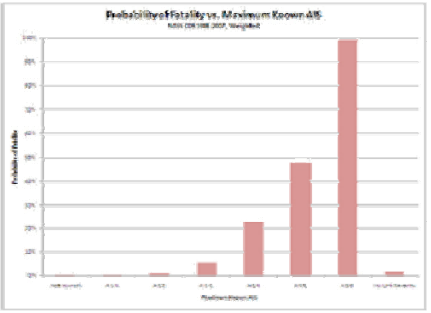


Figure 24. Probability of Fatality vs. Maximum Known AIS

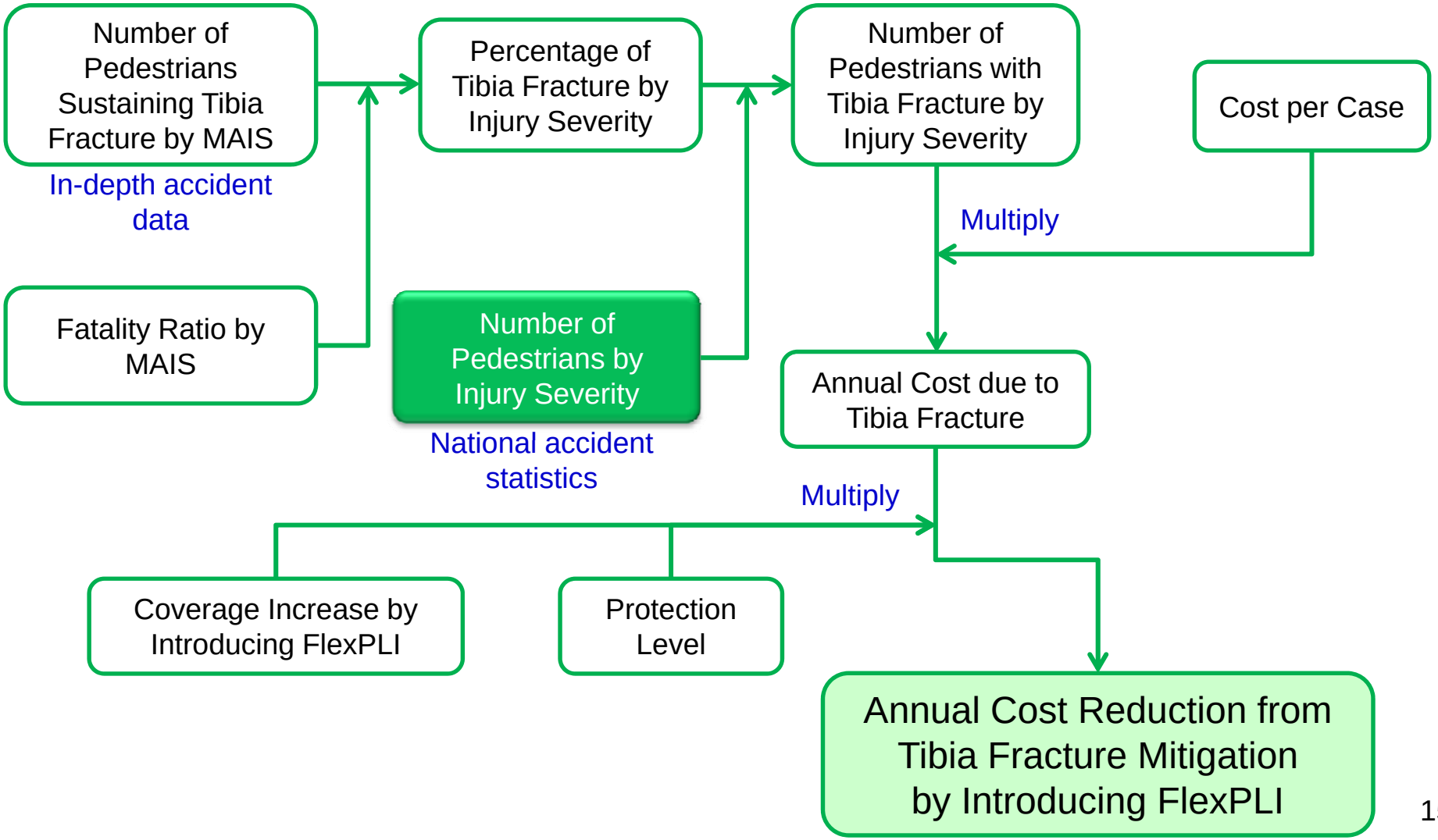
Reference : Goertz A., Accident Statistical Distributions from NAS CDS, SAE Paper #2010-01-0139 (2010)

Percentage of Tibia Fracture by Injury Severity

Injury Severity	US With Tibia Fracture (%)	US Without Tibia Fracture (%)	JPN With Tibia Fracture (%)	JPN Without Tibia Fracture (%)
Fatal	32.7%	67.3%	12.9%	87.1%
Severe	22.6%	77.4%	19.4%	80.6%
Minor	0.0%	100.0%	0.0%	100.0%

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

US - Number of Pedestrians by Injury Severity -

Injury Severity	16 YO and older	0-15 YO
Fatal	3816	276
Severe	11501	2357
Minor	31112	11399

Number of Fatal was derived from FARS(2009)

Number of Severe and Minor was derived from NASS-GES (2009)

NASS-GES data

NASS-GES Variable: INJSEV	16 YO and older		0-15 YO	
	Case	Weighted case	Case	Weighted case
No Injury (O)	6	776.4	1	15.6
Possible Injury (C)	82	11669.3	25	5439.3
Non-incapacitating Evident Injury (B)	801	19442.4	259	5959.8
Incapacitating Injury (A)	441	11501.4	89	2356.9
Fatal Injury (K)	84	2447.6	9	247.0

Number for Minor Injury

Number for Severe Injury

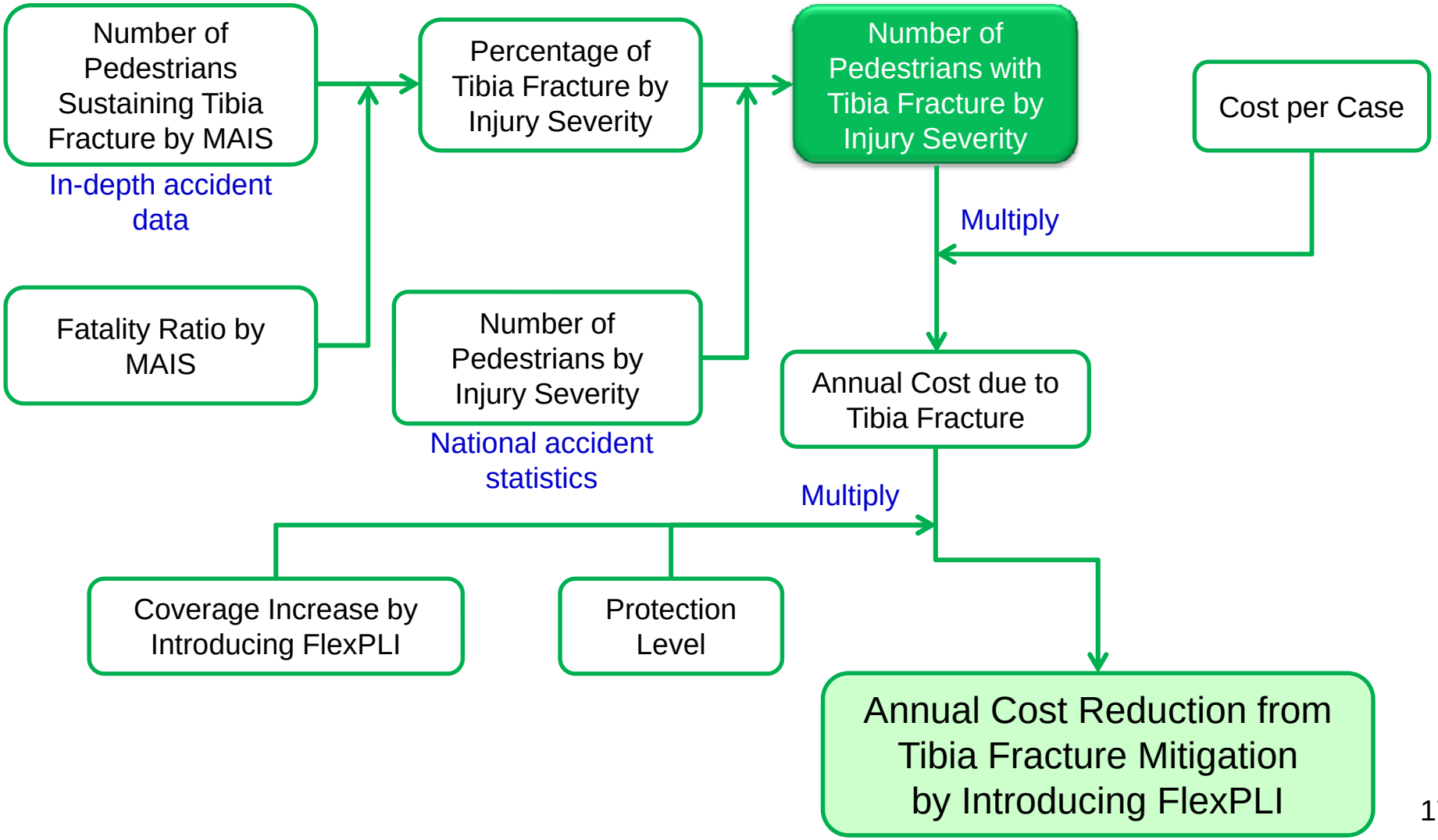
JPN

Injury Severity	16 YO and older	0-15 YO
Fatal	1372	29
Severe	6730	1277
Minor	36517	8974

All of Japanese data were derived from ITARDA (2009)
Fatal: Died within 24 hours from accident
Severe: Injury that requires 30 days or more for cure
Minor : injury that requires less than 30 days for cure

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Number of Pedestrians with Tibia Fracture by Injury Severity -

Percentage of Tibia Fracture by Injury Severity

Injury Severity	With Tibia Fracture (%)		Without Tibia Fracture (%)	
	US	JPN	US	JPN
Fatal	32.7%	12.9%	67.3%	87.1%
Severe	22.6%	19.4%	77.4%	80.6%
Minor	0.0%	0.0%	100.0%	100.0%

×

Number of Pedestrians by Injury Severity

Injury Severity	16YO and older		0-15YO	
	US	JPN	US	JPN
Fatal	3816	1372	276	29
Severe	11501	6730	2357	1277
Minor	31112	36517	11399	8974

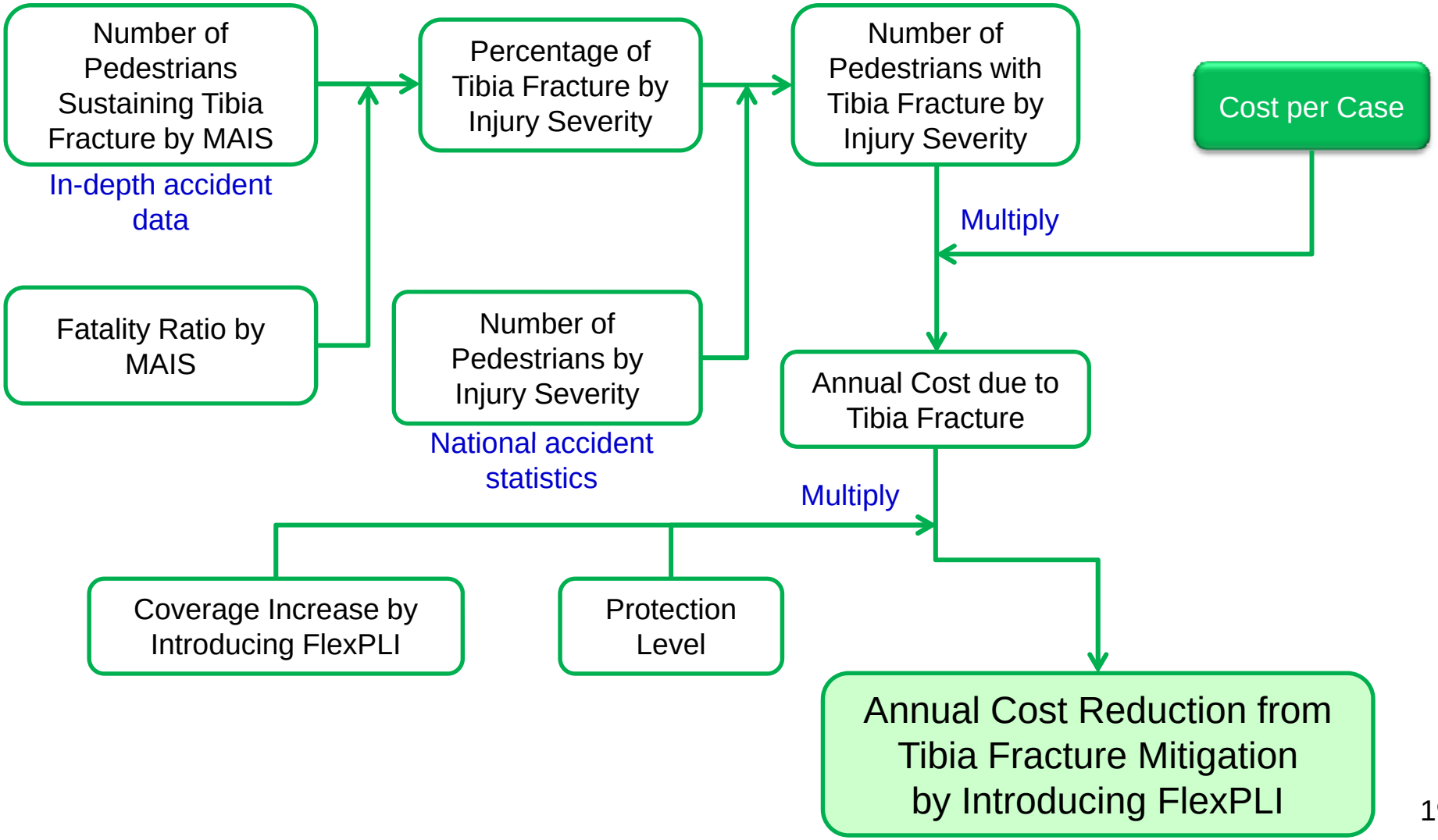
US Fatal : FARS
US Non-fatal : NASS-GES (Weighed)
JPN : ITARDA

Number of Pedestrians with Tibia Fracture by Injury Severity

Injury Severity	16YO and older		0-15YO	
	US	JPN	US	JPN
Fatal	1248	177	90	4
Severe	2599	1306	533	248
Minor	0	0	0	0

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Cost per Case (US) -

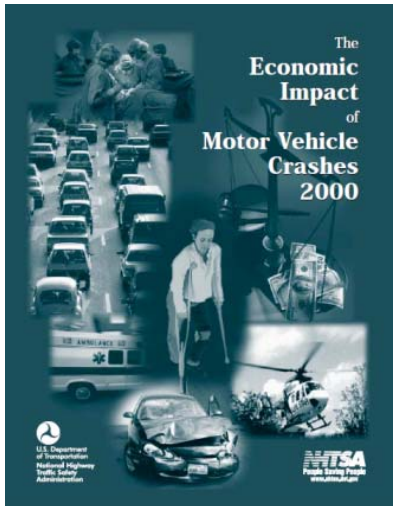


Table A-1
Summary of Unit Costs, 2000
2000 Dollars

	PDO	MAIS0	MAIS1	MAIS2	MAIS3	MAIS4	MAIS5	Fatal
INJURY COMPONENTS								
Medical	$0	$1	$2,380	$15,625	$46,495	$131,306	$332,457	$22,095
Emergency Services	$31	$22	$97	$212	$368	$830	$852	$833
Market Productivity	$0	$0	$1,749	$25,017	$71,454	$106,439	$438,705	$595,358
HH Productivity	$47	$33	$572	$7,322	$21,075	$28,009	$149,308	$191,541
Insurance Admin.	$116	$80	$741	$6,909	$18,893	$32,335	$68,197	$37,120
Workplace Cost	$51	$34	$252	$1,953	$4,266	$4,698	$8,191	$8,702
Legal Costs	$0	$0	$150	$4,981	$15,808	$33,685	$79,856	$102,138
Subtotal	**$245**	**$170**	**$5,941**	**$62,020**	**$178,358**	**$337,301**	**$1,077,567**	**$957,787**
NON-INJURY COMPONENTS								
Travel Delay	$803	$773	$777	$846	$940	$999	$9,148	$9,148
Property Damage	$1,484	$1,019	$3,844	$3,954	$6,799	$9,833	$9,446	$10,273
Subtotal	**$2,287**	**$1,792**	**$4,621**	**$4,800**	**$7,739**	**$10,832**	**$18,594**	**$19,421**
Total	**$2,532**	**$1,962**	**$10,562**	**$66,820**	**$186,097**	**$348,133**	**$1,096,161**	**$977,208**
QALYs	$0	$0	$4,455	$91,137	$128,107	$383,446	$1,306,836	$2,389,179
Comprehensive	**$0**	**$0**	**$15,017**	**$157,958**	**$314,204**	**$731,580**	**$2,402,997**	**$3,366,388**
Total Comprehensive ratio/Fatal	0.45%		4.69%	9.33%	21.73%	71.38%	100.00%	
Injury Component ratio/Fatal			0.31%	4.58%	9.16%	21.53%	71.24%	100.00%

Note: Unit costs are on a per-person basis for all injury levels. PDO costs are on a per damaged vehicle basis.

Cost per case for MAIS 2 and 3 injuries

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Cost per Case (US) -

Cost per Case by MAIS
(NHTSA,2002)

Injury Level	Economic Cost				Intangible Consequences	Comprehensive Cost
	Human Cost	Property Cost	Company Cost	Public Agency Cost		
MAIS 2	$47,964	$3,954	$1,953	$12,948	$91,137	$157,956
MAIS 3	$139,024	$6,799	$4,266	$36,009	$128,107	$314,205

Number of Pedestrians Sustaining Tibia Fracture by AIS
(NASS-PCDS, age>15)

×

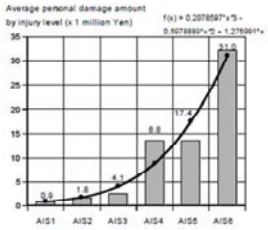
MAIS	count
2	4
3	25

Weighted Cost per Case

Economic Cost				Intangible Consequences	Comprehensive Cost
Human Cost	Property Cost	Company Cost	Public Agency Cost		
$126,464	$6,407	$3,947	$32,828	$123,008	$292,654

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Cost per Case (JPN) -



- Unpublished data for average human cost by MAIS
- Based on Japanese insurance data
- Human cost only

Cost per Case by MAIS

Exchange rate used : $1=107.4 yen @2000

Injury Level	Economic Cost				Intangible Consequences	Comprehensive Cost
	Human Cost	Property Cost	Company Cost	Public Agency Cost		
MAIS 2	$16,760	N/A	N/A	N/A	N/A	N/A
MAIS 3	$38,175	N/A	N/A	N/A	N/A	N/A

×

Number of Pedestrians Sustaining Tibia Fracture by AIS
(NASS-PCDS, age>15)

MAIS	count
2	12
3	7

Weighted Cost per Case

Economic Cost				Intangible Consequences	Comprehensive Cost
Human Cost	Property Cost	Company Cost	Public Agency Cost		
$24,650	N/A	N/A	N/A	N/A	N/A

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Cost per Case Comparison -

		Economic Cost				Intangible Consequences	Comprehensive Cost
Definition		Human Cost	Property Cost	Company Cost	Public Agency Cost		
		• Medical Cost • Market Productivity • Household Productivity	• Property Damage	• Workplace Costs	• Emergency Services • Insurance Administration • Legal Costs • Travel Delay	• QALYs	• Sum of Economic Cost and Intangible Consequence
Cost	US	$126,464	$6,407	$3,947	$32,828	$123,008	$292,654
	JPN	$24,650	N/A	N/A	N/A	N/A	N/A

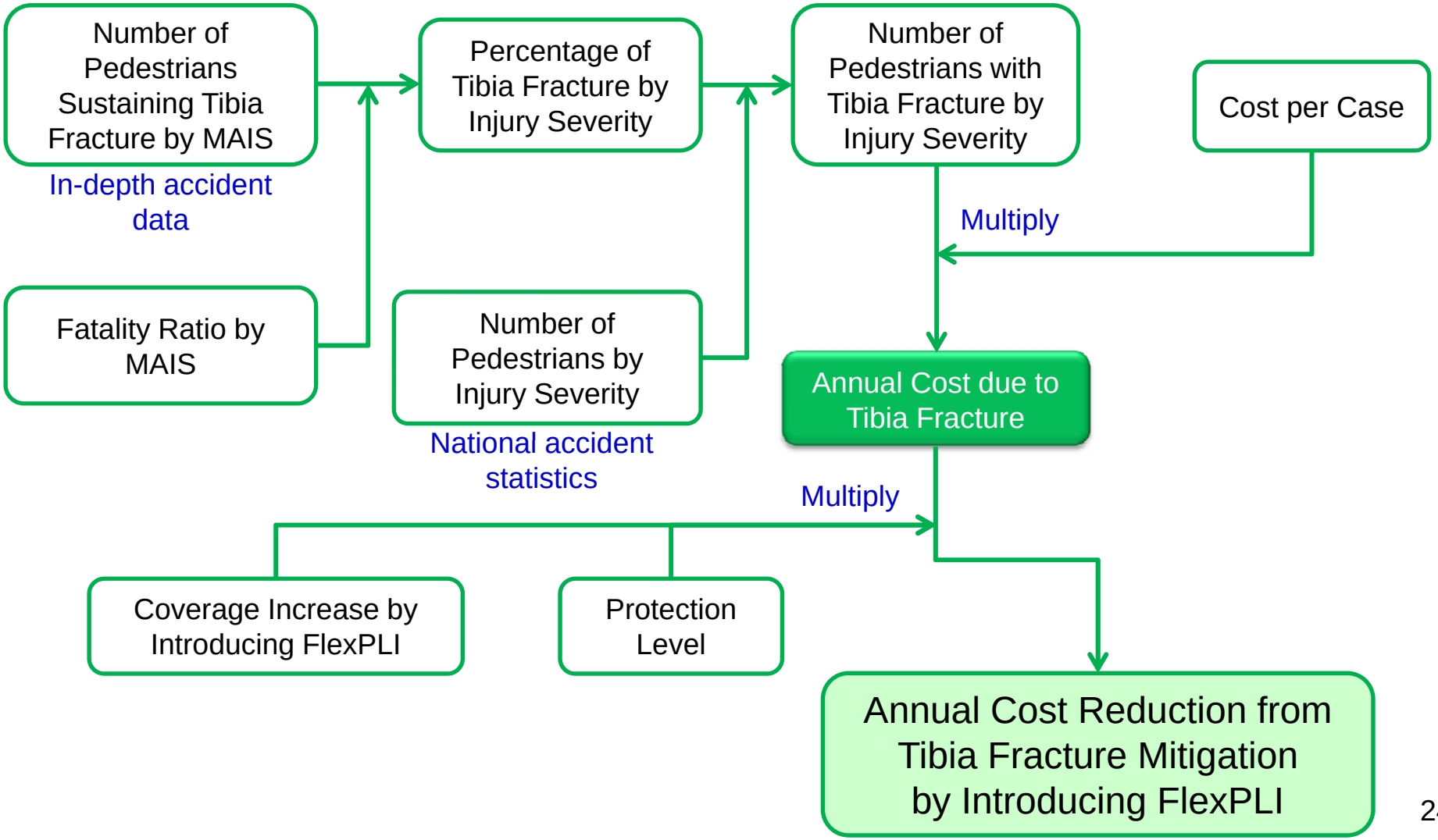
QALY : Quality-Adjusted Life Years lost

Breakdown of Human Cost

	Human Cost		
	Medical Cost	Market Productivity	Household Productivity
US	$42,237	$65,049	$19,178
JPN	$24,650		

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Estimated Annual Cost due to Tibia Fracture -

Number of Pedestrians with Tibia Fracture by Injury Severity

Injury Severity	16 YO and older	
	US	JPN
Fatal	1248	177
Severe	2599	1306
Minor	0	0

×

Cost per Case

Country	Economic Cost	Intangible Consequences	Comprehensive Cost
US	$169,646	$123,008	$292,654
JPN	$24,650	N/A	N/A

JPN: Economic Cost includes Human Cost only

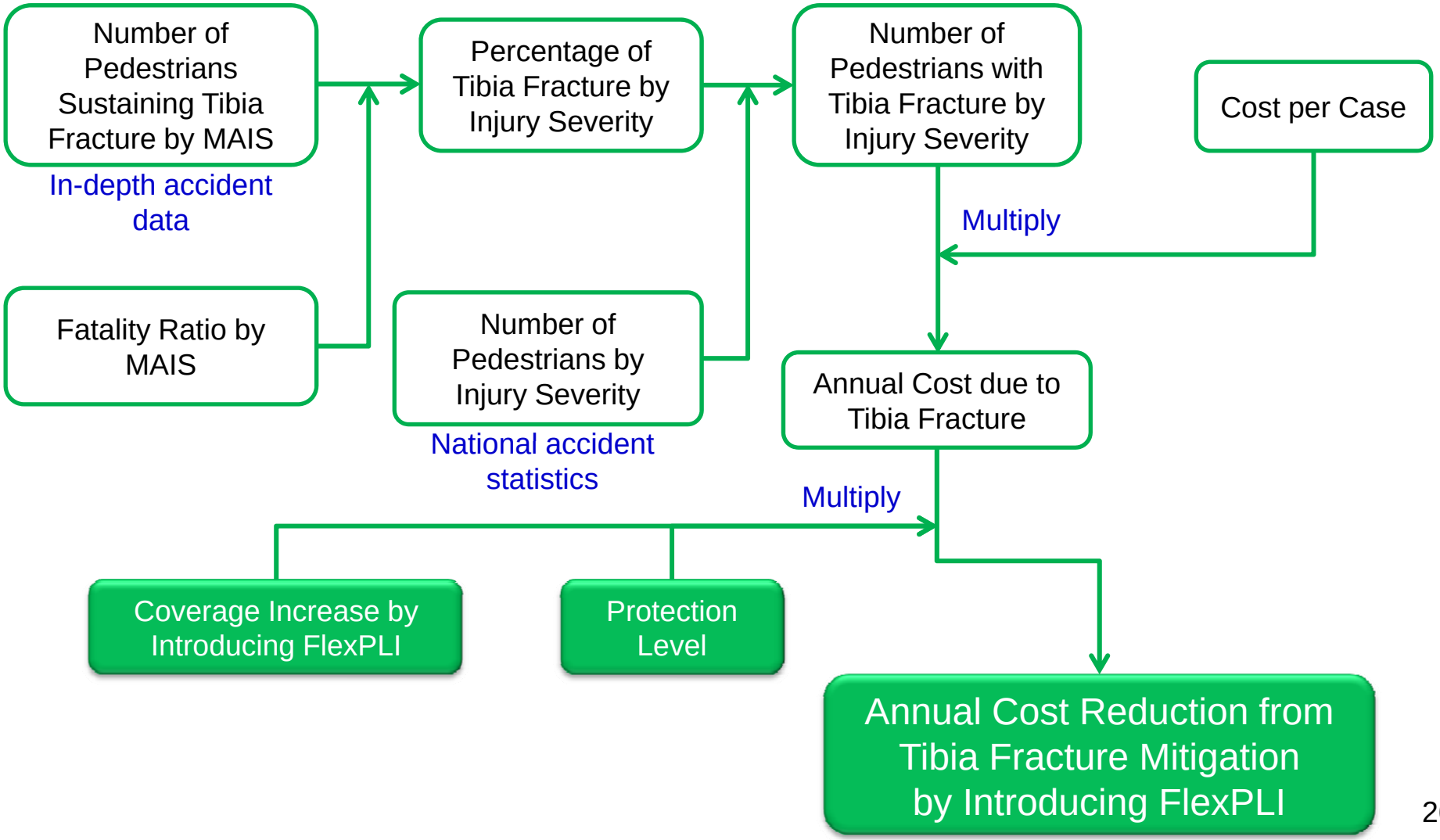
Annual Cost due to Tibia Fracture

Country	Economic Cost	Intangible Consequences	Comprehensive Cost
US	$652,628,162	$473,211,776	$1,125,839,938
JPN	$36,555,950	N/A	N/A

JPN: Economic Cost includes Human Cost only

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Overview of Cost Estimation Procedure -



2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Estimated Annual Cost Reduction -

Annual Cost due to Tibia Fracture

Country	Economic Cost	Intangible Consequences	Comprehensive Cost
US	$652,628,162	$473,211,776	$1,125,839,938
JPN	$36,555,950	N/A	N/A

JPN: Economic Cost includes Human Cost only

Protection Level × 0.825

- Coverage increase relative to TRL legform
- Otte et al. (2007) : Tibia fracture due to indirect loading = 82.5%

Coverage Increase by Introducing FlexPLI × 0.7

- Protection Level by complying with injury thresholds that correspond to 30% injury probability

Annual Cost Reduction from Tibia Fracture Mitigation by Introducing FlexPLI

Country	Economic Cost	Intangible Consequences	Comprehensive Cost
US	$376,892,764	$273,279,801	$650,172,564
JPN	$21,111,061	N/A	N/A

JPN: Economic Cost includes Human Cost only

2. Estimation of Cost Reduction due to Tibia Fracture Mitigation

- Comparison with Previous Results -

	Cost per Case						# Ped w/Tib Fx	Ann. Cost Tib Fx	Coeff.	Benefit
	Human	Property	Company	Public	Intangible	Total				
JPN Previous	$44,684	N/A	N/A	N/A	N/A	$44,684	1970	$88M	0.825 *0.7	$51M
JPN Current	$24,650	N/A	N/A	N/A	N/A	$24,650	1483	$37M	0.825 *0.7	$21M
US Previous	$44,684	Not Included	Not Included	Not Included	Not Included	$44,684	3847	$172M	0.825 *0.7	$99M
US Current	$126,464	$6,407	$3,947	$32,828	$123,008	$292,654	3847	$1,126M	0.825 *0.7	$650M

3. Summary

- The Flex-PLI provides improved biofidelity of the tibia and knee at both assembly and component levels
- Accident data show that tibia fracture is most frequent in pedestrian severe (AIS 2+) injuries
- Most significant factor that would contribute to injury mitigation is enhanced biofidelity of the tibia and much wider coverage of injury measurements over the tibia
- Additional annual cost reduction due to tibia fracture mitigation by introducing the Flex-PLI was estimated to be approximately $377M of Economic Cost and $650M of Comprehensive Cost in the US, relative to the use of TRL legform
- Japan data could not be processed in the same way as performed with the US data due to the lack of information – may require further study

References

- Otte, D., Haasper, C., Characteristics on Fractures of Tibia and Fibula in Car Impacts to Pedestrians – Influences of Car Bumper Height and Shape, IRCOBI Conference (2007)
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- NHTSA, The Economic Impact of Motor Vehicle Crashes 2000, DOT HS 809 446 (2002)

Thank you for your attention