APPENDIX **A**

METHODOLOGY FOR DETERMINING CRASH-HARM RATING FOR TREATMENTS

As described in Chapter 2, there were a large number of treatments whose AMFs (or lack thereof) made them candidates for additional research in the Phase 2 efforts of this project. The factors that influenced the final decision on addition research included

- **User Priority Level --** the priority based on the combined inputs from State DOT AMF users who responded to the project survey.
- **Level of Predictive Certainty –** the quality of the AMF estimate that could be derived from the research literature.
- **Ongoing/Future Research –** whether or not there was ongoing or planned research that might improve the AMF.
- **Availability of Needed Research Data –** for each treatment to be studied, whether there was an adequate sample size of treatment implementation sites and whether or not the necessary crash, roadway inventory and traffic data were available in the implementing state or in existing national databases (e.g., FHWA's Highway Safety Information System).
- **Estimate of Crash-Related Harm Possibly Affected by the Treatment**.

This final factor is the subject of this appendix.

The importance of a treatment, and thus its AMF, is a function of the size of the safety problem that the treatment effects and the probability that the treatment will be implemented. A treatment that will only affect a small percentage of the total array of crashes should be given less priority than a treatment affecting a larger component. In like fashion, one would assign lower priority to a treatment that is less likely to be implemented by users. In this project, this latter assessment was based on the user priority for treatments – if a treatment was judged important, it was assumed that it would be implemented widely if a sound AMF were available. The remainder of this section describes how the "safety problem size" was assigned to each treatment under consideration. The term "crash harm" will be used in the following discussion to indicate that what is measured is a combination of both crash frequency and crash severity.

One possible comprehensive way to develop a national estimate of the crash harm that might potentially be affected by a given treatment would include specifying the crash type or types that would be affected by the treatment (e.g., angle crashes, run-off-road crashes, nighttime total crashes), specifying the type of sites where the treatment would likely be implemented (e.g., unsignalized intersections, two-lane rural roads), and specifying to the extent possible limitations on the national population of such sites where the treatment might be applicable (e.g., conversion of four-leg intersections to offset-T configurations would only be possible for a low percentage of existing intersections). For this subpopulation of locations, a national estimate of crash frequency and severity would be extracted from a national data base such as GES, and the estimate of crash harm would be developed by multiplying these frequencies by accepted estimates of the societal cost of such crashes.

It was not possible to conduct such a procedure for each treatment noted in the Knowledge Matrix cited earlier since this would require a much more detailed crash data analysis than can be conducted in this project. Instead, the research team used a reduced version of this procedure to develop a four-point scale for crash problem size (low, medium-low, medium-high, and high), which reflects the amount of harm that may be reduced by implementation of a given treatment with subsequent reductions in specific types of collisions.

Development of these "problem size ratings" was based primarily on two sources of information:

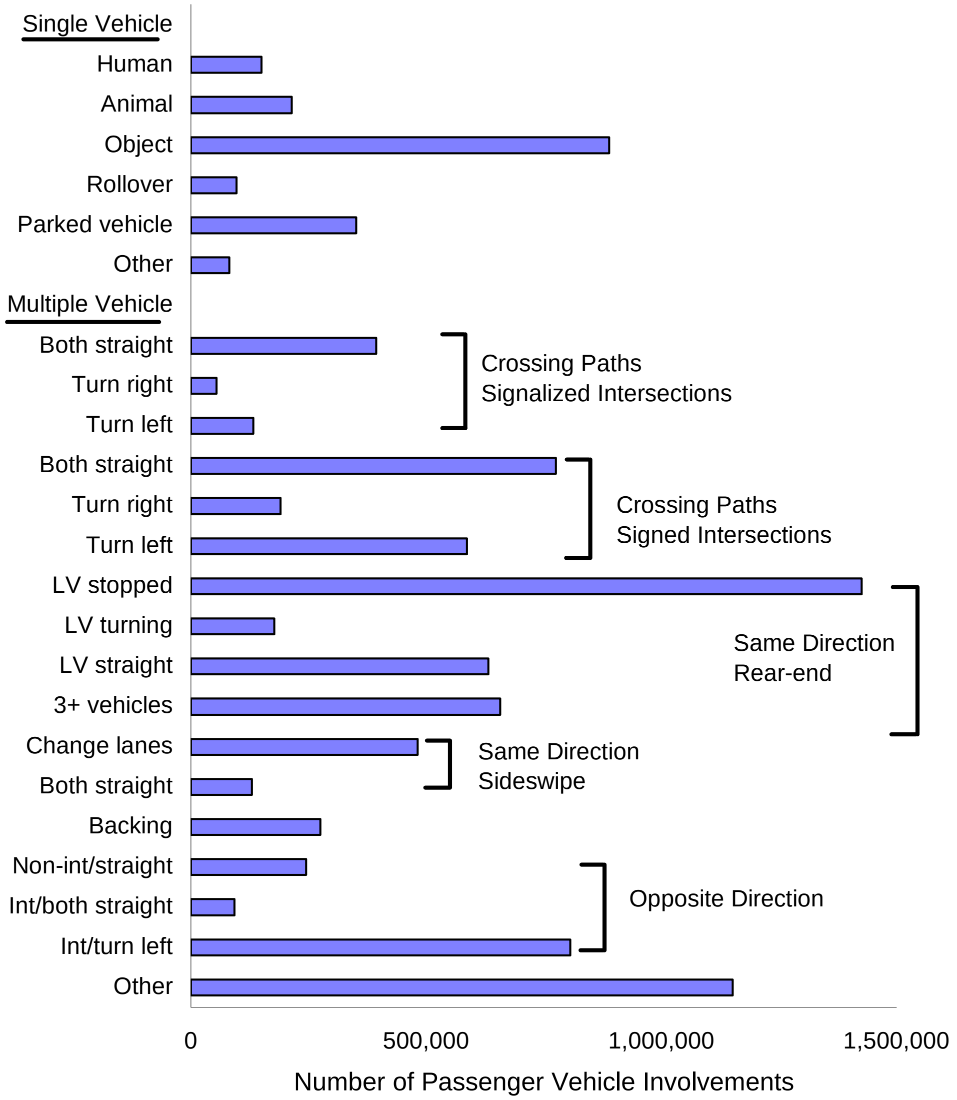
- Data on various "crash typologies" presented in the final report for NCHRP Project 20-58(2), *Research Plan for Study 2 – Detailed Planning for Research on Making a Significant Improvement in Highway Safety* developed by Campbell, Lepofsky, and Bittner in 2003. (*1*)

- Information on "crash harm" provided by Miller in a 1995 study entitled *Understanding the Harm from U.S. Motor Vehicle Crashes*. (*2*)

As noted by Campbell et al., the objective of collision typologies is to classify collisions based on pre-collision circumstances or initiating events. This is done in order to provide information about the event that must be prevented to avoid the collision. Usually, single-vehicle accidents are distinguished from multiple-vehicle, and multiple-vehicle collisions are subsequently distinguished by the pre-collision relative position and movement of each vehicle. Figure A-1 shows a typical typology based on passenger vehicles involved in police-reported accidents (based on 1992 GES data). Note that this typology counts vehicles involved rather than crashes, and thus the single-vehicle categories are diminished relative to multiple vehicle categories.

Based on this figure, within the single vehicle grouping, fixed-object crashes are the most prevalent, thus indicating the importance of segment-based treatments aimed at either keeping the vehicle on the road (e.g., rumble strips), or reducing the number of fixed objects on the roadside or making them less severe when struck.

Interpretation of the multiple-vehicle information is more complex. It would appear that, based on crash frequency, treatments related to reducing same-direction rear-end crashes should be given high priority. (Note that we assume most of these are at intersections, but this typology does not separate crashes by crash location.) In addition, crossing path crashes at signed intersections would be of more importance than crossing path crashes at signalized intersections (which is logical, since the signal decreases the probability of these crossing path crashes). However, also note that "crossing path" defines crashes which involve vehicles that entered an intersection from different roadways. The bar next to the bottom of the chart involves another higher-priority crash types – left turns at intersections where the turning vehicle is struck by an



LV = Lead Vehicle
Int = Intersection

Figure A-1. UMTRI crash typology (from Campbell, Lepofsky, and Bittner, 2003).

oncoming vehicle. Unfortunately, this typology does not separate these by signalized vs. unsignalized intersections.

It is also noted here that the above "conclusions" are based only on crash frequency, without regard to crash severity. For example, while rear-end crashes are the most prevalent multiple-vehicle crash type in the figure, they may be of less importance than other crash types since they are usually less severe than, say, cross-path or left-turning crashes. Thus, a better way of determining priority would be to look at frequency and severity simultaneously. This can be done using economic cost of crashes, where a dollar value based on crash type and crash severity is assigned to each crash, and the value of "total crash harm" is calculated by summing the dollar costs.

In their 1995 study, Miller et al. indeed do combine injury cost estimates with nationwide crash frequencies and severities from NASS-GES data to produce crash-cost totals for 30 different crash types (e.g., multiple-vehicle cross-path crashes in which both were going straight at a signalized intersection – the "T-bone" crash). As shown in Table A-1, the authors do not combine direct plus indirect crash cost into what is called "comprehensive cost." Instead, they present two different finding for each crash type – the total direct crash cost (which includes medical costs, burial cost, short term work loss), and the "years of life and functioning lost" (which measures the number of productive years lost in fatalities and the functional capacity lost in non-fatal crashes). The latter component is used in the calculation of "indirect cost" in other studies, but that was not done here.

As can be seen, the vehicle-related crash types shown in Table A-1 are categorized to a useful, but not complete, level of detail. Most are divided into intersection vs. non-intersection categories, and some into signed vs. signalized intersections. An exception is rear-end crashes that are categorized by vehicle maneuver, but not by crash location. Most of the single-vehicle crashes can be assumed to be at non-intersection locations, with the exception of the "struck human" category, which could contain both pedestrian and pedalcycle crashes at both intersection and non-intersection locations. To gain more insight into the struck-human harm costs, this total figure was further categorized using 2002 GES crash statistics from NHTSA's *Traffic Safety Facts 2002*. (*3*) Here, the total "direct costs" estimate from the table above was split between pedestrians and pedalcyclists using proportions based on the total numbers of killed plus injured pedestrians and bicyclists. Thus, since 61% of the total killed or injured in 2002 was pedestrians, 61% of the direct costs were assigned to the pedestrians. In like fashion, the "life years lost" were apportioned based on the numbers of pedestrians and pedalcyclists killed in 2002, resulting in 88% of the "life years lost" being assigned to pedestrians. The assigned pedestrian and pedalcyclist direct cost and life years lost were each further categorized into intersection vs. non-intersection components using the same weighting scheme, with the intersection/non-intersection percentages again taken from the NHTSA document. The results of this further categorization are shown in Table A-2.

The next step for all of the crash types shown in Table A-1 was to combine both the "direct cost" and "years lost" measures to develop a categorization of "harm cost" by crash type. Four categories were defined as follows:

- High: Direct cost > $2,000 million and Life Years Lost > 100K
- Medium High: Direct cost > $1,000 million and Life Years Lost > 50K
- Medium Low: Direct cost > $1,000 million and Life Years Lost < 20K
  or Direct cost < $1,000 million and Life Years Lost > 20-50K
- Low: Direct cost < $1,000 million and Life Years Lost < 20K

Table A-1. Annual direct cost, present value years of life and functioning lost (life years), and number of crashed vehicles by crash type. (*2*)
(S = 12/93 dollars, M = millions, K = thousands)

	Direct Cost	Life Years	Crashed Vehicles
Single Vehicle Crashes:	$18,678 M	937 K	2412K
Struck Human	4,236 M	251 K	346 K
Struck Animal	641 M	4 K	321 K
Struck Object	10,261 M	523 K	1,221 K
Rollover	2,348 M	131 K	155 K
Struck Parked Car	1,192 M	28 K	369 K
Multiple Vehicle Crashes:	41,553 M	973 K	10,483 K
Cross Paths	14,523 M	341 K	3,398 K
At Signal			
Both Vehicles Straight	2,948 M	72 K	544 K
One Vehicle Turn Right	213 M	3 K	74 K
One Vehicle Turn Left	723 M	12 K	179 K
At Sign			
Both Vehicles Straight	4,414 M	138 K	830 K
One Vehicle Turn Right	312 M	5 K	114 K
One Vehicle Turn Left	1,854 M	62 K	429 K
No Signage			
Both Vehicles Straight	1,033 M	16 K	253 K
One Vehicle Turn Right	403 M	4 K	142 K
One.Vehicle Turn Left	1,417 M	19 K	392 K
Unspecified	1,206 M	10 K	441 K
Rear-End	13,906 M	204 K	4,028 K
Lead Vehicle Stopped	6,824 M	78 K	2,063 K
Lead Vehicle Turning	763 M	10 K	254 K
Lead Vehicle Straight	3,015 M	47 K	938 K
3+ Vehicles Straight	3,101 M	67 K	670 K
Unspecified	203 M	2 K	103 K
Sideswipe	2,794 M	36 K	1,089 K
Lane Change	1,712 M	20 K	733 K
Vehicles Straight	395 M	8 K	167 K
Unspecified	687 M	8 K	189 K
Opposite Direction	9,517 M	387 K	1,589 K
Non-intersection			
Both Vehicles Straight	3,261 M	220 K	361 K
One Vehicle Turn Left	968 M	27 K	188 K
Intersection			
Both Vehicles Straight	545 M	20 K	106 K
One Vehicle Turn Left	4,743 M	120 K	934 K
Backing	813 M	5 K	379 K
Undefined:	5,835 M	147 K	1,613 K
Unreported:	22,354 M	150 K	11,736 K

Table A-2. Re-apportioned "Struck Human" direct cost and life years lost based on 2002 GES data. (*3*)

	Direct Costs	Life Years Lost
Struck Pedestrian		
At intersection	$1,124 M	49 K
Not at intersection	$1,460 M	172K
Struck Pedalcyclist		
At intersection	$1,082 M	10 K
Not at intersection	$ 570 M	20 K
Total Struck Human (from Miller)	$ 4,236 M	251 K

Table A-3 shows the categorization of crash types by these categories. In this table, "SV" denotes single-vehicle crashes and "MV" denotes multiple-vehicle crashes. No attempt is made to order the crash types within the categories. (Note that "Struck Pedestrian, not at intersection" was rated "high" rather than "medium high" due to the large number of life years lost relative to other medium-high categories.) The crash type reference numbers in the first column are used in the CRF Knowledge Matrix.

Note again in Table A-3 that "cross-path" indicates vehicles entering from different roadways. So the "low" ranked crash type labeled, "MV – Cross-path, signalized intersection, one vehicle turning left" refers to an impact between a left-turning vehicle and a vehicle on the crossing road. In contrast, the "high" ranked crash type labeled, "MV – Opposite direction, intersection, one vehicle turning left" refers to an impact between a left-turning vehicle and an oncoming vehicle from the opposite direction on the same roadway.

Unfortunately, the "opposite direction" intersection-related categories are not further categorized by type of intersection – signalized vs. signed. The rear-end categories are not categorized by intersection/non-intersection. And even though the original "struck human" category was divided into intersection/non-intersection categories, it was not possible to further divide these into signalized vs. signed intersections. Thus, because the cross-path categories is more finely divided than these other crash categories, the cross-path crashes are "penalized" to some extent. For example, it is not possible to know if the major rear-end categories would remain as "medium high" if they could be categorized by intersection/non-intersection and signalized vs. signed intersections. In addition, none of these crash categories are categorized by roadway type (e.g., non-intersection locations on two-lane rural roads), something that is important if a treatment is specific to limited road types. However, even with these limitations, these ratings do at least provide some rationale basis for estimating the degree of crash harm associated with a given treatment, and thus a given CRF.

In general, the rankings based on this "economic harm" data are similar to those from the earlier crash-frequency based data from Campbell, et al. (*1*) The major difference is that rear-end collisions move down to "medium high" in this final ranking due to the lower severity

Table A-3. Crash harm ratings for 31 crash types based on Miller et al. (*2*)

Crash Type Ref. No.	Crash Type	Crash Harm Rating
1	SV – Struck pedestrian, not at intersection	High
2	SV – Struck fixed object	High
3	SV – Rollover	High
4	MV – Cross-path, signed intersection, both vehicle straight (“T-bone”)	High
5	MV – Opposite direction, intersection, one vehicle turning left	High
6	MV – Opposite direction, non-intersection, both vehicle straight (“head-on”)	High
7	SV – Struck pedestrian at intersection	Medium High
8	MV—Cross-path, signalized intersection, both vehicles straight	Medium High
9	MV – Cross-path, signed intersection, one vehicle turning left	Medium High
10	MV – Rear-end, lead vehicle stopped	Medium High
11	MV – Rear-end, lead vehicle straight	Medium High
12	MV – Rear-end, 3+ vehicles straight	Medium High
13	SV – Struck pedalcyclist at intersection	Medium Low
14	SV – Struck pedalcyclist not at intersection	Medium Low
15	SV – Struck parked car	Medium Low
16	MV – Cross-path, unsigned intersection, both vehicles straight	Medium Low
17	MV – Cross-path, unsigned intersection, one vehicle turning left	Medium Low
18	MV – Cross-path, intersection with unknown signage,	Medium Low
19	MV – Sideswipe, lane change	Medium Low
20	MV – Opposite direction, non-intersection, one vehicle turning left	Medium Low
21	MV – Opposite direction, intersection, both vehicles straight	Medium Low
22	SV – Struck animal	Low
23	MV – Cross-path, signalized intersection, one vehicle turning right	Low
24	MV – Cross-path, signalized intersection, one vehicle turning left	Low
25	MV – Cross-path, signed intersection, one vehicle turning right	Low
26	MV – Cross path, unsigned intersection, one vehicle turning right	Low
27	MV – Rear-end, lead vehicle turning	Low
28	MV – Rear-end, unspecified vehicle maneuver	Low
29	MV – Sideswipe, both vehicles straight	Low
30	MV – Sideswipe, unspecified vehicle maneuvers	Low
31	MV – Backing	Low

of these crashes. Because of the similarities of rankings and the fact that "crash harm" captures both crash frequency and severity, we will use the "harm" rankings in our treatment (and thus CRF) prioritization efforts.

Thus, for each of the treatments in the CRF Knowledge Matrix, a primary crash type was defined. The assigned crash type (or types) is included in Table 3 of Chapter 2. The treatment (and thus the CRF) was then assigned the "crash harm rating" from the Table A-3. In some cases, it was felt that the treatment would prevent or lessen the severity of more than one primary crash type. In these cases, the higher rating was used.

Subsequent use of this procedure indicated that an additional downward adjustment needed to be applied to the estimate of national crash harm for certain treatments. In some cases, it was felt that the treatment being studied could potentially be applied to all locations nationwide where the primary crash type still exists. For example, installing a traffic signal would be a potential treatment for most of the "cross-path, both vehicles straight" crashes at unsignalized intersections. (Clearly, not every unsignalized intersection will be signalized, but signalization will be considered for intersections with high counts of angle crashes). In these cases, the full crash cost value from Table A-1 was used in defining the crash harm category rating for a treatment. However, in other cases, the population of potential sites would logically be limited below that reflected in the national estimates of crash harm shown for the primary crash type in Table A-1. In general, these limitations were of three types:

1. Some treatments are for specific road types (e.g., shoulder rumble strips on non-freeway multilane divided roads) while the crash harm estimate is related to all road types combined.
2. Some treatments only affect subsets of crashes (e.g., midblock pedestrian crossings only affect those pedestrians crossing the street, not those walking along it) while the crash harm estimate is related to a broader category (i.e., struck pedestrian at non-intersection location).
3. Some treatments would logically only be installed at a limited subpopulation of a certain type of sites (e.g., conversion of four-leg intersections to an offset-T configuration), while the crash harm estimate is related to a broader population of sites (i.e., opposite direction left-turning crashes at all intersections).

In these cases, the research team extracted additional information on the national problem size for pertinent crash categories (e.g., the proportion of total crashes occurring during nighttime for the treatments related to roadway lighting). As in the pedestrian-crash categorization efforts noted above, these data were extracted from 2002 GES crash statistics from NHTSA's *Traffic Safety Facts 2002* when possible. (*3*) In some cases, GES did not contain the needed information (e.g., there is no GES roadway class/type variable). In these cases, 2002 FARS data were used. Thus, for each treatment where an adjustment was felt necessary, these additional detailed data on national problem size allowed the research team to decrease the estimate of related national crash cost for the primary crash type found in Table A-1 above, and thus to better define the crash-harm rating for that treatment.

REFERENCES

1. Campbell, K.L., M. Lepofsky, and A. Bittner. *Detailed Planning for Research on Making a Significant Improvement in Highway Safety, Study 2 – Safety*. Transportation Research Board, The National Academies, 2003.

2. Miller, T., Lestina, D., Galbraith, M., Schlax, T., Mabery, P., Deering, R., Massie, D.L. and Campbell, K.L. (1995), "Understanding the Harm from U.S. Motor Vehicle Crashes," *39th Annual Proceedings of the Association for the Advancement of Automotive Medicine*.

3. *Traffic Safety Facts 2002*, Publication No. DOT HS 809 620. U.S. Department of Transportation, National Highway Traffic Safety Administration, 2003.

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