APPENDIX A.

TRUCK IN-SERVICE DATES

Appendix A.

Truck In-Service Dates

Fleet	Vehicle ID	USX ID	In-Service Date
Baseline	3932	10312	10-Jul-01
	3936	10316	Unknown
	3937	10317	29-Oct-01
	3938	10318	17-May-01
	3942	10322	20-Sep-01
	3943	10323	Unknown
	3946	10326	24-Oct-01
	3947	10327	22-May-01
	3953	10333	19-Jun-01
	3955	10335	25-Sep-01
	3958	10338	4-Jan-01
	3959	10339	Unknown
	3960	10340	5-Sep-01
	3961	10341	7-Aug-01
	3962	10342	Unknown
	3966	10346	Unknown
	3971	10351	19-Sep-01
	3972	10352	23-Oct-01
	3973	10353	28-Sep-01
	3974	10354	Unknown
Control	253975	10355	05-Jan-01
	253976	10356	24-Jan-01
	253977	10357	24-Jan-01
	253978	10358	05-Jan-01
	253970	10350	29-Dec-00
	253967	10347	24-Jan-01
	253968	10348	28-Dec-00
	253969	10349	28-Dec-00
	253963	10343	01-Dec-00
	253964	10344	15-Dec-00
	253965	10345	28-Dec-00
	253954	10334	01-Dec-00
	253956	10336	08-Dec-00
	253957	10337	01-Dec-00
	253952	10332	22-Dec-00
	253950	10330	01-Dec-00
	253951	10331	01-Dec-00
	253948	10328	01-Dec-00
	253949	10329	15-Dec-00
	253944	10324	01-Dec-00
	253945	10325	15-Dec-00
	253939	10319	01-Dec-00
	253940	10320	19-Jan-01
	253941	10321	24-Jan-01
	253934	10314	01-Dec-00
	253935	10315	01-Dec-00
	253933	10313	21-Dec-00
	253930	10196	01-Dec-00
	253931	10311	01-Dec-00
	253929	10195	01-Dec-00

Fleet	Vehicle ID	USX ID	In-Service Date
Test	247484	10159	13-Jun-01
	247482	10157	
	247483	10158	
	254009	10359	13-Jun-01
	254010	10360	03-Aug-01
	254011	10361	03-Aug-01
	254012	10362	11-Jul-01
	254013	10363	20-Jun-01
	254014	10364	25-Jun-01
	254015	10365	
	254016	10366	20-Jul-01
	254017	10367	20-Jul-01
	254018	10368	05-Jul-01
	254019	10369	27-Jun-01
	254020	10383	26-Jul-01
	254021	10384	27-Jul-01
	254022	10385	28-Jun-01
	254023	10386	
	254024	10387	
	254025	10388	13-Jun-01
	254026	10389	25-Jun-01
	254027	10390	25-Jun-01
	254028	10391	06-Aug-01
	254029	10392	09-Jul-01
	254030	10393	26-Jul-01
	254031	10394	
	254032	10395	24-Jun-01
	254033	10396	19-Jun-01
	254034	10397	19-Jun-01
	254035	10398	28-Jun-01
	254036	10399	20-Jun-01
	254037	10400	
	254038	10501	25-Jun-01
	254039	10502	05-Jul-01
	254040	10503	
	254041	10504	27-Jul-01
	254042	10505	27-Jun-01
	254043	10506	26-Jun-01
	254044	10507	06-Aug-01
	254045	10508	
	254046	10509	25-Jun-01
	254047	10510	03-Jul-01
	254048	10511	05-Jul-01
	254049	10512	25-Jun-01
	254050	10513	20-Jul-01
	254051	10514	11-Jul-01
	254052	10515	05-Jul-01
	254053	10516	27-Jul-01
	254054	10517	26-Jun-01
	254055	10518	26-Jun-01

APPENDIX B.

CODING SCHEME USED IN HISTORICAL CRASH DATA ANALYSIS (GES AND FARS)

Appendix B.

Coding Scheme Used in Historical Crash Data Analysis (GES and FARS)

This appendix explains how the General Estimates System (GES) and Fatality Analysis Reporting System (FARS) data sets were used in the analysis of historical crash statistics. Only crash data from 1999 to 2003 were used in this analysis. Similar variables in the GES and the FARS data sets were used whenever possible to define categories of interest for analysis. Sometimes multiple variables were necessary to define a category.

The tables in this document all have the same general form. Both the name and alphanumeric name are given for the GES variables, while the SAS names are given for the FARS variables. For each variable the coded SAS values that were utilized—and a text description of what they represent—are provided. In some cases, for the sake of simplicity, the coded SAS values that were excluded are provided, in which case the text describes what was omitted. Starting with the 2002 GES data sets, significant changes were made to the coding schemes of several variables used in the analysis. Those changes that affected how the variables of interest were defined are provided in parenthesis in the tables. An important change that should be mentioned is that the meaning of the "manner of collision" variable in FARS changed. Prior to 2002 the manner of collision variable was dependent on the direction of travel of the vehicles involved, where this was determined by the pre-crash condition direction of travel. Beginning in 2002, the manner of collision was dependent on the points of impact.

The analysis is performed on two categories of trucks: All large trucks (classes 3 through 8) and tractors (classes 7 and 8) pulling trailers. These subsets of trucks were used to create Excel tables, which give the relative frequency of predominant driving conflicts. The method used to define the truck categories from the GES and FARS data is provided in Table B-1.

A total of five crash types were determined from the GES and FARS data sets. Table B-2 displays the variables used to determine the crash types. Classifying the crashes into these categories for the GES data was straightforward given the crash-type diagrams supplied in the GES User's Manual. Since FARS did not have an accident type variable similar to GES, several variables were identified to determine the crash type.

The crash types were further broken down into predominant driving conflicts for the GES data only since the necessary variables do not exist in FARS. Table B-3 provides the process used to determine predominant driving conflicts for rear-end crashes.

Table B-1. Determination of Truck Categories

Data Source	Category	Variables			
GES		**Hot-deck Imputed Body Type V5H**	**Tailing units V13**	**Cargo Body Type V33**	**Hazmat Placard V34**
	Large Truck	60- Step Van	All	All	All
		64 – Single Unit Straight Truck	All	All	All
		66- Truck-Tractor	All	All	All
		78 – Unknown Medium/Heavy Truck	All	All	All
	Tractor Trailer	66-Truck Tractor	2,3,4,5 – Trailing units	All	All
FARS		**Body_typ**	**Tow_veh**	**cargo_bt**	**haz_carg**
	Large Truck	60- Step Van	All	All	All
		61-Single Unit Straight Truck low GVWR	All	All	All
		62-Single Unit Straight Truck med GVWR	All	All	All
		63-Single Unit Straight Truck high GVWR	All	All	All
		64 – Single Unit Straight Truck	All	All	All
		66- Truck-Tractor	All	All	All
		71-Med. Single Unit Straight Truck or Combination Truck	All	All	All
		72- Heavy Single Unit Straight Truck or Combination Truck	All	All	All
		78 – Unknown Medium/Heavy Truck	All	All	All
		79- Unknown Truck	1,2,3,4 – Trailing units	All	All
	Tractor Trailer	66-Truck Tractor	1,2,3,4 – Trailing units	All	All

Table B-2. Determination of Crash Type (Changes made due to variable recoding in 2002 in parenthesis)

Crash Type	GES			FARS				
	Accident type V23	Rollover V30	Univariate Imputed Vehicle Role V22I	Man_col*	Rel_road	Rollover	Impacts	J_knife
SVRD	1-10	All	All	3 - Rear to rear	2 - Shoulder 4 – Roadside 6 – Off roadway	All All All	All All All	All All All
				6 - Sideswipe (Opp Direction)	2, 4, or 6	All	All	All
				9 – Unknown	2, 4, or 6	All	All	All
				2 – Head On	2, 4, or 6	All	Not 2 –Omit Struck	All
Rear-End	20-43	All	1 or 3	1 – Rear End (Front-to-Rear)	All	All	All	All
Lane Change / Merge	44-49	All	Not 2 –Omit Struck	4 (3,4,5,6) – Angle	All	All	Not 2 –Omit Struck	All
				5 (7) – Side Swipe - Same Direction	All	All	Not 2 –Omit Struck	All
Untripped Rollover	98 –Other	10-Untripped Rollover	All	3 (10) – Rear to Rear	Not 2, not 4, and not 6	1 –first event	All	Not 2 –omit first event
				(09) – Rear to Side	Not 2, not 4, and not 6	1 –first event	All	Not 2 –omit first event
				6 (8) - Sideswipe -Opp Direction	Not 2, not 4, and not 6	1 –first event	All	Not 2 –omit first event
				(11) – Other	Not 2, not 4, and not 6	1 –first event	All	Not 2 –omit first event
				9 (99) – Unknown	Not 2, not 4, and not 6	1 –first event	All	Not 2 –omit first event
Other	Everything not categorized above			Everything not categorized above				

* Prior to 2002 the manner of collision was dependent on the direction of travel of the vehicles involved, where this was determined by the pre-crash condition direction of travel. In 2002 the manner of collision was dependent on the points of impact.

Table B-3. Determination of Rear-End Predominant Driving Conflicts from GES Data

Conflict Number	Accident Type V23	Rollover V30	Vehicles Involved A3	Univariate Imputed Vehicle Role V22I	Univariate Imputed Movement Prior to Critical Event V21I	Critical Event V26	Imputed Roadway Alignment A13I
Rear-End.1	20-43	All	<3	1 or 3	01 - Going Straight	051 – Other vehicle lower speed	All
Rear-End.2*	20-43	All	<3	1 or 3	02 – Decelerating	All except 050 – other vehicle stopped	All
Rear-End.3	20-43	All	<3	1 or 3	15,16 – Changing Lanes/ Merging	051 – Other vehicle lower speed	All
Rear-End.4*	20-43	All	<3	1 or 3	All	050 - Other vehicle stopped	All
Rear-End.5	20-43	All	<3	1 or 3	01 - Going Straight	052 – Other vehicle decelerating	All
Rear-End.9	20-43	All	All	1 or 3	Everything not categorized in Rearend.1-Rearend.5		

* Note: The accidents where the lead vehicle is stopped and the truck was decelerating are counted in both these categories. Removal of these accidents from the conflict total for 1992-1998 data did not alter the percentages reported.

APPENDIX C.

BENEFIT-COST ANALYSIS LIFE-CYCLE TABLES

Appendix C.
Benefit-Cost Analysis Life-Cycle Tables

This appendix presents supporting detail on the benefit-cost analysis. The first part shows annual cost and benefit values over the 20-year deployment being modeled, with various discount rate assumptions. The second part shows the total life-cycle costs and benefits per scenario, which were used to derive the benefit-cost ratios discussed in the text.

Tables C-1 through C-24 show representative examples of the detailed year-by-year forecasts for all the benefits and costs included in the BCA scenarios described in Section 5.3, including the present value for each benefit or cost at each future year, discounted at both 4 percent and 7 percent (real). Undiscounted dollar values are also shown. A table is presented for each combination of truck fleet, IVSS deployed, conflict threshold, and equipment cost assumption:

- All-truck scenarios—Tables C-1 through C-12
- Tractor-Trailer scenarios—Tables C-13 through C-24.

Examination of these tables can be helpful in understanding the relative importance of each category of project benefits and costs, how these are projected to increase over time, and how the arithmetic of discounting decreases the present value of a benefit or cost, the farther into the future it occurs. The present value of a benefit or cost that occurs n years into the future using discount rate i is equal to the future value divided by $(1+ i)^n$.

For example, assume that the base year is 2005, which makes the year 2008 into model year 3 (i.e., 2008 – 2005 = 3). Also, assume that the discount rate is 4%, or 0.04. If the undiscounted dollar benefit of crashes avoided in a given scenario during 2008 is $551,334,727, then the following equation is used to calculate that year's corresponding discounted value of $490,134,564.70:

$$[551,334,727 / (1 + 0.04)^3] = [551,334,727 / 1.124864] = 490,134,564.70.$$

Note that the discounted totals at the bottom of these tables are the same values used in computing the benefits and costs in the BCA summary tables for those scenarios summarized in Section 5.3.

Table C-1

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Effect of CWS Only Using Conservative Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	-$74,809,754	$16,779,754,291	$393,580,498	-$74,809,754	$16,779,754,291	$393,580,498	-$74,809,754	$16,779,754,291	$393,580,498
2006	-$77,035,764	$0	$357,523,084	-$74,072,850	$0	$343,772,196	-$71,996,041	$0	$334,133,723
2007	-$79,328,010	$0	$368,161,402	-$73,343,205	$0	$340,385,911	-$69,288,157	$0	$321,566,426
2008	-$81,688,464	$0	$379,116,269	-$72,620,747	$0	$337,032,983	-$66,682,120	$0	$309,471,806
2009	-$84,119,154	$0	$390,397,106	-$71,905,405	$0	$333,713,082	-$64,174,100	$0	$297,832,083
2010	-$86,622,171	$0	$402,013,611	-$71,197,110	$0	$330,425,884	-$61,760,411	$0	$286,630,148
2011	-$89,199,667	$0	$413,975,772	-$70,495,792	$0	$327,171,066	-$59,437,504	$0	$275,849,536
2012	-$91,853,857	$0	$426,293,874	-$69,801,382	$0	$323,948,309	-$57,201,966	$0	$265,474,400
2013	-$94,587,025	$0	$438,978,509	-$69,113,813	$0	$320,757,297	-$55,050,510	$0	$255,489,489
2014	-$97,401,520	$21,847,065,143	$452,040,583	-$68,433,016	$15,349,458,181	$317,597,718	-$52,979,973	$11,883,355,908	$245,880,126
2015	-$100,299,762	$0	$465,491,327	-$67,758,925	$0	$314,469,262	-$50,987,313	$0	$236,632,187
2016	-$103,284,242	$0	$479,342,307	-$67,091,474	$0	$311,371,622	-$49,069,600	$0	$227,732,077
2017	-$106,357,528	$0	$493,605,430	-$66,430,598	$0	$308,304,495	-$47,224,015	$0	$219,166,714
2018	-$109,522,262	$0	$508,292,962	-$65,776,232	$0	$305,267,581	-$45,447,845	$0	$210,923,508
2019	-$112,781,164	$0	$523,417,530	-$65,128,312	$0	$302,260,581	-$43,738,480	$0	$202,990,342
2020	-$116,137,036	$0	$538,992,139	-$64,486,774	$0	$299,283,202	-$42,093,406	$0	$195,355,555
2021	-$119,592,765	$0	$555,030,179	-$63,851,555	$0	$296,335,151	-$40,510,207	$0	$188,007,925
2022	-$123,151,321	$0	$571,545,442	-$63,222,593	$0	$293,416,139	-$38,986,554	$0	$180,936,650
2023	-$126,815,763	$0	$588,552,126	-$62,599,827	$0	$290,525,880	-$37,520,208	$0	$174,131,337
2024	-$130,589,244	$0	$606,064,855	-$61,983,195	$0	$287,664,092	-$36,109,014	$0	$167,581,983
Total	-$2,005,176,473	$38,626,819,433	$9,352,415,004	-$1,364,122,561	$32,129,212,471	$6,377,282,947	-$1,065,067,177	$28,663,110,198	$4,989,366,514

Table C-2

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Effect of CWS Only Using Conservative Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	-$74,809,754	$25,169,631,436	$393,580,498	-$74,809,754	$25,169,631,436	$393,580,498	-$74,809,754	$25,169,631,436	$393,580,498
2006	-$77,035,764	$0	$357,523,084	-$74,072,850	$0	$343,772,196	-$71,996,041	$0	$334,133,723
2007	-$79,328,010	$0	$368,161,402	-$73,343,205	$0	$340,385,911	-$69,288,157	$0	$321,566,426
2008	-$81,688,464	$0	$379,116,269	-$72,620,747	$0	$337,032,983	-$66,682,120	$0	$309,471,806
2009	-$84,119,154	$0	$390,397,106	-$71,905,405	$0	$333,713,082	-$64,174,100	$0	$297,832,083
2010	-$86,622,171	$0	$402,013,611	-$71,197,110	$0	$330,425,884	-$61,760,411	$0	$286,630,148
2011	-$89,199,667	$0	$413,975,772	-$70,495,792	$0	$327,171,066	-$59,437,504	$0	$275,849,536
2012	-$91,853,857	$0	$426,293,874	-$69,801,382	$0	$323,948,309	-$57,201,966	$0	$265,474,400
2013	-$94,587,025	$0	$438,978,509	-$69,113,813	$0	$320,757,297	-$55,050,510	$0	$255,489,489
2014	-$97,401,520	$32,770,597,714	$452,040,583	-$68,433,016	$23,024,187,271	$317,597,718	-$52,979,973	$17,825,033,861	$245,880,126
2015	-$100,299,762	$0	$465,491,327	-$67,758,925	$0	$314,469,262	-$50,987,313	$0	$236,632,187
2016	-$103,284,242	$0	$479,342,307	-$67,091,474	$0	$311,371,622	-$49,069,600	$0	$227,732,077
2017	-$106,357,528	$0	$493,605,430	-$66,430,598	$0	$308,304,495	-$47,224,015	$0	$219,166,714
2018	-$109,522,262	$0	$508,292,962	-$65,776,232	$0	$305,267,581	-$45,447,845	$0	$210,923,508
2019	-$112,781,164	$0	$523,417,530	-$65,128,312	$0	$302,260,581	-$43,738,480	$0	$202,990,342
2020	-$116,137,036	$0	$538,992,139	-$64,486,774	$0	$299,283,202	-$42,093,406	$0	$195,355,555
2021	-$119,592,765	$0	$555,030,179	-$63,851,555	$0	$296,335,151	-$40,510,207	$0	$188,007,925
2022	-$123,151,321	$0	$571,545,442	-$63,222,593	$0	$293,416,139	-$38,986,554	$0	$180,936,650
2023	-$126,815,763	$0	$588,552,126	-$62,599,827	$0	$290,525,880	-$37,520,208	$0	$174,131,337
2024	-$130,589,244	$0	$606,064,855	-$61,983,195	$0	$287,664,092	-$36,109,014	$0	$167,581,983
Total	-$2,005,176,473	$57,940,229,150	$9,352,415,004	-$1,364,122,561	$48,193,818,707	$6,377,282,947	-$1,065,067,177	$42,994,665,297	$4,989,366,514

Table C-3

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Effect of CWS Only Using Medium Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$696,145,992	$16,779,754,291	$393,580,498	$696,145,992	$16,779,754,291	$393,580,498	$696,145,992	$16,779,754,291	$393,580,498
2006	$716,860,242	$0	$357,523,084	$689,288,694	$0	$343,772,196	$669,962,843	$0	$334,133,723
2007	$738,190,857	$0	$368,161,402	$682,498,943	$0	$340,385,911	$644,764,483	$0	$321,566,426
2008	$760,156,177	$0	$379,116,269	$675,776,074	$0	$337,032,983	$620,513,874	$0	$309,471,806
2009	$782,775,089	$0	$390,397,106	$669,119,427	$0	$333,713,082	$597,175,368	$0	$297,832,083
2010	$806,067,041	$0	$402,013,611	$662,528,351	$0	$330,425,884	$574,714,660	$0	$286,630,148
2011	$830,052,059	$0	$413,975,772	$656,002,199	$0	$327,171,066	$553,098,735	$0	$275,849,536
2012	$854,750,766	$0	$426,293,874	$649,540,333	$0	$323,948,309	$532,295,819	$0	$265,474,400
2013	$880,184,398	$0	$438,978,509	$643,142,118	$0	$320,757,297	$512,275,333	$0	$255,489,489
2014	$906,374,823	$21,847,065,143	$452,040,583	$636,806,928	$15,349,458,181	$317,597,718	$493,007,850	$11,883,355,908	$245,880,126
2015	$933,344,561	$0	$465,491,327	$630,534,142	$0	$314,469,262	$474,465,047	$0	$236,632,187
2016	$961,116,799	$0	$479,342,307	$624,323,146	$0	$311,371,622	$456,619,668	$0	$227,732,077
2017	$989,715,417	$0	$493,605,430	$618,173,330	$0	$308,304,495	$439,445,482	$0	$219,166,714
2018	$1,019,165,005	$0	$508,292,962	$612,084,092	$0	$305,267,581	$422,917,244	$0	$210,923,508
2019	$1,049,490,883	$0	$523,417,530	$606,054,835	$0	$302,260,581	$407,010,659	$0	$202,990,342
2020	$1,080,719,127	$0	$538,992,139	$600,084,969	$0	$299,283,202	$391,702,346	$0	$195,355,555
2021	$1,112,876,586	$0	$555,030,179	$594,173,908	$0	$296,335,151	$376,969,803	$0	$188,007,925
2022	$1,145,990,909	$0	$571,545,442	$588,321,073	$0	$293,416,139	$362,791,374	$0	$180,936,650
2023	$1,180,090,570	$0	$588,552,126	$582,525,891	$0	$290,525,880	$349,146,218	$0	$174,131,337
2024	$1,215,204,887	$0	$606,064,855	$576,787,793	$0	$287,664,092	$336,014,278	$0	$167,581,983
Total	$18,659,272,188	$38,626,819,433	$9,352,415,004	$12,693,912,235	$32,129,212,471	$6,377,282,947	$9,911,037,071	$28,663,110,198	$4,989,366,514

Table C-4

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Effect of CWS Only Using Medium Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$696,145,992	$25,169,631,436	$393,580,498	$696,145,992	$25,169,631,436	$393,580,498	$696,145,992	$25,169,631,436	$393,580,498
2006	$716,860,242	$0	$357,523,084	$689,288,694	$0	$343,772,196	$669,962,843	$0	$334,133,723
2007	$738,190,857	$0	$368,161,402	$682,498,943	$0	$340,385,911	$644,764,483	$0	$321,566,426
2008	$760,156,177	$0	$379,116,269	$675,776,074	$0	$337,032,983	$620,513,874	$0	$309,471,806
2009	$782,775,089	$0	$390,397,106	$669,119,427	$0	$333,713,082	$597,175,368	$0	$297,832,083
2010	$806,067,041	$0	$402,013,611	$662,528,351	$0	$330,425,884	$574,714,660	$0	$286,630,148
2011	$830,052,059	$0	$413,975,772	$656,002,199	$0	$327,171,066	$553,098,735	$0	$275,849,536
2012	$854,750,766	$0	$426,293,874	$649,540,333	$0	$323,948,309	$532,295,819	$0	$265,474,400
2013	$880,184,398	$0	$438,978,509	$643,142,118	$0	$320,757,297	$512,275,333	$0	$255,489,489
2014	$906,374,823	$32,770,597,714	$452,040,583	$636,806,928	$23,024,187,271	$317,597,718	$493,007,850	$17,825,033,861	$245,880,126
2015	$933,344,561	$0	$465,491,327	$630,534,142	$0	$314,469,262	$474,465,047	$0	$236,632,187
2016	$961,116,799	$0	$479,342,307	$624,323,146	$0	$311,371,622	$456,619,668	$0	$227,732,077
2017	$989,715,417	$0	$493,605,430	$618,173,330	$0	$308,304,495	$439,445,482	$0	$219,166,714
2018	$1,019,165,005	$0	$508,292,962	$612,084,092	$0	$305,267,581	$422,917,244	$0	$210,923,508
2019	$1,049,490,883	$0	$523,417,530	$606,054,835	$0	$302,260,581	$407,010,659	$0	$202,990,342
2020	$1,080,719,127	$0	$538,992,139	$600,084,969	$0	$299,283,202	$391,702,346	$0	$195,355,555
2021	$1,112,876,586	$0	$555,030,179	$594,173,908	$0	$296,335,151	$376,969,803	$0	$188,007,925
2022	$1,145,990,909	$0	$571,545,442	$588,321,073	$0	$293,416,139	$362,791,374	$0	$180,936,650
2023	$1,180,090,570	$0	$588,552,126	$582,525,891	$0	$290,525,880	$349,146,218	$0	$174,131,337
2024	$1,215,204,887	$0	$606,064,855	$576,787,793	$0	$287,664,092	$336,014,278	$0	$167,581,983
Total	$18,659,272,188	$57,940,229,150	$9,352,415,004	$12,693,912,235	$48,193,818,707	$6,377,282,947	$9,911,037,071	$42,994,665,297	$4,989,366,514

Table C-5

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Effect of CWS Only Using Aggressive Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$856,295,203	$16,779,754,291	$393,580,498	$856,295,203	$16,779,754,291	$393,580,498	$856,295,203	$16,779,754,291	$393,580,498
2006	$881,774,791	$0	$357,523,084	$847,860,376	$0	$343,772,196	$824,088,589	$0	$334,133,723
2007	$908,012,539	$0	$368,161,402	$839,508,634	$0	$340,385,911	$793,093,317	$0	$321,566,426
2008	$935,031,008	$0	$379,116,269	$831,239,161	$0	$337,032,983	$763,263,826	$0	$309,471,806
2009	$962,853,427	$0	$390,397,106	$823,051,145	$0	$333,713,082	$734,556,270	$0	$297,832,083
2010	$991,503,720	$0	$402,013,611	$814,943,784	$0	$330,425,884	$706,928,449	$0	$286,630,148
2011	$1,021,006,520	$0	$413,975,772	$806,916,284	$0	$327,171,066	$680,339,755	$0	$275,849,536
2012	$1,051,387,194	$0	$426,293,874	$798,967,857	$0	$323,948,309	$654,751,103	$0	$265,474,400
2013	$1,082,671,863	$0	$438,978,509	$791,097,725	$0	$320,757,297	$630,124,881	$0	$255,489,489
2014	$1,114,887,427	$21,847,065,143	$452,040,583	$783,305,118	$15,349,458,181	$317,597,718	$606,424,890	$11,883,355,908	$245,880,126
2015	$1,148,061,584	$0	$465,491,327	$775,589,270	$0	$314,469,262	$583,616,294	$0	$236,632,187
2016	$1,182,222,859	$0	$479,342,307	$767,949,426	$0	$311,371,622	$561,665,564	$0	$227,732,077
2017	$1,217,400,623	$0	$493,605,430	$760,384,838	$0	$308,304,495	$540,540,436	$0	$219,166,714
2018	$1,253,625,124	$0	$508,292,962	$752,894,763	$0	$305,267,581	$520,209,857	$0	$210,923,508
2019	$1,290,927,506	$0	$523,417,530	$745,478,469	$0	$302,260,581	$500,643,944	$0	$202,990,342
2020	$1,329,339,844	$0	$538,992,139	$738,135,227	$0	$299,283,202	$481,813,935	$0	$195,355,555
2021	$1,368,895,164	$0	$555,030,179	$730,864,320	$0	$296,335,151	$463,692,153	$0	$188,007,925
2022	$1,409,627,478	$0	$571,545,442	$723,665,034	$0	$293,416,139	$446,251,960	$0	$180,936,650
2023	$1,451,571,806	$0	$588,552,126	$716,536,663	$0	$290,525,880	$429,467,719	$0	$174,131,337
2024	$1,494,764,213	$0	$606,064,855	$709,478,509	$0	$287,664,092	$413,314,761	$0	$167,581,983
Total	$22,951,859,892	$38,626,819,433	$9,352,415,004	$15,614,161,805	$32,129,212,471	$6,377,282,947	$12,191,082,908	$28,663,110,198	$4,989,366,514

Table C-6

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Effect of CWS Only Using Aggressive Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$856,295,203	$25,169,631,436	$393,580,498	$856,295,203	$25,169,631,436	$393,580,498	$856,295,203	$25,169,631,436	$393,580,498
2006	$881,774,791	$0	$357,523,084	$847,860,376	$0	$343,772,196	$824,088,589	$0	$334,133,723
2007	$908,012,539	$0	$368,161,402	$839,508,634	$0	$340,385,911	$793,093,317	$0	$321,566,426
2008	$935,031,008	$0	$379,116,269	$831,239,161	$0	$337,032,983	$763,263,826	$0	$309,471,806
2009	$962,853,427	$0	$390,397,106	$823,051,145	$0	$333,713,082	$734,556,270	$0	$297,832,083
2010	$991,503,720	$0	$402,013,611	$814,943,784	$0	$330,425,884	$706,928,449	$0	$286,630,148
2011	$1,021,006,520	$0	$413,975,772	$806,916,284	$0	$327,171,066	$680,339,755	$0	$275,849,536
2012	$1,051,387,194	$0	$426,293,874	$798,967,857	$0	$323,948,309	$654,751,103	$0	$265,474,400
2013	$1,082,671,863	$0	$438,978,509	$791,097,725	$0	$320,757,297	$630,124,881	$0	$255,489,489
2014	$1,114,887,427	$32,770,597,714	$452,040,583	$783,305,118	$23,024,187,271	$317,597,718	$606,424,890	$17,825,033,861	$245,880,126
2015	$1,148,061,584	$0	$465,491,327	$775,589,270	$0	$314,469,262	$583,616,294	$0	$236,632,187
2016	$1,182,222,859	$0	$479,342,307	$767,949,426	$0	$311,371,622	$561,665,564	$0	$227,732,077
2017	$1,217,400,623	$0	$493,605,430	$760,384,838	$0	$308,304,495	$540,540,436	$0	$219,166,714
2018	$1,253,625,124	$0	$508,292,962	$752,894,763	$0	$305,267,581	$520,209,857	$0	$210,923,508
2019	$1,290,927,506	$0	$523,417,530	$745,478,469	$0	$302,260,581	$500,643,944	$0	$202,990,342
2020	$1,329,339,844	$0	$538,992,139	$738,135,227	$0	$299,283,202	$481,813,935	$0	$195,355,555
2021	$1,368,895,164	$0	$555,030,179	$730,864,320	$0	$296,335,151	$463,692,153	$0	$188,007,925
2022	$1,409,627,478	$0	$571,545,442	$723,665,034	$0	$293,416,139	$446,251,960	$0	$180,936,650
2023	$1,451,571,806	$0	$588,552,126	$716,536,663	$0	$290,525,880	$429,467,719	$0	$174,131,337
2024	$1,494,764,213	$0	$606,064,855	$709,478,509	$0	$287,664,092	$413,314,761	$0	$167,581,983
Total	$22,951,859,892	$57,940,229,150	$9,352,415,004	$15,614,161,805	$48,193,818,707	$6,377,282,947	$12,191,082,908	$42,994,665,297	$4,989,366,514

Table C-7

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Bundled System Using Conservative Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$260,651,318	$19,296,717,434	$393,580,498	$260,651,318	$19,296,717,434	$393,580,498	$260,651,318	$19,296,717,434	$393,580,498
2006	$268,407,158	$0	$357,523,084	$258,083,805	$0	$343,772,196	$250,847,811	$0	$334,133,723
2007	$276,393,777	$0	$368,161,402	$255,541,584	$0	$340,385,911	$241,413,029	$0	$321,566,426
2008	$284,618,043	$0	$379,116,269	$253,024,404	$0	$337,032,983	$232,333,104	$0	$309,471,806
2009	$293,087,027	$0	$390,397,106	$250,532,019	$0	$333,713,082	$223,594,689	$0	$297,832,083
2010	$301,808,011	$0	$402,013,611	$248,064,185	$0	$330,425,884	$215,184,940	$0	$286,630,148
2011	$310,788,493	$0	$413,975,772	$245,620,660	$0	$327,171,066	$207,091,495	$0	$275,849,536
2012	$320,036,194	$0	$426,293,874	$243,201,205	$0	$323,948,309	$199,302,457	$0	$265,474,400
2013	$329,559,067	$0	$438,978,509	$240,805,582	$0	$320,757,297	$191,806,378	$0	$255,489,489
2014	$339,365,299	$25,124,124,914	$452,040,583	$238,433,557	$17,651,876,908	$317,597,718	$184,592,237	$13,665,859,294	$245,880,126
2015	$349,463,321	$0	$465,491,327	$236,084,898	$0	$314,469,262	$177,649,432	$0	$236,632,187
2016	$359,861,816	$0	$479,342,307	$233,759,374	$0	$311,371,622	$170,967,756	$0	$227,732,077
2017	$370,569,724	$0	$493,605,430	$231,456,756	$0	$308,304,495	$164,537,389	$0	$219,166,714
2018	$381,596,253	$0	$508,292,962	$229,176,821	$0	$305,267,581	$158,348,879	$0	$210,923,508
2019	$392,950,883	$0	$523,417,530	$226,919,344	$0	$302,260,581	$152,393,127	$0	$202,990,342
2020	$404,643,377	$0	$538,992,139	$224,684,104	$0	$299,283,202	$146,661,381	$0	$195,355,555
2021	$416,683,788	$0	$555,030,179	$222,470,881	$0	$296,335,151	$141,145,215	$0	$188,007,925
2022	$429,082,469	$0	$571,545,442	$220,279,460	$0	$293,416,139	$135,836,521	$0	$180,936,650
2023	$441,850,081	$0	$588,552,126	$218,109,625	$0	$290,525,880	$130,727,495	$0	$174,131,337
2024	$454,997,600	$0	$606,064,855	$215,961,164	$0	$287,664,092	$125,810,628	$0	$167,581,983
Total	$6,986,413,700	$44,420,842,348	$9,352,415,004	$4,752,860,747	$36,948,594,342	$6,377,282,947	$3,710,895,285	$32,962,576,728	$4,989,366,514

Table C-8

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Bundled System Using Conservative Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$260,651,318	$52,856,226,015	$980,871,898	$260,651,318	$52,856,226,015	$980,871,898	$260,651,318	$52,856,226,015	$980,871,898
2006	$268,407,158	$0	$962,289,699	$258,083,805	$0	$925,278,556	$250,847,811	$0	$899,336,167
2007	$276,393,777	$0	$990,923,217	$255,541,584	$0	$916,164,217	$241,413,029	$0	$865,510,715
2008	$284,618,043	$0	$1,020,408,744	$253,024,404	$0	$907,139,658	$232,333,104	$0	$832,957,491
2009	$293,087,027	$0	$1,050,771,631	$250,532,019	$0	$898,203,994	$223,594,689	$0	$801,628,646
2010	$301,808,011	$0	$1,082,037,983	$248,064,185	$0	$889,356,349	$215,184,940	$0	$771,478,128
2011	$310,788,493	$0	$1,114,234,685	$245,620,660	$0	$880,595,857	$207,091,495	$0	$742,461,618
2012	$320,036,194	$0	$1,147,389,420	$243,201,205	$0	$871,921,659	$199,302,457	$0	$714,536,465
2013	$329,559,067	$0	$1,181,530,694	$240,805,582	$0	$863,332,905	$191,806,378	$0	$687,661,622
2014	$339,365,299	$68,818,255,200	$1,216,687,863	$238,433,557	$48,350,793,269	$854,828,754	$184,592,237	$37,432,571,109	$661,797,583
2015	$349,463,321	$0	$1,252,891,155	$236,084,898	$0	$846,408,372	$177,649,432	$0	$636,906,332
2016	$359,861,816	$0	$1,290,171,698	$233,759,374	$0	$838,070,933	$170,967,756	$0	$612,951,280
2017	$370,569,724	$0	$1,328,561,546	$231,456,756	$0	$829,815,622	$164,537,389	$0	$589,897,215
2018	$381,596,253	$0	$1,368,093,708	$229,176,821	$0	$821,641,628	$158,348,879	$0	$567,710,250
2019	$392,950,883	$0	$1,408,802,173	$226,919,344	$0	$813,548,152	$152,393,127	$0	$546,357,772
2020	$404,643,377	$0	$1,450,721,944	$224,684,104	$0	$805,534,399	$146,661,381	$0	$525,808,394
2021	$416,683,788	$0	$1,493,889,063	$222,470,881	$0	$797,599,584	$141,145,215	$0	$506,031,911
2022	$429,082,469	$0	$1,538,340,646	$220,279,460	$0	$789,742,931	$135,836,521	$0	$486,999,252
2023	$441,850,081	$0	$1,584,114,913	$218,109,625	$0	$781,963,668	$130,727,495	$0	$468,682,442
2024	$454,997,600	$0	$1,631,251,221	$215,961,164	$0	$774,261,034	$125,810,628	$0	$451,054,556
Total	$6,986,413,700	$121,674,481,215	$25,093,983,901	$4,752,860,747	$101,207,019,284	$17,086,280,169	$3,710,895,285	$90,288,797,124	$13,350,639,736

Table C-9

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Bundled System Using Medium Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$943,150,534	$19,296,717,434	$393,580,498	$943,150,534	$19,296,717,434	$393,580,498	$943,150,534	$19,296,717,434	$393,580,498
2006	$971,214,555	$0	$357,523,084	$933,860,149	$0	$343,772,196	$907,677,154	$0	$334,133,723
2007	$1,000,113,638	$0	$368,161,402	$924,661,278	$0	$340,385,911	$873,537,984	$0	$321,566,426
2008	$1,029,872,631	$0	$379,116,269	$915,553,019	$0	$337,032,983	$840,682,843	$0	$309,471,806
2009	$1,060,517,122	$0	$390,397,106	$906,534,480	$0	$333,713,082	$809,063,434	$0	$297,832,083
2010	$1,092,073,458	$0	$402,013,611	$897,604,777	$0	$330,425,884	$778,633,282	$0	$286,630,148
2011	$1,124,568,771	$0	$413,975,772	$888,763,035	$0	$327,171,066	$749,347,656	$0	$275,849,536
2012	$1,158,031,003	$0	$426,293,874	$880,008,388	$0	$323,948,309	$721,163,508	$0	$265,474,400
2013	$1,192,488,924	$0	$438,978,509	$871,339,977	$0	$320,757,297	$694,039,411	$0	$255,489,489
2014	$1,227,972,162	$25,124,124,914	$452,040,583	$862,756,953	$17,651,876,908	$317,597,718	$667,935,494	$13,665,859,294	$245,880,126
2015	$1,264,511,225	$0	$465,491,327	$854,258,475	$0	$314,469,262	$642,813,386	$0	$236,632,187
2016	$1,302,137,530	$0	$479,342,307	$845,843,710	$0	$311,371,622	$618,636,160	$0	$227,732,077
2017	$1,340,883,429	$0	$493,605,430	$837,511,833	$0	$308,304,495	$595,368,278	$0	$219,166,714
2018	$1,380,782,236	$0	$508,292,962	$829,262,029	$0	$305,267,581	$572,975,538	$0	$210,923,508
2019	$1,421,868,256	$0	$523,417,530	$821,093,489	$0	$302,260,581	$551,425,024	$0	$202,990,342
2020	$1,464,176,816	$0	$538,992,139	$813,005,412	$0	$299,283,202	$530,685,059	$0	$195,355,555
2021	$1,507,744,293	$0	$555,030,179	$804,997,005	$0	$296,335,151	$510,725,157	$0	$188,007,925
2022	$1,552,608,147	$0	$571,545,442	$797,067,484	$0	$293,416,139	$491,515,978	$0	$180,936,650
2023	$1,598,806,952	$0	$588,552,126	$789,216,072	$0	$290,525,880	$473,029,286	$0	$174,131,337
2024	$1,646,380,431	$0	$606,064,855	$781,441,999	$0	$287,664,092	$455,237,908	$0	$167,581,983
Total	$25,279,902,112	$44,420,842,348	$9,352,415,004	$17,197,930,096	$36,948,594,342	$6,377,282,947	$13,427,643,076	$32,962,576,728	$4,989,366,514

Table C-10

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Bundled System Using Medium Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$943,150,534	$52,856,226,015	$980,871,898	$943,150,534	$52,856,226,015	$980,871,898	$943,150,534	$52,856,226,015	$980,871,898
2006	$971,214,555	$0	$962,289,699	$933,860,149	$0	$925,278,556	$907,677,154	$0	$899,336,167
2007	$1,000,113,638	$0	$990,923,217	$924,661,278	$0	$916,164,217	$873,537,984	$0	$865,510,715
2008	$1,029,872,631	$0	$1,020,408,744	$915,553,019	$0	$907,139,658	$840,682,843	$0	$832,957,491
2009	$1,060,517,122	$0	$1,050,771,631	$906,534,480	$0	$898,203,994	$809,063,434	$0	$801,628,646
2010	$1,092,073,458	$0	$1,082,037,983	$897,604,777	$0	$889,356,349	$778,633,282	$0	$771,478,128
2011	$1,124,568,771	$0	$1,114,234,685	$888,763,035	$0	$880,595,857	$749,347,656	$0	$742,461,618
2012	$1,158,031,003	$0	$1,147,389,420	$880,008,388	$0	$871,921,659	$721,163,508	$0	$714,536,465
2013	$1,192,488,924	$0	$1,181,530,694	$871,339,977	$0	$863,332,905	$694,039,411	$0	$687,661,622
2014	$1,227,972,162	$68,818,255,200	$1,216,687,863	$862,756,953	$48,350,793,269	$854,828,754	$667,935,494	$37,432,571,109	$661,797,583
2015	$1,264,511,225	$0	$1,252,891,155	$854,258,475	$0	$846,408,372	$642,813,386	$0	$636,906,332
2016	$1,302,137,530	$0	$1,290,171,698	$845,843,710	$0	$838,070,933	$618,636,160	$0	$612,951,280
2017	$1,340,883,429	$0	$1,328,561,546	$837,511,833	$0	$829,815,622	$595,368,278	$0	$589,897,215
2018	$1,380,782,236	$0	$1,368,093,708	$829,262,029	$0	$821,641,628	$572,975,538	$0	$567,710,250
2019	$1,421,868,256	$0	$1,408,802,173	$821,093,489	$0	$813,548,152	$551,425,024	$0	$546,357,772
2020	$1,464,176,816	$0	$1,450,721,944	$813,005,412	$0	$805,534,399	$530,685,059	$0	$525,808,394
2021	$1,507,744,293	$0	$1,493,889,063	$804,997,005	$0	$797,599,584	$510,725,157	$0	$506,031,911
2022	$1,552,608,147	$0	$1,538,340,646	$797,067,484	$0	$789,742,931	$491,515,978	$0	$486,999,252
2023	$1,598,806,952	$0	$1,584,114,913	$789,216,072	$0	$781,963,668	$473,029,286	$0	$468,682,442
2024	$1,646,380,431	$0	$1,631,251,221	$781,441,999	$0	$774,261,034	$455,237,908	$0	$451,054,556
Total	$25,279,902,112	$121,674,481,215	$25,093,983,901	$17,197,930,096	$101,207,019,284	$17,086,280,169	$13,427,643,076	$90,288,797,124	$13,350,639,736

Table C-11

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Bundled System Using Aggressive Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$1,006,610,696	$19,296,717,434	$393,580,498	$1,006,610,696	$19,296,717,434	$393,580,498	$1,006,610,696	$19,296,717,434	$393,580,498
2006	$1,036,563,013	$0	$357,523,084	$996,695,205	$0	$343,772,196	$968,750,479	$0	$334,133,723
2007	$1,067,406,579	$0	$368,161,402	$986,877,385	$0	$340,385,911	$932,314,245	$0	$321,566,426
2008	$1,099,167,915	$0	$379,116,269	$977,156,274	$0	$337,032,983	$897,248,436	$0	$309,471,806
2009	$1,131,874,329	$0	$390,397,106	$967,530,920	$0	$333,713,082	$863,501,506	$0	$297,832,083
2010	$1,165,553,942	$0	$402,013,611	$958,000,380	$0	$330,425,884	$831,023,852	$0	$286,630,148
2011	$1,200,235,713	$0	$413,975,772	$948,563,718	$0	$327,171,066	$799,767,734	$0	$275,849,536
2012	$1,235,949,461	$0	$426,293,874	$939,220,012	$0	$323,948,309	$769,687,208	$0	$265,474,400
2013	$1,272,725,893	$0	$438,978,509	$929,968,344	$0	$320,757,297	$740,738,058	$0	$255,489,489
2014	$1,310,596,631	$25,124,124,914	$452,040,583	$920,807,809	$17,651,876,908	$317,597,718	$712,877,730	$13,665,859,294	$245,880,126
2015	$1,349,594,236	$0	$465,491,327	$911,737,508	$0	$314,469,262	$686,065,274	$0	$236,632,187
2016	$1,389,752,238	$0	$479,342,307	$902,756,553	$0	$311,371,622	$660,261,277	$0	$227,732,077
2017	$1,431,105,166	$0	$493,605,430	$893,864,064	$0	$308,304,495	$635,427,809	$0	$219,166,714
2018	$1,473,688,576	$0	$508,292,962	$885,059,170	$0	$305,267,581	$611,528,366	$0	$210,923,508
2019	$1,517,539,081	$0	$523,417,530	$876,341,006	$0	$302,260,581	$588,527,819	$0	$202,990,342
2020	$1,562,694,385	$0	$538,992,139	$867,708,720	$0	$299,283,202	$566,392,360	$0	$195,355,555
2021	$1,609,193,312	$0	$555,030,179	$859,161,466	$0	$296,335,151	$545,089,449	$0	$188,007,925
2022	$1,657,075,844	$0	$571,545,442	$850,698,405	$0	$293,416,139	$524,587,775	$0	$180,936,650
2023	$1,706,383,149	$0	$588,552,126	$842,318,708	$0	$290,525,880	$504,857,201	$0	$174,131,337
2024	$1,757,157,624	$0	$606,064,855	$834,021,554	$0	$287,664,092	$485,868,725	$0	$167,581,983
Total	$26,980,867,783	$44,420,842,348	$9,352,415,004	$18,355,097,895	$36,948,594,342	$6,377,282,947	$14,331,126,001	$32,962,576,728	$4,989,366,514

Table C-12

Benefits and Costs for Volvo FOT ($2005)
Scenario: All Trucks with Bundled System Using Aggressive Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$1,006,610,696	$52,856,226,015	$980,871,898	$1,006,610,696	$52,856,226,015	$980,871,898	$1,006,610,696	$52,856,226,015	$980,871,898
2006	$1,036,563,013	$0	$962,289,699	$996,695,205	$0	$925,278,556	$968,750,479	$0	$899,336,167
2007	$1,067,406,579	$0	$990,923,217	$986,877,385	$0	$916,164,217	$932,314,245	$0	$865,510,715
2008	$1,099,167,915	$0	$1,020,408,744	$977,156,274	$0	$907,139,658	$897,248,436	$0	$832,957,491
2009	$1,131,874,329	$0	$1,050,771,631	$967,530,920	$0	$898,203,994	$863,501,506	$0	$801,628,646
2010	$1,165,553,942	$0	$1,082,037,983	$958,000,380	$0	$889,356,349	$831,023,852	$0	$771,478,128
2011	$1,200,235,713	$0	$1,114,234,685	$948,563,718	$0	$880,595,857	$799,767,734	$0	$742,461,618
2012	$1,235,949,461	$0	$1,147,389,420	$939,220,012	$0	$871,921,659	$769,687,208	$0	$714,536,465
2013	$1,272,725,893	$0	$1,181,530,694	$929,968,344	$0	$863,332,905	$740,738,058	$0	$687,661,622
2014	$1,310,596,631	$68,818,255,200	$1,216,687,863	$920,807,809	$48,350,793,269	$854,828,754	$712,877,730	$37,432,571,109	$661,797,583
2015	$1,349,594,236	$0	$1,252,891,155	$911,737,508	$0	$846,408,372	$686,065,274	$0	$636,906,332
2016	$1,389,752,238	$0	$1,290,171,698	$902,756,553	$0	$838,070,933	$660,261,277	$0	$612,951,280
2017	$1,431,105,166	$0	$1,328,561,546	$893,864,064	$0	$829,815,622	$635,427,809	$0	$589,897,215
2018	$1,473,688,576	$0	$1,368,093,708	$885,059,170	$0	$821,641,628	$611,528,366	$0	$567,710,250
2019	$1,517,539,081	$0	$1,408,802,173	$876,341,006	$0	$813,548,152	$588,527,819	$0	$546,357,772
2020	$1,562,694,385	$0	$1,450,721,944	$867,708,720	$0	$805,534,399	$566,392,360	$0	$525,808,394
2021	$1,609,193,312	$0	$1,493,889,063	$859,161,466	$0	$797,599,584	$545,089,449	$0	$506,031,911
2022	$1,657,075,844	$0	$1,538,340,646	$850,698,405	$0	$789,742,931	$524,587,775	$0	$486,999,252
2023	$1,706,383,149	$0	$1,584,114,913	$842,318,708	$0	$781,963,668	$504,857,201	$0	$468,682,442
2024	$1,757,157,624	$0	$1,631,251,221	$834,021,554	$0	$774,261,034	$485,868,725	$0	$451,054,556
Total	$26,980,867,783	$121,674,481,215	$25,093,983,901	$18,355,097,895	$101,207,019,284	$17,086,280,169	$14,331,126,001	$90,288,797,124	$13,350,639,736

Table C-13

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Effect of CWS Only Using Conservative Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	-$21,573,046	$3,726,844,511	$87,415,661	-$21,573,046	$3,726,844,511	$87,415,661	-$21,573,046	$3,726,844,511	$87,415,661
2006	-$22,214,965	$0	$79,407,178	-$21,360,544	$0	$76,353,056	-$20,761,650	$0	$74,212,316
2007	-$22,875,985	$0	$81,769,988	-$21,150,134	$0	$75,600,950	-$19,980,771	$0	$71,421,074
2008	-$23,556,674	$0	$84,203,104	-$20,941,798	$0	$74,856,252	-$19,229,263	$0	$68,734,815
2009	-$24,257,617	$0	$86,708,618	-$20,735,513	$0	$74,118,890	-$18,506,020	$0	$66,149,590
2010	-$24,979,418	$0	$89,288,686	-$20,531,261	$0	$73,388,792	-$17,809,980	$0	$63,661,599
2011	-$25,722,696	$0	$91,945,526	-$20,329,020	$0	$72,665,885	-$17,140,118	$0	$61,267,186
2012	-$26,488,090	$0	$94,681,421	-$20,128,772	$0	$71,950,099	-$16,495,451	$0	$58,962,831
2013	-$27,276,259	$0	$97,498,725	-$19,930,496	$0	$71,241,363	-$15,875,031	$0	$56,745,146
2014	-$28,087,881	$4,852,312,698	$100,399,859	-$19,734,173	$3,409,170,539	$70,539,609	-$15,277,946	$2,639,336,606	$54,610,871
2015	-$28,923,653	$0	$103,387,318	-$19,539,784	$0	$69,844,768	-$14,703,319	$0	$52,556,870
2016	-$29,784,294	$0	$106,463,671	-$19,347,310	$0	$69,156,771	-$14,150,304	$0	$50,580,123
2017	-$30,670,544	$0	$109,631,563	-$19,156,731	$0	$68,475,551	-$13,618,088	$0	$48,677,725
2018	-$31,583,165	$0	$112,893,717	-$18,968,030	$0	$67,801,041	-$13,105,891	$0	$46,846,879
2019	-$32,522,941	$0	$116,252,939	-$18,781,188	$0	$67,133,175	-$12,612,957	$0	$45,084,894
2020	-$33,490,681	$0	$119,712,116	-$18,596,187	$0	$66,471,889	-$12,138,564	$0	$43,389,180
2021	-$34,487,217	$0	$123,274,223	-$18,413,007	$0	$65,817,116	-$11,682,014	$0	$41,757,244
2022	-$35,513,405	$0	$126,942,323	-$18,231,632	$0	$65,168,793	-$11,242,635	$0	$40,186,689
2023	-$36,570,129	$0	$130,719,570	-$18,052,044	$0	$64,526,856	-$10,819,781	$0	$38,675,204
2024	-$37,658,295	$0	$134,609,211	-$17,874,224	$0	$63,891,242	-$10,412,832	$0	$37,220,568
Total	-$578,236,958	$8,579,157,210	$2,077,205,418	-$393,374,893	$7,136,015,050	$1,416,417,758	-$307,135,663	$6,366,181,118	$1,108,156,466

Table C-14

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Effect of CWS Only Using Conservative Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	-$21,573,046	$5,590,266,767	$87,415,661	-$21,573,046	$5,590,266,767	$87,415,661	-$21,573,046	$5,590,266,767	$87,415,661
2006	-$22,214,965	$0	$79,407,178	-$21,360,544	$0	$76,353,056	-$20,761,650	$0	$74,212,316
2007	-$22,875,985	$0	$81,769,988	-$21,150,134	$0	$75,600,950	-$19,980,771	$0	$71,421,074
2008	-$23,556,674	$0	$84,203,104	-$20,941,798	$0	$74,856,252	-$19,229,263	$0	$68,734,815
2009	-$24,257,617	$0	$86,708,618	-$20,735,513	$0	$74,118,890	-$18,506,020	$0	$66,149,590
2010	-$24,979,418	$0	$89,288,686	-$20,531,261	$0	$73,388,792	-$17,809,980	$0	$63,661,599
2011	-$25,722,696	$0	$91,945,526	-$20,329,020	$0	$72,665,885	-$17,140,118	$0	$61,267,186
2012	-$26,488,090	$0	$94,681,421	-$20,128,772	$0	$71,950,099	-$16,495,451	$0	$58,962,831
2013	-$27,276,259	$0	$97,498,725	-$19,930,496	$0	$71,241,363	-$15,875,031	$0	$56,745,146
2014	-$28,087,881	$7,278,469,047	$100,399,859	-$19,734,173	$5,113,755,808	$70,539,609	-$15,277,946	$3,959,004,909	$54,610,871
2015	-$28,923,653	$0	$103,387,318	-$19,539,784	$0	$69,844,768	-$14,703,319	$0	$52,556,870
2016	-$29,784,294	$0	$106,463,671	-$19,347,310	$0	$69,156,771	-$14,150,304	$0	$50,580,123
2017	-$30,670,544	$0	$109,631,563	-$19,156,731	$0	$68,475,551	-$13,618,088	$0	$48,677,725
2018	-$31,583,165	$0	$112,893,717	-$18,968,030	$0	$67,801,041	-$13,105,891	$0	$46,846,879
2019	-$32,522,941	$0	$116,252,939	-$18,781,188	$0	$67,133,175	-$12,612,957	$0	$45,084,894
2020	-$33,490,681	$0	$119,712,116	-$18,596,187	$0	$66,471,889	-$12,138,564	$0	$43,389,180
2021	-$34,487,217	$0	$123,274,223	-$18,413,007	$0	$65,817,116	-$11,682,014	$0	$41,757,244
2022	-$35,513,405	$0	$126,942,323	-$18,231,632	$0	$65,168,793	-$11,242,635	$0	$40,186,689
2023	-$36,570,129	$0	$130,719,570	-$18,052,044	$0	$64,526,856	-$10,819,781	$0	$38,675,204
2024	-$37,658,295	$0	$134,609,211	-$17,874,224	$0	$63,891,242	-$10,412,832	$0	$37,220,568
Total	-$578,236,958	$12,868,735,815	$2,077,205,418	-$393,374,893	$10,704,022,575	$1,416,417,758	-$307,135,663	$9,549,271,676	$1,108,156,466

Table C-15

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Effect of CWS Only Using Medium Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$504,908,691	$3,726,844,511	$87,415,661	$504,908,691	$3,726,844,511	$87,415,661	$504,908,691	$3,726,844,511	$87,415,661
2006	$519,932,558	$0	$79,407,178	$499,935,151	$0	$76,353,056	$485,918,278	$0	$74,212,316
2007	$535,403,469	$0	$81,769,988	$495,010,604	$0	$75,600,950	$467,642,125	$0	$71,421,074
2008	$551,334,727	$0	$84,203,104	$490,134,564	$0	$74,856,252	$450,053,367	$0	$68,734,815
2009	$567,740,029	$0	$86,708,618	$485,306,556	$0	$74,118,890	$433,126,150	$0	$66,149,590
2010	$584,633,481	$0	$89,288,686	$480,526,105	$0	$73,388,792	$416,835,592	$0	$63,661,599
2011	$602,029,608	$0	$91,945,526	$475,792,744	$0	$72,665,885	$401,157,748	$0	$61,267,186
2012	$619,943,367	$0	$94,681,421	$471,106,008	$0	$71,950,099	$386,069,572	$0	$58,962,831
2013	$638,390,161	$0	$97,498,725	$466,465,438	$0	$71,241,363	$371,548,886	$0	$56,745,146
2014	$657,385,851	$4,852,312,698	$100,399,859	$461,870,579	$3,409,170,539	$70,539,609	$357,574,346	$2,639,336,606	$54,610,871
2015	$676,946,769	$0	$103,387,318	$457,320,981	$0	$69,844,768	$344,125,411	$0	$52,556,870
2016	$697,089,734	$0	$106,463,671	$452,816,199	$0	$69,156,771	$331,182,311	$0	$50,580,123
2017	$717,832,066	$0	$109,631,563	$448,355,791	$0	$68,475,551	$318,726,022	$0	$48,677,725
2018	$739,191,598	$0	$112,893,717	$443,939,319	$0	$67,801,041	$306,738,233	$0	$46,846,879
2019	$761,186,697	$0	$116,252,939	$439,566,351	$0	$67,133,175	$295,201,325	$0	$45,084,894
2020	$783,836,272	$0	$119,712,116	$435,236,458	$0	$66,471,889	$284,098,337	$0	$43,389,180
2021	$807,159,800	$0	$123,274,223	$430,949,216	$0	$65,817,116	$273,412,950	$0	$41,757,244
2022	$831,177,334	$0	$126,942,323	$426,704,206	$0	$65,168,793	$263,129,458	$0	$40,186,689
2023	$855,909,524	$0	$130,719,570	$422,501,010	$0	$64,526,856	$253,232,744	$0	$38,675,204
2024	$881,377,636	$0	$134,609,211	$418,339,217	$0	$63,891,242	$243,708,261	$0	$37,220,568
Total	$13,533,409,371	$8,579,157,210	$2,077,205,418	$9,206,785,188	$7,136,015,050	$1,416,417,758	$7,188,389,805	$6,366,181,118	$1,108,156,466

Table C-16

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Effect of CWS Only Using Medium Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$504,908,691	$5,590,266,767	$87,415,661	$504,908,691	$5,590,266,767	$87,415,661	$504,908,691	$5,590,266,767	$87,415,661
2006	$519,932,558	$0	$79,407,178	$499,935,151	$0	$76,353,056	$485,918,278	$0	$74,212,316
2007	$535,403,469	$0	$81,769,988	$495,010,604	$0	$75,600,950	$467,642,125	$0	$71,421,074
2008	$551,334,727	$0	$84,203,104	$490,134,564	$0	$74,856,252	$450,053,367	$0	$68,734,815
2009	$567,740,029	$0	$86,708,618	$485,306,556	$0	$74,118,890	$433,126,150	$0	$66,149,590
2010	$584,633,481	$0	$89,288,686	$480,526,105	$0	$73,388,792	$416,835,592	$0	$63,661,599
2011	$602,029,608	$0	$91,945,526	$475,792,744	$0	$72,665,885	$401,157,748	$0	$61,267,186
2012	$619,943,367	$0	$94,681,421	$471,106,008	$0	$71,950,099	$386,069,572	$0	$58,962,831
2013	$638,390,161	$0	$97,498,725	$466,465,438	$0	$71,241,363	$371,548,886	$0	$56,745,146
2014	$657,385,851	$7,278,469,047	$100,399,859	$461,870,579	$5,113,755,808	$70,539,609	$357,574,346	$3,959,004,909	$54,610,871
2015	$676,946,769	$0	$103,387,318	$457,320,981	$0	$69,844,768	$344,125,411	$0	$52,556,870
2016	$697,089,734	$0	$106,463,671	$452,816,199	$0	$69,156,771	$331,182,311	$0	$50,580,123
2017	$717,832,066	$0	$109,631,563	$448,355,791	$0	$68,475,551	$318,726,022	$0	$48,677,725
2018	$739,191,598	$0	$112,893,717	$443,939,319	$0	$67,801,041	$306,738,233	$0	$46,846,879
2019	$761,186,697	$0	$116,252,939	$439,566,351	$0	$67,133,175	$295,201,325	$0	$45,084,894
2020	$783,836,272	$0	$119,712,116	$435,236,458	$0	$66,471,889	$284,098,337	$0	$43,389,180
2021	$807,159,800	$0	$123,274,223	$430,949,216	$0	$65,817,116	$273,412,950	$0	$41,757,244
2022	$831,177,334	$0	$126,942,323	$426,704,206	$0	$65,168,793	$263,129,458	$0	$40,186,689
2023	$855,909,524	$0	$130,719,570	$422,501,010	$0	$64,526,856	$253,232,744	$0	$38,675,204
2024	$881,377,636	$0	$134,609,211	$418,339,217	$0	$63,891,242	$243,708,261	$0	$37,220,568
Total	$13,533,409,371	$12,868,735,815	$2,077,205,418	$9,206,785,188	$10,704,022,575	$1,416,417,758	$7,188,389,805	$9,549,271,676	$1,108,156,466

Table C-17

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Effect of CWS Only Using Aggressive Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$561,300,859	$3,726,844,511	$87,415,661	$561,300,859	$3,726,844,511	$87,415,661	$561,300,859	$3,726,844,511	$87,415,661
2006	$578,002,709	$0	$79,407,178	$555,771,836	$0	$76,353,056	$540,189,448	$0	$74,212,316
2007	$595,201,533	$0	$81,769,988	$550,297,276	$0	$75,600,950	$519,872,070	$0	$71,421,074
2008	$612,912,119	$0	$84,203,104	$544,876,642	$0	$74,856,252	$500,318,862	$0	$68,734,815
2009	$631,149,694	$0	$86,708,618	$539,509,404	$0	$74,118,890	$481,501,080	$0	$66,149,590
2010	$649,929,940	$0	$89,288,686	$534,195,035	$0	$73,388,792	$463,391,065	$0	$63,661,599
2011	$669,269,003	$0	$91,945,526	$528,933,014	$0	$72,665,885	$445,962,196	$0	$61,267,186
2012	$689,183,511	$0	$94,681,421	$523,722,827	$0	$71,950,099	$429,188,854	$0	$58,962,831
2013	$709,690,588	$0	$97,498,725	$518,563,961	$0	$71,241,363	$413,046,384	$0	$56,745,146
2014	$730,807,866	$4,852,312,698	$100,399,859	$513,455,913	$3,409,170,539	$70,539,609	$397,511,058	$2,639,336,606	$54,610,871
2015	$752,553,501	$0	$103,387,318	$508,398,181	$0	$69,844,768	$382,560,040	$0	$52,556,870
2016	$774,946,191	$0	$106,463,671	$503,390,269	$0	$69,156,771	$368,171,353	$0	$50,580,123
2017	$798,005,189	$0	$109,631,563	$498,431,687	$0	$68,475,551	$354,323,848	$0	$48,677,725
2018	$821,750,322	$0	$112,893,717	$493,521,949	$0	$67,801,041	$340,997,169	$0	$46,846,879
2019	$846,202,005	$0	$116,252,939	$488,660,573	$0	$67,133,175	$328,171,727	$0	$45,084,894
2020	$871,381,264	$0	$119,712,116	$483,847,084	$0	$66,471,889	$315,828,671	$0	$43,389,180
2021	$897,309,746	$0	$123,274,223	$479,081,010	$0	$65,817,116	$303,949,856	$0	$41,757,244
2022	$924,009,747	$0	$126,942,323	$474,361,883	$0	$65,168,793	$292,517,822	$0	$40,186,689
2023	$951,504,222	$0	$130,719,570	$469,689,241	$0	$64,526,856	$281,515,766	$0	$38,675,204
2024	$979,816,813	$0	$134,609,211	$465,062,627	$0	$63,891,242	$270,927,513	$0	$37,220,568
Total	$15,044,926,823	$8,579,157,210	$2,077,205,418	$10,235,071,270	$7,136,015,050	$1,416,417,758	$7,991,245,638	$6,366,181,118	$1,108,156,466

Table C-18

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Effect of CWS Only Using Aggressive Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$561,300,859	$5,590,266,767	$87,415,661	$561,300,859	$5,590,266,767	$87,415,661	$561,300,859	$5,590,266,767	$87,415,661
2006	$578,002,709	$0	$79,407,178	$555,771,836	$0	$76,353,056	$540,189,448	$0	$74,212,316
2007	$595,201,533	$0	$81,769,988	$550,297,276	$0	$75,600,950	$519,872,070	$0	$71,421,074
2008	$612,912,119	$0	$84,203,104	$544,876,642	$0	$74,856,252	$500,318,862	$0	$68,734,815
2009	$631,149,694	$0	$86,708,618	$539,509,404	$0	$74,118,890	$481,501,080	$0	$66,149,590
2010	$649,929,940	$0	$89,288,686	$534,195,035	$0	$73,388,792	$463,391,065	$0	$63,661,599
2011	$669,269,003	$0	$91,945,526	$528,933,014	$0	$72,665,885	$445,962,196	$0	$61,267,186
2012	$689,183,511	$0	$94,681,421	$523,722,827	$0	$71,950,099	$429,188,854	$0	$58,962,831
2013	$709,690,588	$0	$97,498,725	$518,563,961	$0	$71,241,363	$413,046,384	$0	$56,745,146
2014	$730,807,866	$7,278,469,047	$100,399,859	$513,455,913	$5,113,755,808	$70,539,609	$397,511,058	$3,959,004,909	$54,610,871
2015	$752,553,501	$0	$103,387,318	$508,398,181	$0	$69,844,768	$382,560,040	$0	$52,556,870
2016	$774,946,191	$0	$106,463,671	$503,390,269	$0	$69,156,771	$368,171,353	$0	$50,580,123
2017	$798,005,189	$0	$109,631,563	$498,431,687	$0	$68,475,551	$354,323,848	$0	$48,677,725
2018	$821,750,322	$0	$112,893,717	$493,521,949	$0	$67,801,041	$340,997,169	$0	$46,846,879
2019	$846,202,005	$0	$116,252,939	$488,660,573	$0	$67,133,175	$328,171,727	$0	$45,084,894
2020	$871,381,264	$0	$119,712,116	$483,847,084	$0	$66,471,889	$315,828,671	$0	$43,389,180
2021	$897,309,746	$0	$123,274,223	$479,081,010	$0	$65,817,116	$303,949,856	$0	$41,757,244
2022	$924,009,747	$0	$126,942,323	$474,361,883	$0	$65,168,793	$292,517,822	$0	$40,186,689
2023	$951,504,222	$0	$130,719,570	$469,689,241	$0	$64,526,856	$281,515,766	$0	$38,675,204
2024	$979,816,813	$0	$134,609,211	$465,062,627	$0	$63,891,242	$270,927,513	$0	$37,220,568
Total	$15,044,926,823	$12,868,735,815	$2,077,205,418	$10,235,071,270	$10,704,022,575	$1,416,417,758	$7,991,245,638	$9,549,271,676	$1,108,156,466

Table C-19

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Bundled System Using Conservative Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$209,068,178	$4,285,871,188	$87,415,661	$209,068,178	$4,285,871,188	$87,415,661	$209,068,178	$4,285,871,188	$87,415,661
2006	$215,289,129	$0	$79,407,178	$207,008,778	$0	$76,353,056	$201,204,794	$0	$74,212,316
2007	$221,695,189	$0	$81,769,988	$204,969,664	$0	$75,600,950	$193,637,164	$0	$71,421,074
2008	$228,291,865	$0	$84,203,104	$202,950,637	$0	$74,856,252	$186,354,165	$0	$68,734,815
2009	$235,084,829	$0	$86,708,618	$200,951,497	$0	$74,118,890	$179,345,091	$0	$66,149,590
2010	$242,079,922	$0	$89,288,686	$198,972,050	$0	$73,388,792	$172,599,639	$0	$63,661,599
2011	$249,283,158	$0	$91,945,526	$197,012,101	$0	$72,665,885	$166,107,894	$0	$61,267,186
2012	$256,700,731	$0	$94,681,421	$195,071,458	$0	$71,950,099	$159,860,314	$0	$58,962,831
2013	$264,339,018	$0	$97,498,725	$193,149,932	$0	$71,241,363	$153,847,715	$0	$56,745,146
2014	$272,204,588	$5,580,159,603	$100,399,859	$191,247,333	$3,920,546,120	$70,539,609	$148,061,260	$3,035,237,097	$54,610,871
2015	$280,304,202	$0	$103,387,318	$189,363,475	$0	$69,844,768	$142,492,443	$0	$52,556,870
2016	$288,644,825	$0	$106,463,671	$187,498,174	$0	$69,156,771	$137,133,077	$0	$50,580,123
2017	$297,233,628	$0	$109,631,563	$185,651,247	$0	$68,475,551	$131,975,286	$0	$48,677,725
2018	$306,077,997	$0	$112,893,717	$183,822,513	$0	$67,801,041	$127,011,487	$0	$46,846,879
2019	$315,185,535	$0	$116,252,939	$182,011,793	$0	$67,133,175	$122,234,384	$0	$45,084,894
2020	$324,564,073	$0	$119,712,116	$180,218,909	$0	$66,471,889	$117,636,956	$0	$43,389,180
2021	$334,221,676	$0	$123,274,223	$178,443,685	$0	$65,817,116	$113,212,445	$0	$41,757,244
2022	$344,166,646	$0	$126,942,323	$176,685,948	$0	$65,168,793	$108,954,346	$0	$40,186,689
2023	$354,407,535	$0	$130,719,570	$174,945,526	$0	$64,526,856	$104,856,401	$0	$38,675,204
2024	$364,953,148	$0	$134,609,211	$173,222,247	$0	$63,891,242	$100,912,587	$0	$37,220,568
Total	$5,603,795,872	$9,866,030,791	$2,077,205,418	$3,812,265,144	$8,206,417,308	$1,416,417,758	$2,976,505,625	$7,321,108,285	$1,108,156,466

Table C-20

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Bundled System Using Conservative Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$209,068,178	$11,739,560,211	$217,855,219	$209,068,178	$11,739,560,211	$217,855,219	$209,068,178	$11,739,560,211	$217,855,219
2006	$215,289,129	$0	$213,728,045	$207,008,778	$0	$205,507,736	$201,204,794	$0	$199,745,837
2007	$221,695,189	$0	$220,087,654	$204,969,664	$0	$203,483,408	$193,637,164	$0	$192,233,080
2008	$228,291,865	$0	$226,636,497	$202,950,637	$0	$201,479,020	$186,354,165	$0	$185,002,891
2009	$235,084,829	$0	$233,380,204	$200,951,497	$0	$199,494,377	$179,345,091	$0	$178,044,640
2010	$242,079,922	$0	$240,324,575	$198,972,050	$0	$197,529,283	$172,599,639	$0	$171,348,101
2011	$249,283,158	$0	$247,475,580	$197,012,101	$0	$195,583,545	$166,107,894	$0	$164,903,428
2012	$256,700,731	$0	$254,839,367	$195,071,458	$0	$193,656,975	$159,860,314	$0	$158,701,150
2013	$264,339,018	$0	$262,422,268	$193,149,932	$0	$191,749,381	$153,847,715	$0	$152,732,149
2014	$272,204,588	$15,284,785,000	$270,230,804	$191,247,333	$10,738,887,197	$189,860,578	$148,061,260	$8,313,910,309	$146,987,652
2015	$280,304,202	$0	$278,271,686	$189,363,475	$0	$187,990,381	$142,492,443	$0	$141,459,215
2016	$288,644,825	$0	$286,551,831	$187,498,174	$0	$186,138,605	$137,133,077	$0	$136,138,711
2017	$297,233,628	$0	$295,078,356	$185,651,247	$0	$184,305,070	$131,975,286	$0	$131,018,319
2018	$306,077,997	$0	$303,858,593	$183,822,513	$0	$182,489,597	$127,011,487	$0	$126,090,513
2019	$315,185,535	$0	$312,900,091	$182,011,793	$0	$180,692,006	$122,234,384	$0	$121,348,050
2020	$324,564,073	$0	$322,210,625	$180,218,909	$0	$178,912,122	$117,636,956	$0	$116,783,958
2021	$334,221,676	$0	$331,798,199	$178,443,685	$0	$177,149,771	$113,212,445	$0	$112,391,529
2022	$344,166,646	$0	$341,671,057	$176,685,948	$0	$175,404,780	$108,954,346	$0	$108,164,307
2023	$354,407,535	$0	$351,837,689	$174,945,526	$0	$173,676,977	$104,856,401	$0	$104,096,077
2024	$364,953,148	$0	$362,306,835	$173,222,247	$0	$171,966,194	$100,912,587	$0	$100,180,859
Total	$5,603,795,872	$27,024,345,211	$5,573,465,174	$3,812,265,144	$22,478,447,408	$3,794,925,025	$2,976,505,625	$20,053,470,521	$2,965,225,686

Table C-21

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Bundled System Using Medium Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$661,508,199	$4,285,871,188	$87,415,661	$661,508,199	$4,285,871,188	$87,415,661	$661,508,199	$4,285,871,188	$87,415,661
2006	$681,191,780	$0	$79,407,178	$654,992,096	$0	$76,353,056	$636,627,832	$0	$74,212,316
2007	$701,461,058	$0	$81,769,988	$648,540,180	$0	$75,600,950	$612,683,255	$0	$71,421,074
2008	$722,333,461	$0	$84,203,104	$642,151,817	$0	$74,856,252	$589,639,271	$0	$68,734,815
2009	$743,826,935	$0	$86,708,618	$635,826,382	$0	$74,118,890	$567,462,008	$0	$66,149,590
2010	$765,959,961	$0	$89,288,686	$629,563,255	$0	$73,388,792	$546,118,866	$0	$63,661,599
2011	$788,751,568	$0	$91,945,526	$623,361,821	$0	$72,665,885	$525,578,474	$0	$61,267,186
2012	$812,221,354	$0	$94,681,421	$617,221,475	$0	$71,950,099	$505,810,638	$0	$58,962,831
2013	$836,389,497	$0	$97,498,725	$611,141,613	$0	$71,241,363	$486,786,302	$0	$56,745,146
2014	$861,276,778	$5,580,159,603	$100,399,859	$605,121,640	$3,920,546,120	$70,539,609	$468,477,501	$3,035,237,097	$54,610,871
2015	$886,904,596	$0	$103,387,318	$599,160,966	$0	$69,844,768	$450,857,323	$0	$52,556,870
2016	$913,294,984	$0	$106,463,671	$593,259,007	$0	$69,156,771	$433,899,868	$0	$50,580,123
2017	$940,470,636	$0	$109,631,563	$587,415,184	$0	$68,475,551	$417,580,209	$0	$48,677,725
2018	$968,454,915	$0	$112,893,717	$581,628,925	$0	$67,801,041	$401,874,359	$0	$46,846,879
2019	$997,271,883	$0	$116,252,939	$575,899,663	$0	$67,133,175	$386,759,230	$0	$45,084,894
2020	$1,026,946,318	$0	$119,712,116	$570,226,837	$0	$66,471,889	$372,212,605	$0	$43,389,180
2021	$1,057,503,734	$0	$123,274,223	$564,609,890	$0	$65,817,116	$358,213,102	$0	$41,757,244
2022	$1,088,970,405	$0	$126,942,323	$559,048,271	$0	$65,168,793	$344,740,142	$0	$40,186,689
2023	$1,121,373,386	$0	$130,719,570	$553,541,437	$0	$64,526,856	$331,773,922	$0	$38,675,204
2024	$1,154,740,537	$0	$134,609,211	$548,088,848	$0	$63,891,242	$319,295,381	$0	$37,220,568
Total	$17,730,851,985	$9,866,030,791	$2,077,205,418	$12,062,307,505	$8,206,417,308	$1,416,417,758	$9,417,898,488	$7,321,108,285	$1,108,156,466

Table C-22

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Bundled System Using Medium Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$661,508,199	$11,739,560,211	$217,855,219	$661,508,199	$11,739,560,211	$217,855,219	$661,508,199	$11,739,560,211	$217,855,219
2006	$681,191,780	$0	$213,728,045	$654,992,096	$0	$205,507,736	$636,627,832	$0	$199,745,837
2007	$701,461,058	$0	$220,087,654	$648,540,180	$0	$203,483,408	$612,683,255	$0	$192,233,080
2008	$722,333,461	$0	$226,636,497	$642,151,817	$0	$201,479,020	$589,639,271	$0	$185,002,891
2009	$743,826,935	$0	$233,380,204	$635,826,382	$0	$199,494,377	$567,462,008	$0	$178,044,640
2010	$765,959,961	$0	$240,324,575	$629,563,255	$0	$197,529,283	$546,118,866	$0	$171,348,101
2011	$788,751,568	$0	$247,475,580	$623,361,821	$0	$195,583,545	$525,578,474	$0	$164,903,428
2012	$812,221,354	$0	$254,839,367	$617,221,475	$0	$193,656,975	$505,810,638	$0	$158,701,150
2013	$836,389,497	$0	$262,422,268	$611,141,613	$0	$191,749,381	$486,786,302	$0	$152,732,149
2014	$861,276,778	$15,284,785,000	$270,230,804	$605,121,640	$10,738,887,197	$189,860,578	$468,477,501	$8,313,910,309	$146,987,652
2015	$886,904,596	$0	$278,271,686	$599,160,966	$0	$187,990,381	$450,857,323	$0	$141,459,215
2016	$913,294,984	$0	$286,551,831	$593,259,007	$0	$186,138,605	$433,899,868	$0	$136,138,711
2017	$940,470,636	$0	$295,078,356	$587,415,184	$0	$184,305,070	$417,580,209	$0	$131,018,319
2018	$968,454,915	$0	$303,858,593	$581,628,925	$0	$182,489,597	$401,874,359	$0	$126,090,513
2019	$997,271,883	$0	$312,900,091	$575,899,663	$0	$180,692,006	$386,759,230	$0	$121,348,050
2020	$1,026,946,318	$0	$322,210,625	$570,226,837	$0	$178,912,122	$372,212,605	$0	$116,783,958
2021	$1,057,503,734	$0	$331,798,199	$564,609,890	$0	$177,149,771	$358,213,102	$0	$112,391,529
2022	$1,088,970,405	$0	$341,671,057	$559,048,271	$0	$175,404,780	$344,740,142	$0	$108,164,307
2023	$1,121,373,386	$0	$351,837,689	$553,541,437	$0	$173,676,977	$331,773,922	$0	$104,096,077
2024	$1,154,740,537	$0	$362,306,835	$548,088,848	$0	$171,966,194	$319,295,381	$0	$100,180,859
Total	$17,730,851,985	$27,024,345,211	$5,573,465,174	$12,062,307,505	$22,478,447,408	$3,794,925,025	$9,417,898,488	$20,053,470,521	$2,965,225,686

Table C-23

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Bundled System Using Aggressive Conflict Classes - Low Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$696,223,216	$4,285,871,188	$87,415,661	$696,223,216	$4,285,871,188	$87,415,661	$696,223,216	$4,285,871,188	$87,415,661
2006	$716,939,764	$0	$79,407,178	$689,365,157	$0	$76,353,056	$670,037,162	$0	$74,212,316
2007	$738,272,745	$0	$81,769,988	$682,574,653	$0	$75,600,950	$644,836,008	$0	$71,421,074
2008	$760,240,502	$0	$84,203,104	$675,851,038	$0	$74,856,252	$620,582,708	$0	$68,734,815
2009	$782,861,924	$0	$86,708,618	$669,193,653	$0	$74,118,890	$597,241,613	$0	$66,149,590
2010	$806,156,459	$0	$89,288,686	$662,601,846	$0	$73,388,792	$574,778,414	$0	$63,661,599
2011	$830,144,138	$0	$91,945,526	$656,074,970	$0	$72,665,885	$553,160,091	$0	$61,267,186
2012	$854,845,584	$0	$94,681,421	$649,612,387	$0	$71,950,099	$532,354,867	$0	$58,962,831
2013	$880,282,038	$0	$97,498,725	$643,213,463	$0	$71,241,363	$512,332,161	$0	$56,745,146
2014	$906,475,368	$5,580,159,603	$100,399,859	$636,877,570	$3,920,546,120	$70,539,609	$493,062,540	$3,035,237,097	$54,610,871
2015	$933,448,098	$0	$103,387,318	$630,604,088	$0	$69,844,768	$474,517,680	$0	$52,556,870
2016	$961,223,417	$0	$106,463,671	$624,392,403	$0	$69,156,771	$456,670,321	$0	$50,580,123
2017	$989,825,208	$0	$109,631,563	$618,241,904	$0	$68,475,551	$439,494,230	$0	$48,677,725
2018	$1,019,278,062	$0	$112,893,717	$612,151,991	$0	$67,801,041	$422,964,158	$0	$46,846,879
2019	$1,049,607,305	$0	$116,252,939	$606,122,065	$0	$67,133,175	$407,055,809	$0	$45,084,894
2020	$1,080,839,012	$0	$119,712,116	$600,151,537	$0	$66,471,889	$391,745,798	$0	$43,389,180
2021	$1,113,000,038	$0	$123,274,223	$594,239,820	$0	$65,817,116	$377,011,620	$0	$41,757,244
2022	$1,146,118,035	$0	$126,942,323	$588,386,336	$0	$65,168,793	$362,831,618	$0	$40,186,689
2023	$1,180,221,479	$0	$130,719,570	$582,590,511	$0	$64,526,856	$349,184,949	$0	$38,675,204
2024	$1,215,339,691	$0	$134,609,211	$576,851,777	$0	$63,891,242	$336,051,552	$0	$37,220,568
Total	$18,661,342,083	$9,866,030,791	$2,077,205,418	$12,695,320,386	$8,206,417,308	$1,416,417,758	$9,912,136,514	$7,321,108,285	$1,108,156,466

Table C-24

Benefits and Costs for Volvo FOT ($2005)
Scenario: Truck Tractor and Trailer with Bundled System Using Aggressive Conflict Classes - High Cost Estimate

	Undiscounted			Discounted at 4%			Discounted at 7%		
Year	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance	Avoided Crashes Benefit	Purchase Cost for IVSS	Training Cost Plus Operating/ Maintenance
2005	$696,223,216	$11,739,560,211	$217,855,219	$696,223,216	$11,739,560,211	$217,855,219	$696,223,216	$11,739,560,211	$217,855,219
2006	$716,939,764	$0	$213,728,045	$689,365,157	$0	$205,507,736	$670,037,162	$0	$199,745,837
2007	$738,272,745	$0	$220,087,654	$682,574,653	$0	$203,483,408	$644,836,008	$0	$192,233,080
2008	$760,240,502	$0	$226,636,497	$675,851,038	$0	$201,479,020	$620,582,708	$0	$185,002,891
2009	$782,861,924	$0	$233,380,204	$669,193,653	$0	$199,494,377	$597,241,613	$0	$178,044,640
2010	$806,156,459	$0	$240,324,575	$662,601,846	$0	$197,529,283	$574,778,414	$0	$171,348,101
2011	$830,144,138	$0	$247,475,580	$656,074,970	$0	$195,583,545	$553,160,091	$0	$164,903,428
2012	$854,845,584	$0	$254,839,367	$649,612,387	$0	$193,656,975	$532,354,867	$0	$158,701,150
2013	$880,282,038	$0	$262,422,268	$643,213,463	$0	$191,749,381	$512,332,161	$0	$152,732,149
2014	$906,475,368	$15,284,785,000	$270,230,804	$636,877,570	$10,738,887,197	$189,860,578	$493,062,540	$8,313,910,309	$146,987,652
2015	$933,448,098	$0	$278,271,686	$630,604,088	$0	$187,990,381	$474,517,680	$0	$141,459,215
2016	$961,223,417	$0	$286,551,831	$624,392,403	$0	$186,138,605	$456,670,321	$0	$136,138,711
2017	$989,825,208	$0	$295,078,356	$618,241,904	$0	$184,305,070	$439,494,230	$0	$131,018,319
2018	$1,019,278,062	$0	$303,858,593	$612,151,991	$0	$182,489,597	$422,964,158	$0	$126,090,513
2019	$1,049,607,305	$0	$312,900,091	$606,122,065	$0	$180,692,006	$407,055,809	$0	$121,348,050
2020	$1,080,839,012	$0	$322,210,625	$600,151,537	$0	$178,912,122	$391,745,798	$0	$116,783,958
2021	$1,113,000,038	$0	$331,798,199	$594,239,820	$0	$177,149,771	$377,011,620	$0	$112,391,529
2022	$1,146,118,035	$0	$341,671,057	$588,386,336	$0	$175,404,780	$362,831,618	$0	$108,164,307
2023	$1,180,221,479	$0	$351,837,689	$582,590,511	$0	$173,676,977	$349,184,949	$0	$104,096,077
2024	$1,215,339,691	$0	$362,306,835	$576,851,777	$0	$171,966,194	$336,051,552	$0	$100,180,859
Total	$18,661,342,083	$27,024,345,211	$5,573,465,174	$12,695,320,386	$22,478,447,408	$3,794,925,025	$9,912,136,514	$20,053,470,521	$2,965,225,686

Tables C-25 to C-32 provide 20-year total cost and benefit summaries of the BCA results for the 4% and 7% discount rates, across all scenarios:

All Large Trucks, CWS Only, Low Cost Estimate (Table C-25)
All Large Trucks, CWS Only, High Cost Estimate (Table C-26)
All Large Trucks, Bundled System, Low Cost Estimate (Table C-27)
All Large Trucks, Bundled System, High Cost Estimate (Table C-28)

Tractor-Trailers, CWS Only, Low Cost Estimate (Table C-29)
Tractor-Trailers, CWS Only, High Cost Estimate (Table C-30)
Tractor-Trailers, Bundled System, Low Cost Estimate (Table C-31)
Tractor-Trailers, Bundled System, High Cost Estimate (Table C-32)

Table C-25

Benefit/Cost Comparision for Volvo (Present Value in $2005) - Low Cost Estimate
All Trucks with Effect of CWS Only

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$12,693,912,235	$9,911,037,071
Total benefits	$12,693,912,235	$9,911,037,071
Costs		
Purchase Cost for Onboard IVSS	$32,129,212,471	$28,663,110,198
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$38,506,495,418	$33,652,476,712
Total (Net Present Value)	-$25,812,583,183	-$23,741,439,641
Benefit/Cost Ratio	0.33	0.29

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	-$1,364,122,561	-$1,065,067,177
Total benefits	-$1,364,122,561	-$1,065,067,177
Costs		
Purchase Cost for Onboard IVSS	$32,129,212,471	$28,663,110,198
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$38,506,495,418	$33,652,476,712
Total (Net Present Value)	-$39,870,617,980	-$34,717,543,889
Benefit/Cost Ratio	-0.04	-0.03

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$15,614,161,805	$12,191,082,908
Total benefits	$15,614,161,805	$12,191,082,908
Costs		
Purchase Cost for Onboard IVSS	$32,129,212,471	$28,663,110,198
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$38,506,495,418	$33,652,476,712
Total (Net Present Value)	-$22,892,333,614	-$21,461,393,804
Benefit/Cost Ratio	0.41	0.36

Table C-26

Benefit/Cost Comparision for Volvo (Present Value in $2005) - High Cost Estimate
All Trucks with Effect of CWS Only

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$12,693,912,235	$9,911,037,071
Total benefits	$12,693,912,235	$9,911,037,071
Costs		
Purchase Cost for Onboard IVSS	$48,193,818,707	$42,994,665,297
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$54,571,101,654	$47,984,031,811
Total (Net Present Value)	-$41,877,189,419	-$38,072,994,740
Benefit/Cost Ratio	0.23	0.21

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	-$1,364,122,561	-$1,065,067,177
Total benefits	-$1,364,122,561	-$1,065,067,177
Costs		
Purchase Cost for Onboard IVSS	$48,193,818,707	$42,994,665,297
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$54,571,101,654	$47,984,031,811
Total (Net Present Value)	-$55,935,224,215	-$49,049,098,988
Benefit/Cost Ratio	-0.02	-0.02

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$15,614,161,805	$12,191,082,908
Total benefits	$15,614,161,805	$12,191,082,908
Costs		
Purchase Cost for Onboard IVSS	$48,193,818,707	$42,994,665,297
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$54,571,101,654	$47,984,031,811
Total (Net Present Value)	-$38,956,939,849	-$35,792,948,903
Benefit/Cost Ratio	0.29	0.25

Table C-27

Benefit/Cost Comparision for Volvo (Present Value in $2005) - Low Cost Estimate
All Trucks with Effect of Bundled System

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$17,197,930,096	$13,427,643,076
Total benefits	$17,197,930,096	$13,427,643,076
Costs		
Purchase Cost for Onboard IVSS	$36,948,594,342	$32,962,576,728
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$43,325,877,289	$37,951,943,242
Total (Net Present Value)	-$26,127,947,193	-$24,524,300,166
Benefit/Cost Ratio	0.40	0.35

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$4,752,860,747	$3,710,895,285
Total benefits	$4,752,860,747	$3,710,895,285
Costs		
Purchase Cost for Onboard IVSS	$36,948,594,342	$32,962,576,728
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$43,325,877,289	$37,951,943,242
Total (Net Present Value)	-$38,573,016,542	-$34,241,047,957
Benefit/Cost Ratio	0.11	0.10

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$18,355,097,895	$14,331,126,001
Total benefits	$18,355,097,895	$14,331,126,001
Costs		
Purchase Cost for Onboard IVSS	$36,948,594,342	$32,962,576,728
Training and O & M Cost	$6,377,282,947	$4,989,366,514
Total costs	$43,325,877,289	$37,951,943,242
Total (Net Present Value)	-$24,970,779,394	-$23,620,817,241
Benefit/Cost Ratio	0.42	0.38

Table C-28

Benefit/Cost Comparision for Volvo (Present Value in $2005) - High Cost Estimate
All Trucks with Effect of Bundled System

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$17,197,930,096	$13,427,643,076
Total benefits	$17,197,930,096	$13,427,643,076
Costs		
Purchase Cost for Onboard IVSS	$101,207,019,284	$90,288,797,124
Training and O & M Cost	$17,086,280,169	$13,350,639,736
Total costs	$118,293,299,453	$103,639,436,860
Total (Net Present Value)	-$101,095,369,357	-$90,211,793,785
Benefit/Cost Ratio	0.15	0.13

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$4,752,860,747	$3,710,895,285
Total benefits	$4,752,860,747	$3,710,895,285
Costs		
Purchase Cost for Onboard IVSS	$101,207,019,284	$90,288,797,124
Training and O & M Cost	$17,086,280,169	$13,350,639,736
Total costs	$118,293,299,453	$103,639,436,860
Total (Net Present Value)	-$113,540,438,706	-$99,928,541,576
Benefit/Cost Ratio	0.04	0.04

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$18,355,097,895	$14,331,126,001
Total benefits	$18,355,097,895	$14,331,126,001
Costs		
Purchase Cost for Onboard IVSS	$101,207,019,284	$90,288,797,124
Training and O & M Cost	$17,086,280,169	$13,350,639,736
Total costs	$118,293,299,453	$103,639,436,860
Total (Net Present Value)	-$99,938,201,558	-$89,308,310,859
Benefit/Cost Ratio	0.16	0.14

Table C-29

Benefit/Cost Comparision for Volvo (Present Value in $2005) - Low Cost Estimate
Truck Tractor and Trailer with Effect of CWS Only

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$9,206,785,188	$7,188,389,805
Total benefits	$9,206,785,188	$7,188,389,805
Costs		
Purchase Cost for Onboard IVSS	$7,136,015,050	$6,366,181,118
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$8,552,432,808	$7,474,337,583
Total (Net Present Value)	$654,352,380	-$285,947,778
Benefit/Cost Ratio	1.08	0.96

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	-$393,374,893	-$307,135,663
Total benefits	-$393,374,893	-$307,135,663
Costs		
Purchase Cost for Onboard IVSS	$7,136,015,050	$6,366,181,118
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$8,552,432,808	$7,474,337,583
Total (Net Present Value)	-$8,945,807,701	-$7,781,473,246
Benefit/Cost Ratio	-0.05	-0.04

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$10,235,071,270	$7,991,245,638
Total benefits	$10,235,071,270	$7,991,245,638
Costs		
Purchase Cost for Onboard IVSS	$7,136,015,050	$6,366,181,118
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$8,552,432,808	$7,474,337,583
Total (Net Present Value)	$1,682,638,462	$516,908,055
Benefit/Cost Ratio	1.20	1.07

Table C-30

Benefit/Cost Comparision for Volvo (Present Value in $2005) - High Cost Estimate
Truck Tractor and Trailer with Effect of CWS Only

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$9,206,785,188	$7,188,389,805
Total benefits	$9,206,785,188	$7,188,389,805
Costs		
Purchase Cost for Onboard IVSS	$10,704,022,575	$9,549,271,676
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$12,120,440,333	$10,657,428,142
Total (Net Present Value)	-$2,913,655,145	-$3,469,038,337
Benefit/Cost Ratio	0.76	0.67

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	-$393,374,893	-$307,135,663
Total benefits	-$393,374,893	-$307,135,663
Costs		
Purchase Cost for Onboard IVSS	$10,704,022,575	$9,549,271,676
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$12,120,440,333	$10,657,428,142
Total (Net Present Value)	-$12,513,815,226	-$10,964,563,805
Benefit/Cost Ratio	-0.03	-0.03

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$10,235,071,270	$7,991,245,638
Total benefits	$10,235,071,270	$7,991,245,638
Costs		
Purchase Cost for Onboard IVSS	$10,704,022,575	$9,549,271,676
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$12,120,440,333	$10,657,428,142
Total (Net Present Value)	-$1,885,369,063	-$2,666,182,504
Benefit/Cost Ratio	0.84	0.75

Table C-31

Benefit/Cost Comparision for Volvo (Present Value in $2005) - Low Cost Estimate
Truck Tractor and Trailer with Effect of Bundled System

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$12,062,307,505	$9,417,898,488
Total benefits	$12,062,307,505	$9,417,898,488
Costs		
Purchase Cost for Onboard IVSS	$8,206,417,308	$7,321,108,285
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$9,622,835,066	$8,429,264,751
Total (Net Present Value)	$2,439,472,439	$988,633,737
Benefit/Cost Ratio	1.25	1.12

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$3,812,265,144	$2,976,505,625
Total benefits	$3,812,265,144	$2,976,505,625
Costs		
Purchase Cost for Onboard IVSS	$8,206,417,308	$7,321,108,285
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$9,622,835,066	$8,429,264,751
Total (Net Present Value)	-$5,810,569,921	-$5,452,759,126
Benefit/Cost Ratio	0.40	0.35

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$12,695,320,386	$9,912,136,514
Total benefits	$12,695,320,386	$9,912,136,514
Costs		
Purchase Cost for Onboard IVSS	$8,206,417,308	$7,321,108,285
Training and O & M Cost	$1,416,417,758	$1,108,156,466
Total costs	$9,622,835,066	$8,429,264,751
Total (Net Present Value)	$3,072,485,321	$1,482,871,764
Benefit/Cost Ratio	1.32	1.18

Table C-32

Benefit/Cost Comparision for Volvo (Present Value in $2005) - High Cost Estimate
Truck Tractor and Trailer with Effect of Bundled System

Medium Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$12,062,307,505	$9,417,898,488
Total benefits	$12,062,307,505	$9,417,898,488
Costs		
Purchase Cost for Onboard IVSS	$22,478,447,408	$20,053,470,521
Training and O & M Cost	$3,794,925,025	$2,965,225,686
Total costs	$26,273,372,433	$23,018,696,206
Total (Net Present Value)	-$14,211,064,928	-$13,600,797,719
Benefit/Cost Ratio	0.46	0.41

Conservative Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$3,812,265,144	$2,976,505,625
Total benefits	$3,812,265,144	$2,976,505,625
Costs		
Purchase Cost for Onboard IVSS	$22,478,447,408	$20,053,470,521
Training and O & M Cost	$3,794,925,025	$2,965,225,686
Total costs	$26,273,372,433	$23,018,696,206
Total (Net Present Value)	-$22,461,107,289	-$20,042,190,581
Benefit/Cost Ratio	0.15	0.13

Aggressive Conflict Classes

	Discounted at 4%	Discounted at 7%
Benefits		
Crashes avoided	$12,695,320,386	$9,912,136,514
Total benefits	$12,695,320,386	$9,912,136,514
Costs		
Purchase Cost for Onboard IVSS	$22,478,447,408	$20,053,470,521
Training and O & M Cost	$3,794,925,025	$2,965,225,686
Total costs	$26,273,372,433	$23,018,696,206
Total (Net Present Value)	-$13,578,052,047	-$13,106,559,692
Benefit/Cost Ratio	0.48	0.43

APPENDIX D.

SAFETY BENEFITS SUPPORTING DATA

Appendix D.

Safety Benefits Supporting Data

Appendix D1. Follow-On Time History Treatment

As noted in the Volvo Trucks Final Report (Volvo 2005), there are many follow-on threats, i.e., THs that start immediately after the end of a preceding TH. For this reason, threats were grouped into "follow-on groups" based on start times. Specifically, if the start time of threat A was within 15 seconds of the start time of threat B, threat B was assumed to be a follow-on of threat A. Groups of as many as seven follow-on threats (ABCDFEG) were identified by this process, but 80 percent of the follow-on groups contained only two triggered events (AB), and 14 percent consisted of three triggered events (ABC). Because the majority of the follow-on groups consisted of only two triggered events, only follow-on pairs were created. Longer events were broken into a series of driving conflicts using the process described below. Follow-on threats were important for determining the severity of the conflict.

First, driving conflicts with no follow-ons were identified and then driving conflict pairs were created. Driving conflicts with follow-on threats whose critical targets disappeared before the end of the driving conflict were identified as single driving conflicts and included in the single driving conflict group. The process of creating follow-on driving conflict pairs proceeded for the remaining driving conflicts by appending a single follow-on threat (whether it passes KME or not) to the preceding driving conflict. Using this approach, the initial threat must be a driving conflict, but the follow-on threat may or may not satisfy the KME equations. Only a single follow-on was appended to each driving conflict. However, if the follow-on threat was also a driving conflict, then a follow-on pair was also created for that driving conflict.

A method was implemented to avoid the situation of creating multiple driving conflicts from the same event. If the critical target was still present at the end of a follow-on driving conflict, indicating that the same target was probably present in the follow-on threat, then further driving conflict follow-on pairs were not created. If the last threat in a follow-on group was a driving conflict itself, it appears in the single driving conflict set. Table D1-1 gives examples of how follow-on groups were broken up to produce multiple single and follow-on pair driving conflicts.

Table D1-1. Examples of Creation of Single and Follow-on Pair Driving Conflicts

Original (A) and Follow-On (B,C) Time Histories	Conflicts Created				Number of:	
					Singles	Follow-On Pairs
$\mathbf{A^1 B^1 C^1}$	→	AB	BC	—	0	2
$\mathbf{A^1 B^1 C^2}$	→	AB	BC	C	1	2
$\mathbf{A^1 B^2 C^1}$	→	AB	B	C	2	1
$\mathbf{A^1 B^2 C^2}$	→	AB	B	C	2	1
$\mathbf{A^2 B^1 C^1}$	→	A	BC	—	1	1
$\mathbf{A^2 B^1 C^2}$	→	A	BC	C	2	1
$\mathbf{A^2 B^2 C^1}$	→	A	B	C	3	—
$\mathbf{A^2 B^2 C^2}$	→	A	B	C	3	—
$\mathbf{A^1} B^1 \mathbf{C^1}$	→	AB	C	—	1	1
$\mathbf{A^1} B^1 \mathbf{C^2}$	→	AB	C	—	1	1
$\mathbf{A^1} B^2 \mathbf{C^1}$	→	AB	C	—	1	1
$\mathbf{A^1} B^2 \mathbf{C^2}$	→	AB	C	—	1	1
$\mathbf{A^2} B^1 \mathbf{C^1}$	→	A	C	—	2	—
$\mathbf{A^2} B^1 \mathbf{C^2}$	→	A	C	—	2	—
$\mathbf{A^2} B^2 \mathbf{C^1}$	→	A	C	—	2	—
$\mathbf{A^2} B^2 \mathbf{C^2}$	→	A	C	—	2	—

Notes:

A, B, and C represent time histories (THs) collected in sequence called follow-on THs.
Boldface A, B, and C indicate a TH were the target satisfied the KME conditions.
Non-boldface indicates a TH that did not satisfy the KME conditions.

Key to superscripts in the Time History column:

1. Critical target present throughout the TH.
2. Critical target disappears before end of TH.

The main purposes of appending follow-on threats were to:

1. Improve driving conflict rate estimates by identifying unique, closely spaced driving conflicts as accurately as possible and

2. Aid the estimation of crash probabilities for each individual conflict with additional information for assessing the conflict severity.

The first purpose was addressed by the procedures described above for determining when follow-on THs represent separate driving conflicts and when they were continuations of other driving conflicts. It was anticipated that if the threat continued past the end of a TH, then additional driving data might be needed to assess the severity of the driving conflict. Thus, appending follow-on data to driving conflicts achieved the second purpose. The decision to limit the potential length of a driving conflict to two consecutive THs was based on both (a) the fact that over 80% of follow-on groups contained only one follow-on and (b) the crash probability, which indicates that 5 to 10 seconds of data after the point of conflict identification is typically sufficient to understand conflict resolution.

Appendix D2. Driver Assignments and Log Data

Unit tracking data and log data were processed by Battelle and combined with the on-board driving data. Figure D2-1 indicates the portion of the histogram data for which unit tracking data were available (95% of the 2.69 million VMT) and the portion for which both unit tracking and log data were available (59% of the 2.69 million VMT). Unit tracking data linked the driver to the vehicle. Thus, for all the histograms that have unit tracking data, it was possible to examine the effects of driver variables (age, gender, and experience).

Only two variables were constructed from the log data. The first variable captured the hours of driving the driver performed during the histogram. When two drivers both had driving data within one histogram period, the driving was assigned to the driver with the greater amount of driving during the histogram period. If no log information was available to determine which of the two drivers assigned to each truck did more of the driving during an individual histogram period, one of the two drivers was randomly assigned to that driving period. The second variable captured the driver's hours of service over the last 10-hour period prior to the start of the histogram.

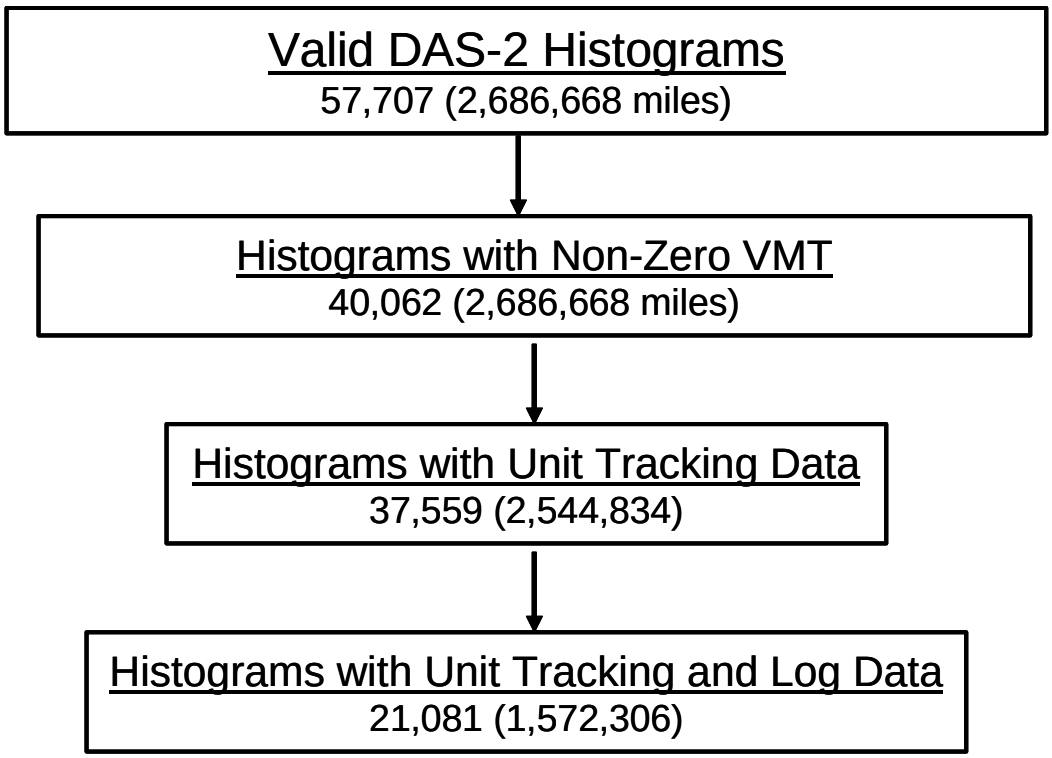

Figure D2-1. Process of Identifying Proper Histograms for Analyses

Figures D2-2, D2-3, and D2-4 show, for Baseline, Control, and Test trucks, respectively, a graphical summary of the overlap between on-board driving data and unit tracking/log data. On each plot, the x axis indicates the time period of the FOT. Each truck in that fleet has a row. To

protect driver confidentiality, the identification numbers of the trucks are not shown. The key to the graphic is as follows:

- **Empty Row:** No data were collected
- **Yellow:** Unit tracking and log data only
- **Green Square:** On-board driving data were collected, but not DAS-2 data
- **Blue Square:** DAS-2 data were collected
- **Black Circle (DAS-1) or Red Circle (DAS-2):** Both on-board driving data for a particular day and unit tracking and log data.

Figures D2-2, D2-3, and D2-4 illustrate why there was a reduction in the number of histograms and the VMT when the histograms were combined with the unit tracking and log data. The information required for the conditional analysis of *exposure rates* is garnered from the histogram, unit tracking, and log data. Because of the reduction in available data when log data were required, conditional analyses of exposure rates were performed twice, once using information acquired from the histogram channels and unit tracking data and once using information from histogram channels, unit tracking, and log data.

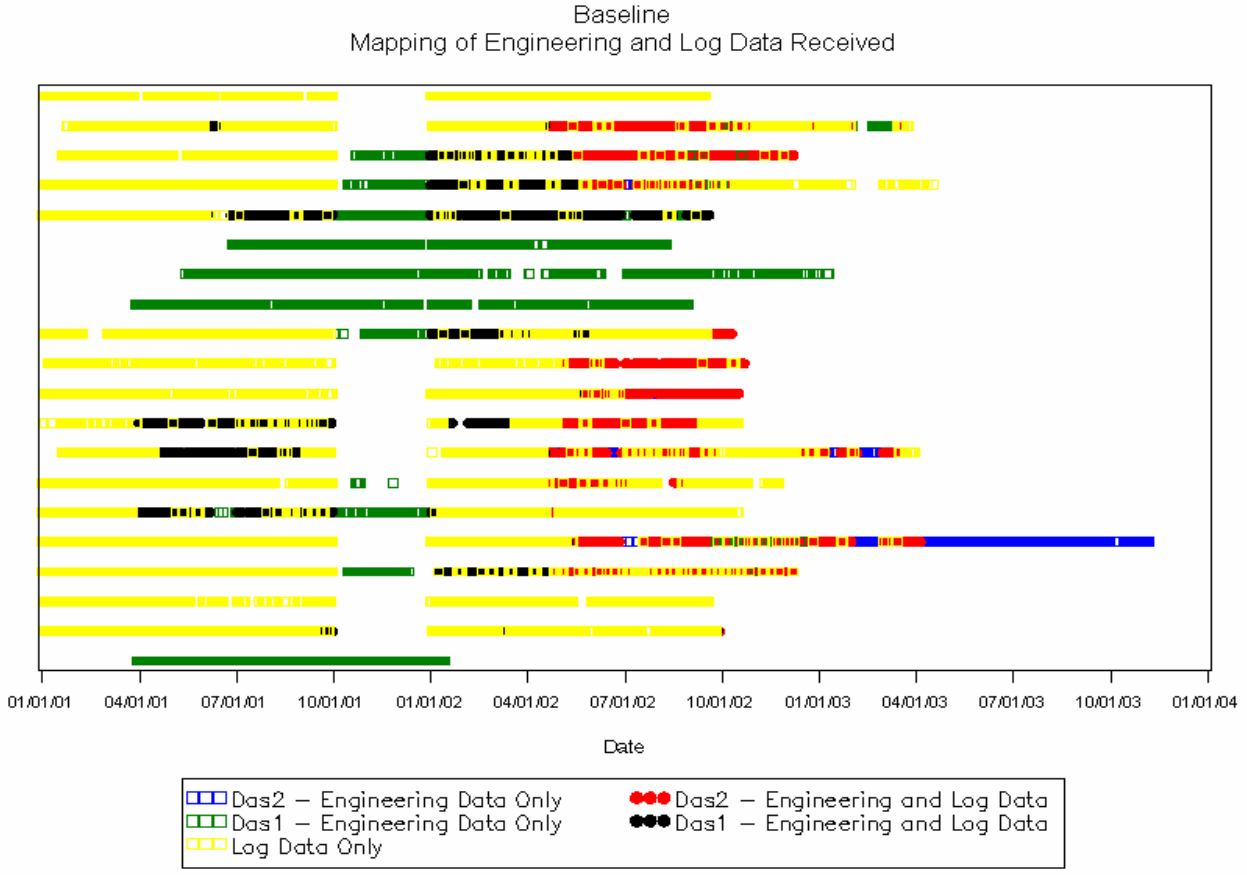

Figure D2-2. Overlap of On-Board Driving Data and Log Data for Baseline Trucks

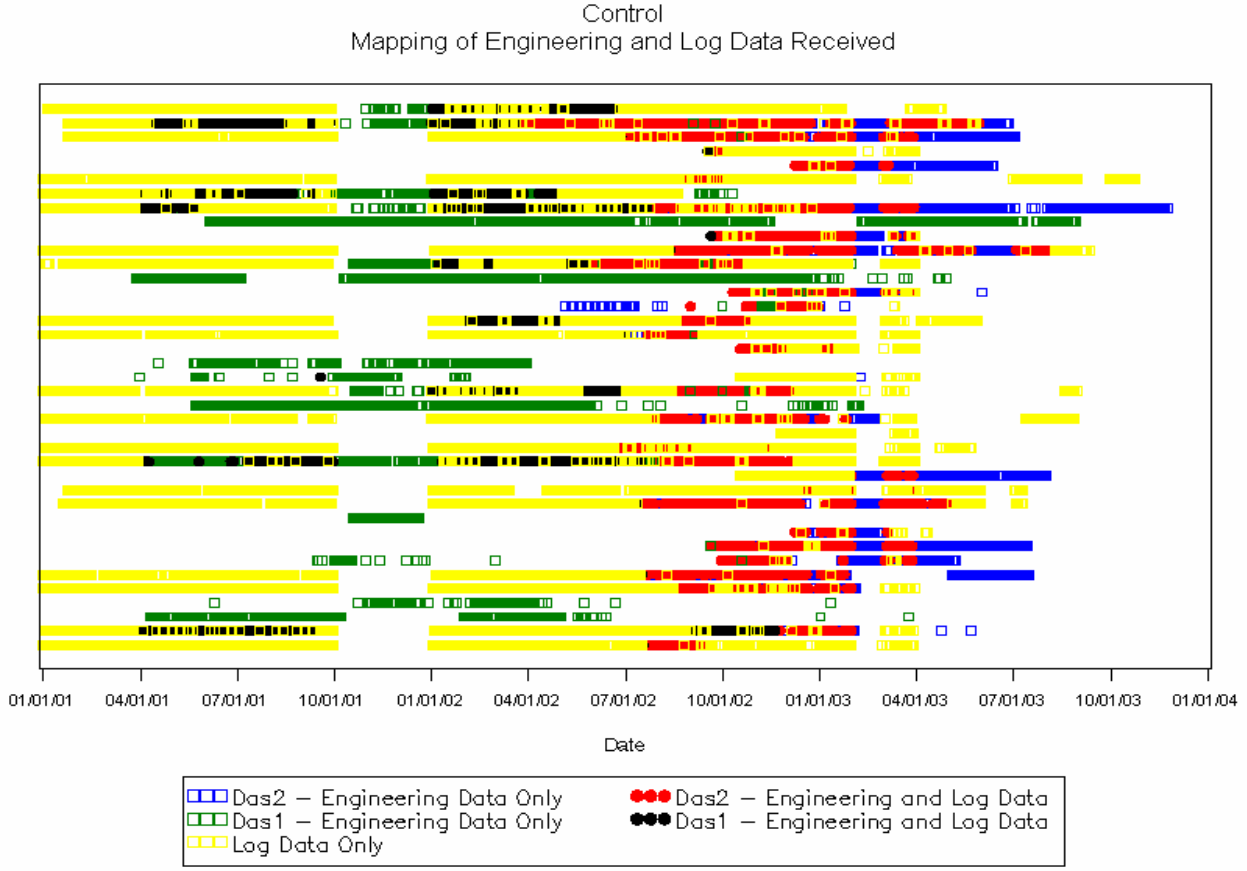

Figure D2-3. Overlap of On-Board Driving Data and Log Data for Control Trucks

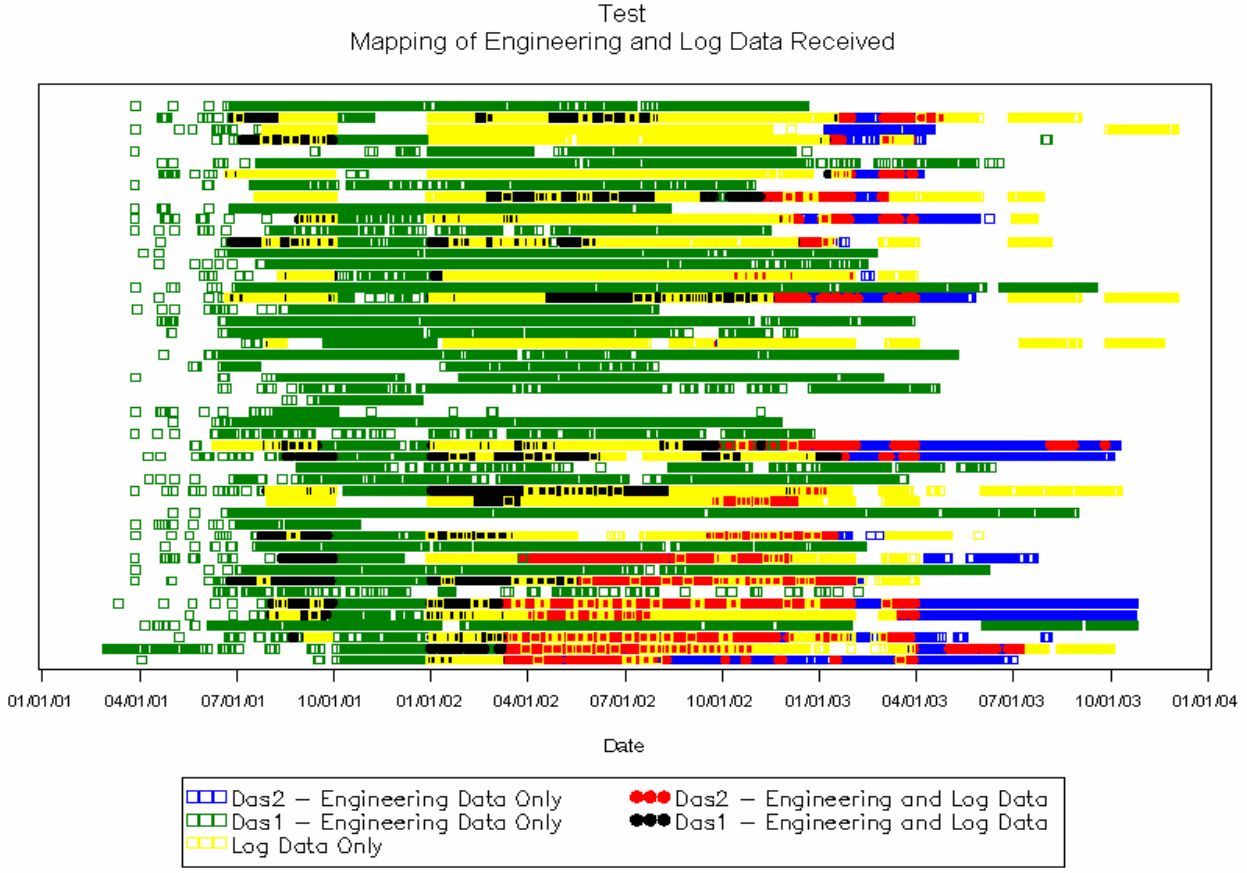

Figure D2-4. Overlap of On-Board Driving Data and Log Data for Test Trucks

Appendix D3. Supplemental Data Summaries

This appendix provides supplemental summaries of driver characteristics and driving data.

Driver Gender

Table D3-1 details the division of driving data by the gender of the driver. For the log data and the valid vehicle data available, there were more male drivers involved in the FOT, 131 men versus 56 women, and the males did a larger portion of the driving, 1,830,214 miles versus 714,478 miles.

Table D3-1. Distribution of VMT and Drivers by Gender

Gender	Fleet	Number of Drivers	Vehicle miles Traveled
Female	Baseline	14	132,114
	Control	19	268,225
	Test	27	314,139
	Tot. (F)	56	714,478
Male	Baseline	25	236,169
	Control	63	749,774
	Test	51	844,271
	Tot. (M)	131	1,830,214
Grand Total		187	2,544,692

Driver Age, Years of Experience, and Years with CDL

Figures D3-1 through D3-3 illustrate the spread of VMT and numbers of drivers over the range of driver ages, years of US Xpress experience, and years with a CDL. It appears from Figure D3-1 that driver ages were fairly evenly spread between 20 and 60 years of age, with a few drivers over 60, for the Baseline fleet. For the Control and Test fleets, however, drivers were centered in the 30 to 49 year old categories. Likewise, the VMT was spread over the age categories proportional to the number in that category. A majority of the driving was done by drivers with less than 1 year of experience at US Xpress (Figure D3-2). All baseline drivers, except one, had one year or less of experience with US Xpress as dictated by the FOT design. A large group of control vehicle drivers involved in the FOT had been with US Xpress 2 years. In general, Figures D3-2 and D3-3 indicate that US Xpress drivers were new to the driving business and new to US Xpress.

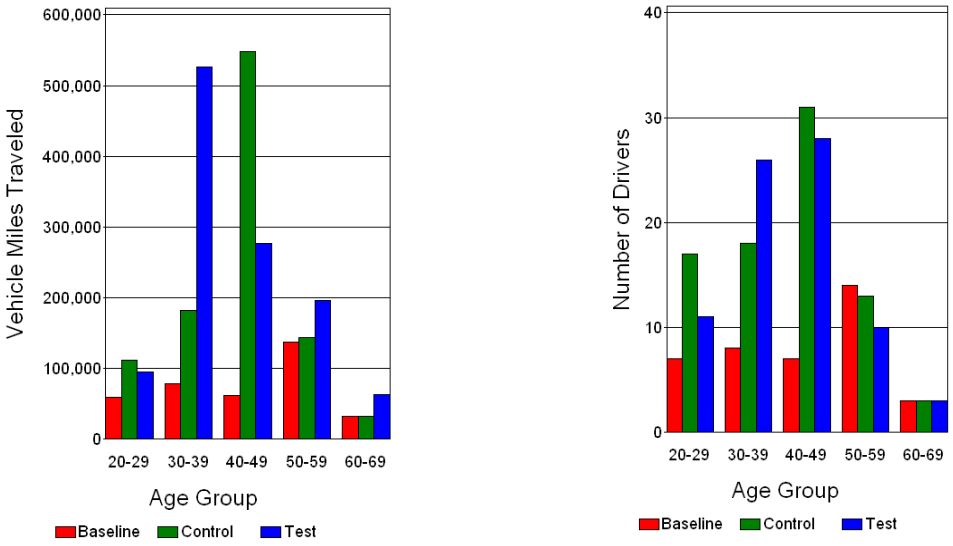

Figure D3-1. Distribution of VMT and Numbers of Drivers by Age Group

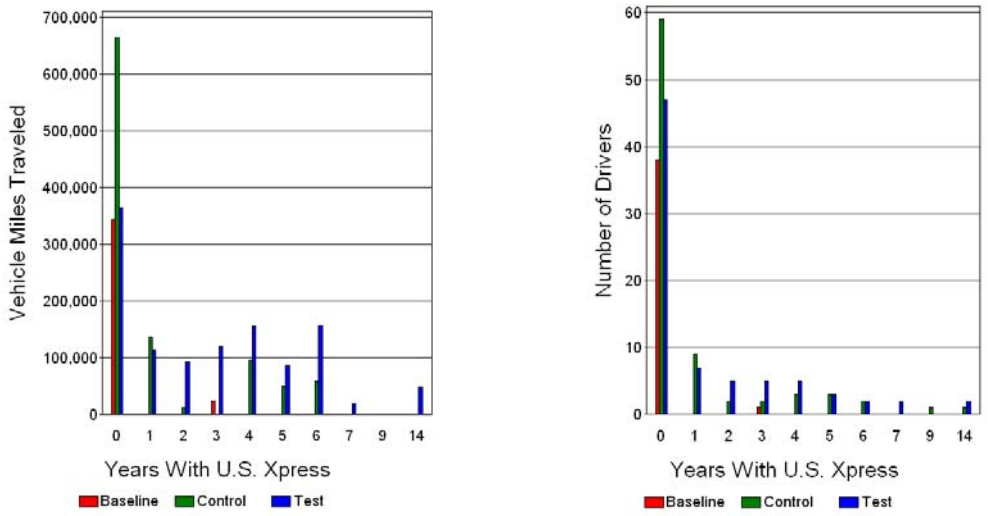

Figure D3-2. Distribution of VMT and Numbers of Drivers by Years of Service with US Xpress

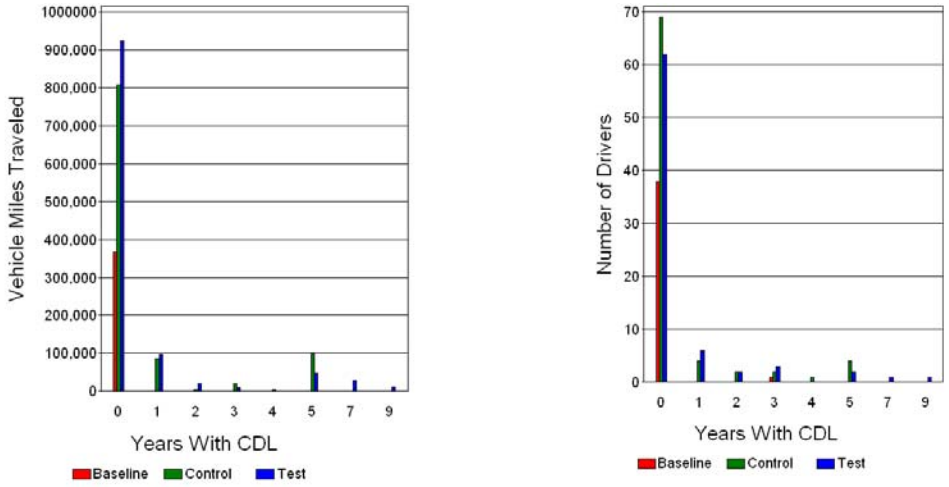

Figure D3-3. Distribution of VMT and Numbers of Drivers by Years with CDL

Distribution of Driving Speed

Figure D3-4 illustrates the breakdown of VMT by average road speed and percent of the time road speed is greater than 55 mph. To divide the VMT by these metrics, the average road speed and the percent of the time road speed was greater than 55 mph (80 fps) was calculated for each histogram reporting period. The VMT value from each histogram was then assigned to a bin along the horizontal axis of Figure D2-4. These bar charts demonstrate that the majority of the driving data was collected at speeds above 55 mph (80 fps). Analyses in Section 5.1.2 further examine the distribution of road speed demonstrated during the FOT by each fleet.

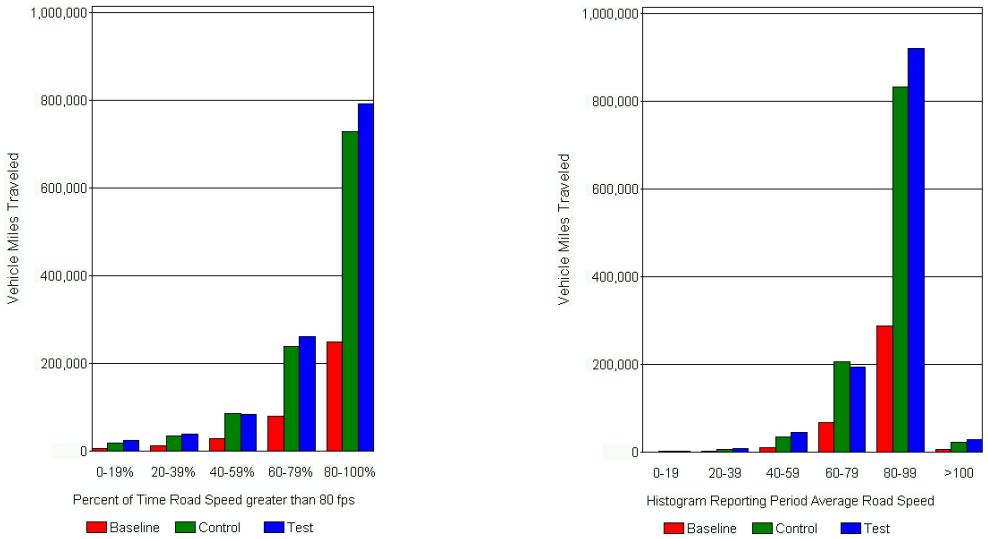

Figure D3-4. Breakdown of VMT by Road Speed (feet per second) Variables

Appendix D4. Calculating Standard Error for Estimating Conflict Rates

In this appendix, two methods for computing the variability of fleet average driving conflict rates are presented. The two methods were shown to produce similar standard errors. The simpler method was chosen for computing standard errors for rates in this report.

Table D4-1 presents the rate of driving conflicts by fleet. Standard errors were calculated for the fleet rates of driving conflicts by two methods. The first method assumed that all the trucks in a fleet should have the same driving conflict rate. Under this assumption, the number of driving conflicts experienced was assumed to have a Poisson distribution, with rate parameter equal to the rate of driving conflicts per unit distance times the total distance traveled by each fleet. In this distribution, the variance of the rate estimate is equal to the rate estimate divided by the total distance. The justification for viewing the number of driving conflicts as a Poisson process is based on a few concepts. First, conflicts are relatively rare events and no more than one conflict is expected in any one small unit of distance traveled. The driving conflicts can be viewed as a series of many binary trials (was there a conflict or not in a small unit of driving) with a small, constant probability of success. Under these conditions, the actual number of events occurring (conflicts) follows a Poisson distribution (Karlin and Taylor 1975).

The second method of calculating the uncertainty in the rate estimate assumed that each truck within a fleet could have a different driving conflict rate. Under this assumption, the variability among individual driving conflict rates estimated for each truck within a fleet is used to gauge the variability in the overall rate estimate. Figure D4-1 illustrates the variability of rates by truck. The second method produces slightly larger but very similar standard errors. The Poisson assumption was used to produce confidence intervals and determine statistical significance of differences in estimated conflict rates in this report.

Table D4-1. Number and Rate (Per 10,000 Miles) of Driving Conflicts by Truck Group

Fleet	VMT	Number of Trucks	Number of Driving Conflicts		
			Rate*	Poisson Standard Error	Standard Error w/ Truck Variability
Baseline	375,935	11	7.95	0.46	0.49
Control	1,108,674	31	8.10	0.27	0.32
Test	1,202,059	23	8.37	0.26	0.28
Total	2,686,668	59	8.20		

**** Rate is the number per 10,000 miles.***

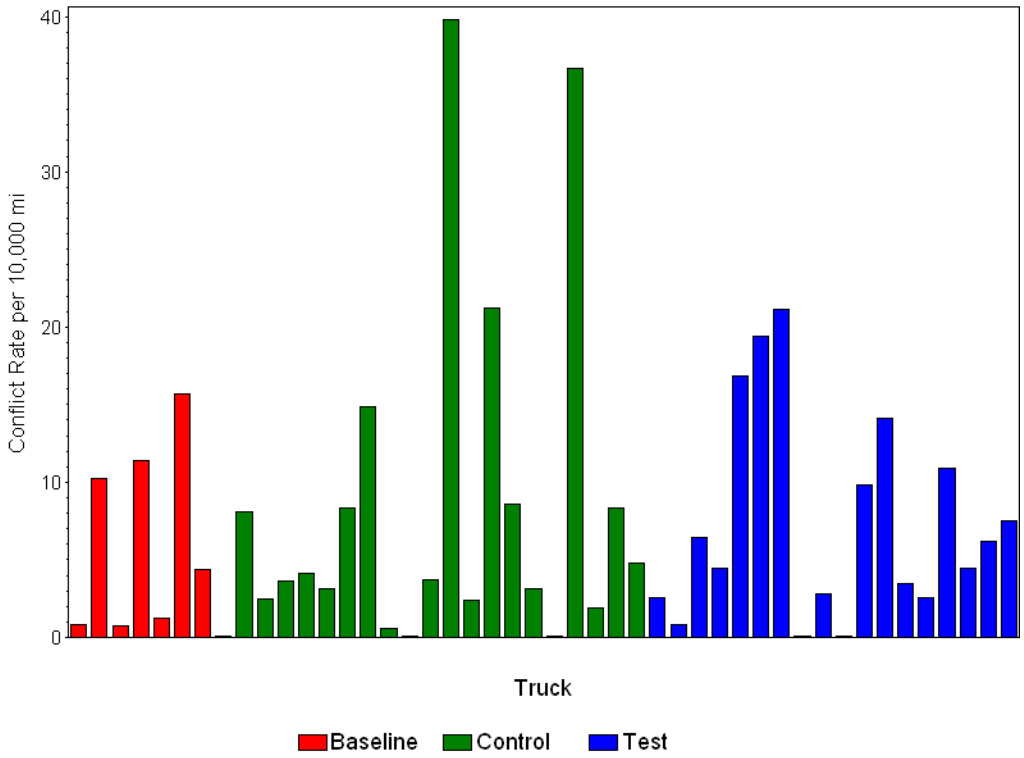

Figure D4-1. Overall Driving Conflict Rates by Truck

Appendix D5. Calculation of Vehicle Miles Traveled with Cruise Control On

The conditional analysis of conflict rates required the calculation of the vehicle miles traveled (VMT) during a 3-hour histogram period with cruise control on. This appendix describes how this calculation was performed.

The amount of time that the cruise control was on during a histogram period was included in the histogram file. Of interest for the Poisson regression was the VMT during which cruise control was on (in use). Additionally, the cruise control histogram channel recorded two cruise control states. The first was when the cruise control was on during driving conditions, and the second was when the cruise control was on and controlling engine speed during a high-idle state. The second cruise control mode occurred when the parking brake was set or when the vehicle was below some threshold speed (typically 5 mph).

In order to separate these two types of cruise control usage for use in the Poisson regression, allowing time to be converted into VMT, a linear regression was performed. The VMT in each histogram was split into VMT with cruise control on *(VMT_{on})* and VMT with cruise control off *(VMT_{off})* in the following manner:

1. The data were subset down to only driving with an average road speed greater than 50 mph with percent cruise control on greater than 0%. These higher average speeds made it likely that the drivers were using their cruise control in the driving mode only.

2. A regression equation was fit to the subset of the data that yielded an average speed with cruise control on (β_{CC} = 53 mph) and an average speed with cruise control off (β_{NOCC} = 41 mph):

$$VMT = \beta_{CC}\,(CC\ on\ time) + \beta_{NOCC}\,(CC\ off\ time)$$

3. The VMT in each histogram with an average road speed greater than 50 mph was then divided into cruise control on and off according to the proportion of the distance likely driven with cruise control on out of the total distance likely driven:

$$VMTon = \frac{\beta_{CC}(CC\ on\ time)}{\beta_{CC}(CC\ on\ time) + \beta_{NOCC}(CC\ off\ time)} \times VMT$$

$$VMToff = \frac{\beta_{NOCC}(CC\ off\ time)}{\beta_{CC}(CC\ on\ time) + \beta_{NOCC}(CC\ off\ time)} \times VMT$$

4. Average road speed with cruise control on was used to estimate the likely VMT_{on} for histograms with average road speed between 30 mph and 50 mph,

$$VMTon = \frac{\beta_{CC}(CC\ on\ time)}{\beta_{CC}(CC\ on\ time) + \beta_{NOCC}(CC\ off\ time)} \times VMT\ .$$

The minimum of this VMT_{on} and total VMT for the histogram was assumed to be VMT_{on}. This assumption was made because the sum of VMT_{on} and VMT_{off} must equal VMT, and neither can be negative.

5. Finally, any driving with an average road speed of less than 30 mph was assumed to be done without cruise control.

Appendix D6. Kinetic Motion Events Trigger

The Kinetic Motion Event (KME) triggers were implemented in order to capture time history data when a truck is in a situation where a high level of deceleration is required within a short period of time to avoid a collision. The KME trigger took its input from the collision warning system. The trigger criteria was that the following vehicle had to respond within 1.5 seconds at a deceleration of more than 0.25g (8 ft/s^2). Conservatively, the trigger criteria assumes that the following vehicle will not respond for the full 1.5 seconds.

Two trigger algorithms were used to account for different situations. The KME0 criteria uses measured lead vehicle deceleration, where the KME1 criteria assumes a constant deceleration for the lead vehicle. The following set of equations and logic describe the KME triggers.

It should be noted that the KME criteria found elsewhere in the report refers to the LVCS/LVS and LVD equations using various threshold parameters. This should be considered separately from the KME trigger criteria discussed here which cast a wider net to capture more situations of interest.

KME0:

If $|a_L| <= 0.25$ ft/s^2, (Lead Vehicle Constant Speed)

$$a_{F,req} = \frac{-\dot{R}^2}{2\left(R + \dot{R}t_{react}\right)}$$

If $a_L < -0.25$ ft/s^2, (Lead Vehicle Decelerating)

$$a_{R,req} = \frac{V_F^2}{2\left(V_L^2 / 2a_L + V_F t_{react} - R\right)}$$

KME1:

If $a_L > -6.4$ ft/s^2, (Lead Vehicle Constant Speed)

$$a_{F,req} = \frac{-\dot{R}^2}{2\left(R + \dot{R}t_{react}\right)}$$

If $a_L < -6.4$ ft/s^2, (Lead Vehicle Decelerating)

$$a_{R,req} = \frac{V_F^2}{2\left(V_L^2 / 2(-6.4\,ft/s^2) + V_F t_{react} - R\right)}$$

F = Following Vehicle
L = Lead Vehicle
t_{react} = reaction time (1.5 seconds)
$a_{F,req}$ = required deceleration

Appendix D7. Time of Critical Target Appearance

Analysis of the time history data focused on the period during which the critical target was present. The critical target is defined as the target under track when the trigger condition first occurs (Following Interval $\leq$ 0.5 sec, KME0, KME1, or Time to Collision $\leq$ 4 sec). Since the trigger condition was required to be present for 4 time steps (4/6 sec), the critical target was the target present just before the time history trigger at time zero. The time at which the critical target was first tracked is defined as the time of critical target appearance. This time is defined to be between -10 seconds and zero seconds in the time history (the first time step to the sixty-first).

Because the VORAD tracking system could rapidly switch between two targets due to a lane change, an algorithm was developed in coordination between the Volvo Partnership and Battelle to determine when a target switched within a time history. Generally, the VORAD could switch between targets or between target and no target. The algorithm used to determine the time of target switches is show below.

- For consecutive time steps, calculate range threshold as

  ΔR_{Thr} = max [|2 * previous Relative Velocity * 1/6|, 8]

  - (Previous Relative Velocity * 1/6) is the projected increase or decrease in range over one time step
  - Multiplication by the factor of two allows for range variability
  - Setting minimum value to 8 allows for VORAD range errors
  - The absolute value function accounts for negative relative velocities

- If $| \Delta R_{actual} | \geq \Delta R_{Thr}$, then a target switch has occurred.

The most difficult situations to determine a target switch were those in which a one time step drop-out of the track occurred. The Volvo Partnership analyzed video data and determined that some one step drop-outs were due to target switches and were correctly handled by the algorithm, while other drop-outs were due to a temporary loss of track by the VORAD system. Because these situations occurred in equal proportions in the analyzed data, no effort was made to distinguish between the two in the whole data set.

Appendix D8. Graphical Representation of Kinematic Analysis

The kinematic analysis is described fully in Step 5 of section 4.3.3. The kinematic analysis of a time history is designed to assign a numerical measure of severity to each FOT driving conflict. The measure of severity for this analysis is the additional time that a following vehicle driver could have waited to take action and still avoid a crash. This analysis assumes that the driver would react in the same manner as they did in the event. It also assumes that they maintain their kinematic profile throughout the additional time. Finally, the analysis assumes that the lead vehicle also behaves in the same way as it did during the actual time history.

Two time histories are shown here as an example of the results of the kinematic analysis. First, a time history is presented where the kinematic analysis predicts a lag time of 2 seconds. Figure D8-1 presents a Range/Range-Rate and following vehicle speed plot for this time history. Also shown on the plot are the range profiles predicted by the kinematic analysis. One profile is shown for 1 second and another for a 2 second lag. The 2 second lag profile reaches zero and therefore, would have resulted in a collision if the following driver had waited 2 seconds to react. The reaction in this case was braking at the 9 second mark. Second a time history is presented in Figure D8-2 where a lag time of longer than 15 seconds is predicted. This plot also shows the predicted range at 1 second time intervals. In this case, the predicted range by the kinematic analysis does not indicate a collision.

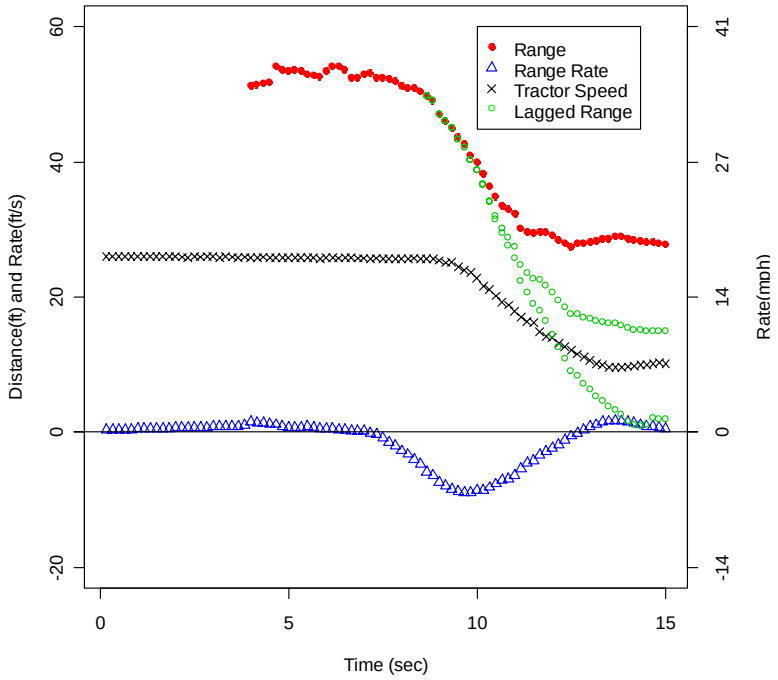

Figure D8-1. Range/Range-Rate/Speed Plot

The green range profile is the range that is predicted by the kinematic analysis at 1 second intervals with a collision at the 2 second lag time.
(UUID = 2F23284807072002544D00D0810000F4)

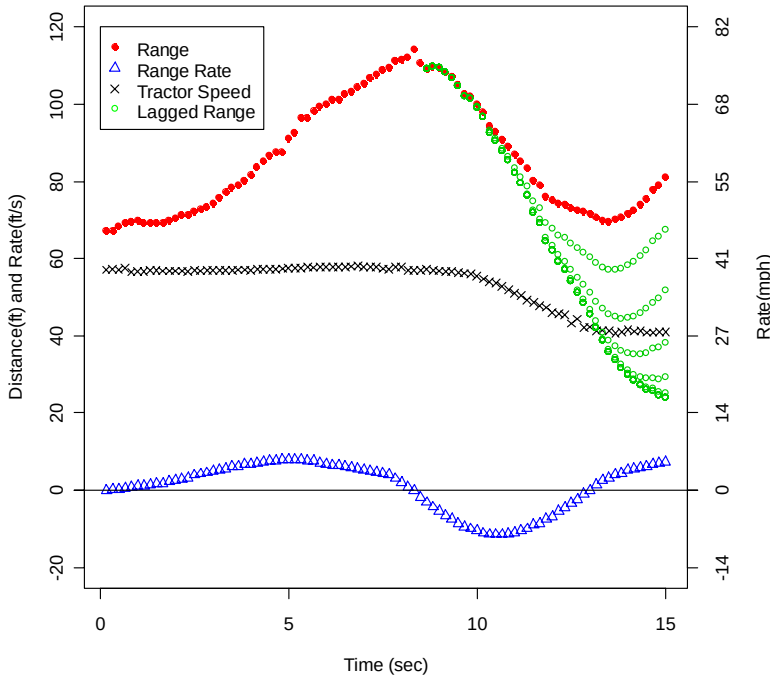

Figure D8-2. Range/Range-Rate/Speed Plot

The green range profile is the range that is predicted by the kinematic analysis at 1 second intervals up to 15 seconds. No collision is predicted.
(UUID = 3C23090703192003544D00D081000102)

Appendix D9. Selected Time Histories

One area of concern in this study was the treatment of time histories which were not KME triggered. All time histories were treated in the same manner regardless of their initial triggering condition. Each time history was analyzed using the LVS/LVCS and LVD equations (KME equations). Then each time history that satisfied the conservative threshold of the KME equations was analyzed using a kinematic analysis. The kinematic analysis calculated the additional time that a driver could have waited to react (lag time) and still not collide with the lead vehicle. Once non-threats were removed from the set of time histories (time histories with a 1/6 second lag time), the remaining time histories were included in the KME Conflict Definition set. Of that group, time histories with a lag time less than 15 seconds were included in the Restricted KME Conflict Definition set. Full details of the process are found in Section 4.

Eight time histories selected for additional analysis are contained in Table D9-1. Two time histories did not have complete channel data and therefore could not be fully analyzed. Two time histories satisfied the KME criteria for the conservative threshold even though they were not triggered by a KME event, while the rest did not. One time history was included in the Restricted KME Conflict Definition. Also included in Table D9-1 is the conflict description and conflict category assigned to that time history. The determination of the type of trigger (FI, TTC, or KME) and the determination of the conflict description were performed by the Volvo Partnership. Conflict category assignments were done according to Section 4.

Table D9-1. Characteristics of Selected Time Histories

Time History UUID	Complete Data	KME Conflict Definition	Restricted KME Conflict Definition	FI Trigger	TTC Trigger
0018095908152002544D00D081000134	X			X	
0101051404142003544D00D0810001E3				X	
0101440905102002544D00D0810001E7	X				X
0101565401142003544D00D0810001AF	X			X	
0104560505122002544D00D0810000F4	X				X
0115291806142002544D00D0810000F7	X	X	X		X
0123404707222002544D00D081000124				X	
5701054706232003544D00D081000178	X	X		X	

Time History UUID	Conflict Description	Conflict Category
0018095908152002544D00D081000134	LV constant or decel and FV decel	2
0101051404142003544D00D0810001E3	LV & FV constant and no lane change	1
0101440905102002544D00D0810001E7	LV & FV constant and lane change	3
0101565401142003544D00D0810001AF	LV & FV constant and lane change	3
0104560505122002544D00D0810000F4	LV & FV constant and no lane change	1
0115291806142002544D00D0810000F7	LV constant or decel and FV decel	2
0123404707222002544D00D081000124	LV decel and FV constant	1
5701054706232003544D00D081000178	LV stopped and FV constant or decel	2

Each time history in Table D9-1 was examine using a Range/Range-Rate/Speed plot and an overhead X-Y plot. In order to give an indication of time and relative position of the vehicles in the X-Y plot, the size of the data points are increased each second. Each time history ends in a unique three letter identifier (indicating that eight different trucks are represented). The unique identifier will be used in the discussion for brevity.

Time history "134" did not meet the conservative KME criteria and was therefore excluded from the KME Conflict Definition group. Although the following vehicle did brake during the time history, at no time during the time history was the conflict severe enough to meet the KME criteria. Figure D9-1 gives the Range/Range-Rate/Speed plot and X-Y plot for "134".

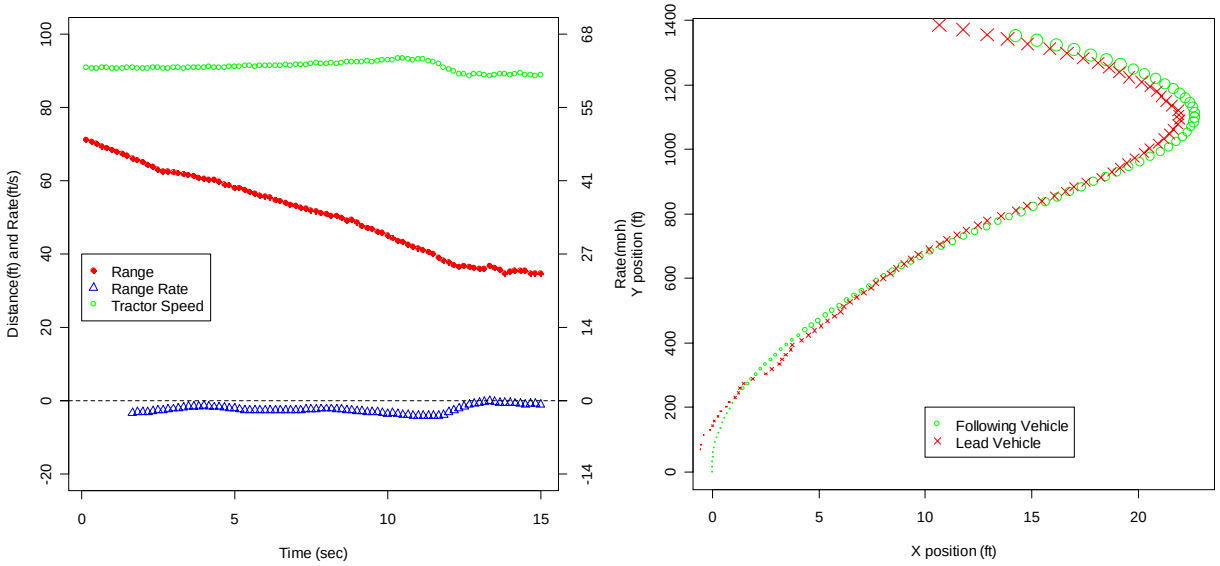

Figure D9-1. Range/Range-Rate/Speed Plot and Overhead X-Y plot for a Time History (UUID=0018095908152002544D00D081000134)

Time history "1E3" did not have complete data, and therefore was not analyzed. Time history "1E7" did not satisfy the conservative KME criteria. Figure D9-2 gives the profile for time history "1E7". In this time history, the conflict is resolved at 11 seconds due to the critical target disappearance. Although range is steadily decreasing over the time history, during the last time step in which the target was present, the required deceleration using the LVCS equation with a 1.5 second reaction time was 5.6 ft/s^2 (less than the 8 ft/s^2 required for the conservative criteria).

Time history "1AF" also did not satisfy the conservative KME criteria. Figure D9-3 shows this time history. Although there is decreasing range throughout the time history until the target disappears at 13.5 seconds, the driver did not recognize that his vehicle was in a conflict as he was accelerating from just before the FI trigger.

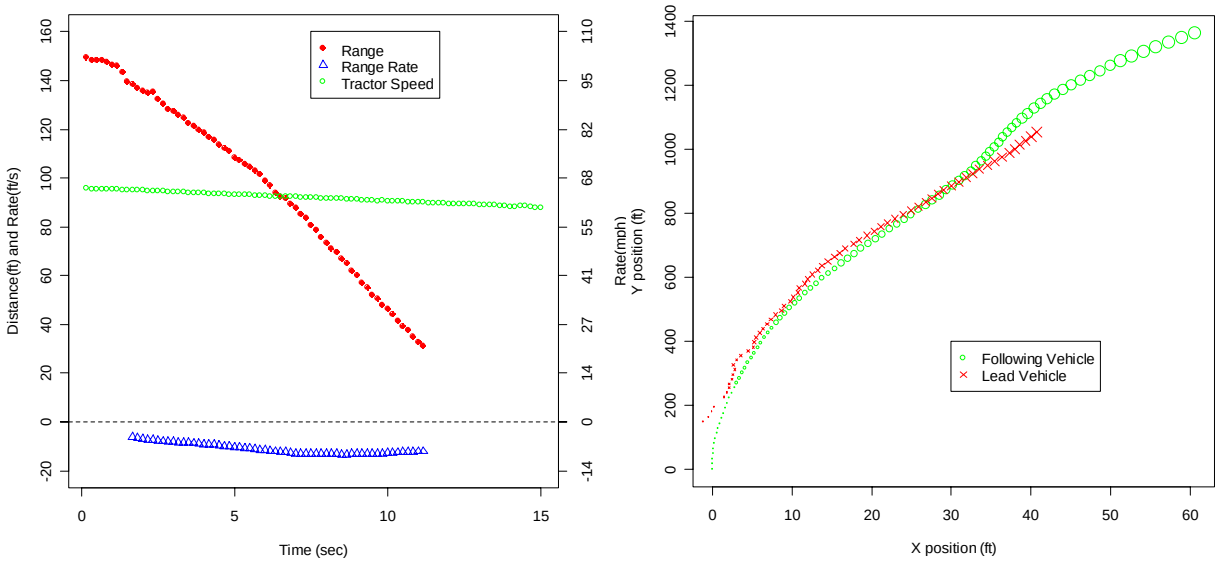

Figure D9-2. Range/Range-Rate/Speed plot and overhead X-Y plot for a Time History (UUID=0101440905102002544D00D0810001E7)

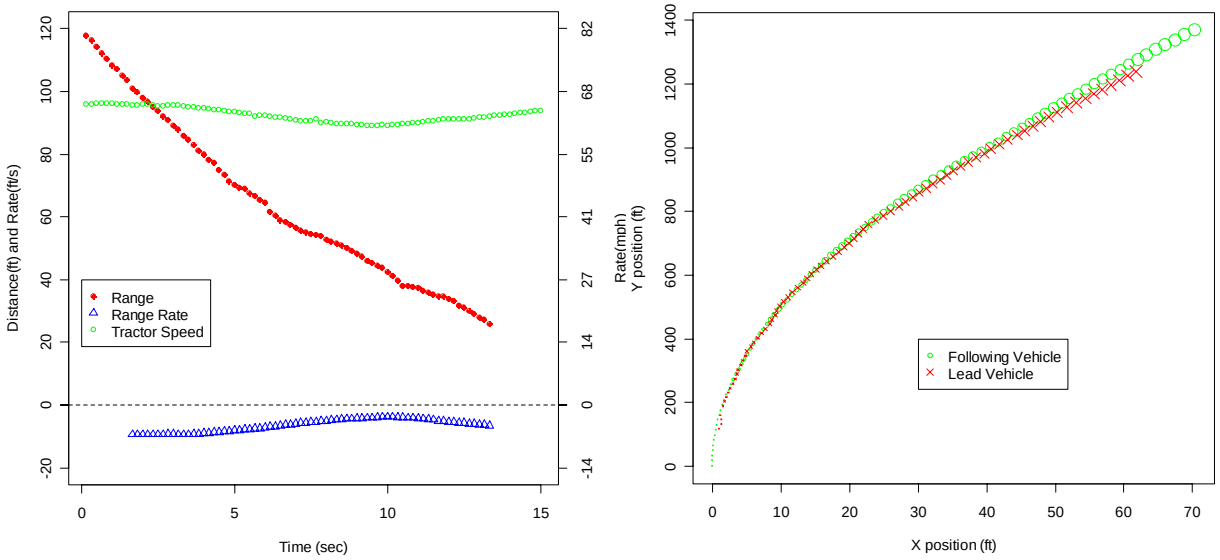

Figure D9-3. Range/Range-Rate/Speed plot and overhead X-Y plot for a Time History (UUID=0101565401142003544D00D0810001AF)

Time history "0F4" was excluded from the KME Conflict Definition group because it did not meet the conservative KME criteria. Figure D9-4 shows that there was a constant negative range rate and a steadily decreasing range. The conflict was most likely resolved by the lead vehicle as the driver did not react by braking or changing lanes during this time history.

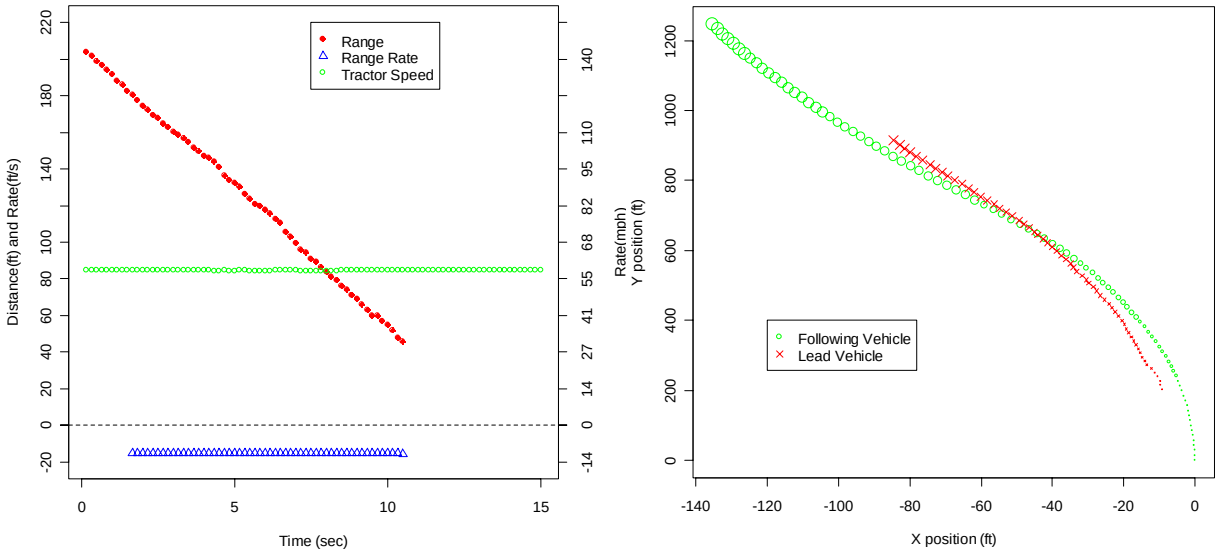

Figure D9-4. Range/Range-Rate/Speed plot and overhead X-Y plot for a Time History (UUID=0104560505122002544D00D0810000F4)

Time history "0F7" was considered a conflict in both the KME Conflict Definition and the Restricted KME conflict Definition. The kinematic analysis predicted that this event would have resulted in a crash if the driver had lagged his reaction (in this case, braking at the 4 second mark). Time history "0F7" is shown in Figure D9-5.

Another time history was selected with incomplete data, "124". No analysis was performed on it.

Finally, time history "128" was also considered a conflict, but only according to the KME Conflict Definition. The kinematic analysis predicted that there would not have been a collision, even if the driver had delayed his reaction for 15 seconds (in this case, a lane change at time 1.2 sec). Figure D9-6 shows that this was actually a short presence target which the Volvo Partnership identified as a possible radar return phantom, but did not exclude from their set of threats.

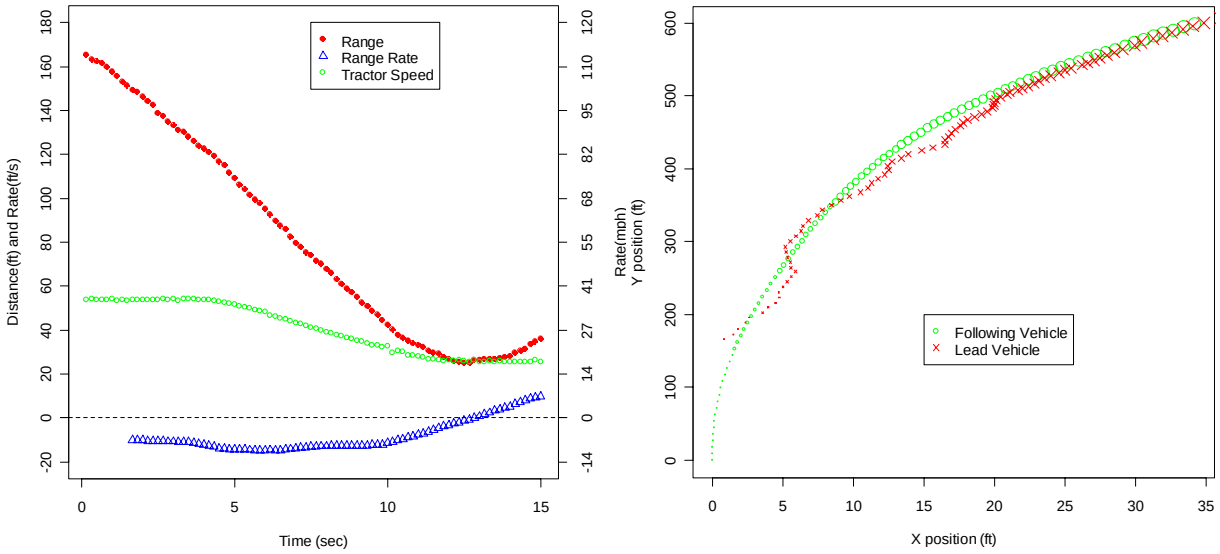

Figure D9-5. Range/Range-Rate/Speed plot and overhead X-Y plot for a Time History (UUID=0115291806142002544D00D0810000F7)

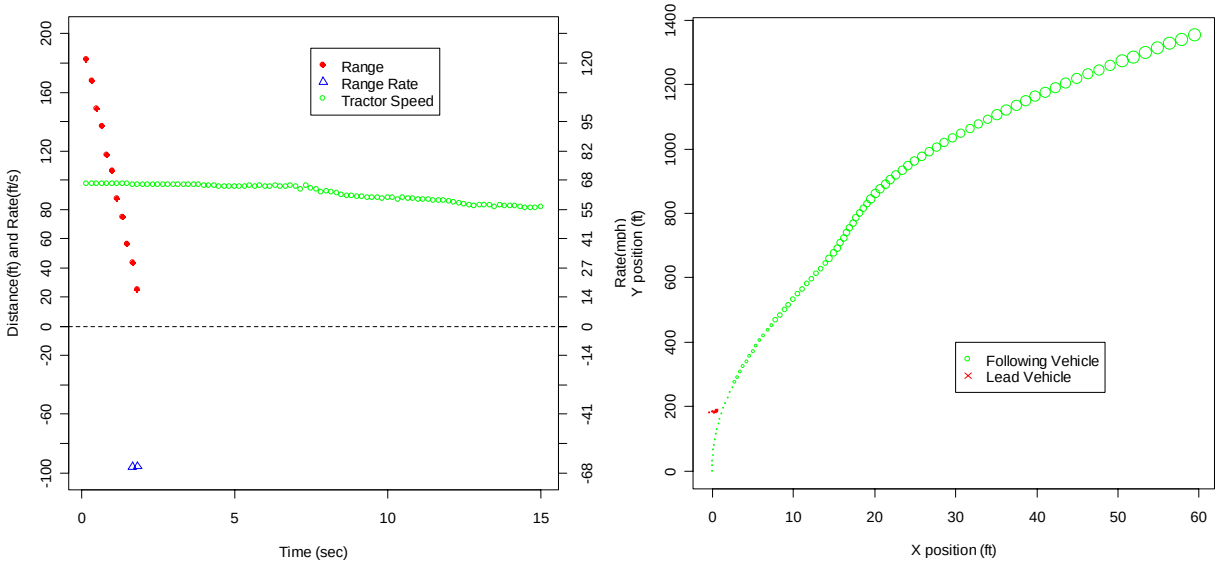

Figure D9-6. Range/Range-Rate/Speed plot and overhead X-Y plot for a Time History (UUID=5701054706232003544D00D081000178)

Appendix D10. Percent Reduction in Rear-End Crashes Simulation

The calculation of the percent reduction in Rear-End crashes involves the combination of four terms with different distributions. In the exposure ratio, the rate of conflicts with an IVI technology (numerator) and the rate of conflicts without an IVI technology (denominator) are Poisson distributed random variables. In the prevention ratio for the Restricted KME Conflict Definition, the lag times with and without an IVI technology are approximately lognormally distributed. In the KME Conflict Definition, the probability of a crash given a conflict category is approximately gamma distributed. The ratios and products of these distributions do not follow any standard, closed form distribution. Therefore, a simulation approach was employed to estimate the distribution of the percent reduction in rear-end crashes. The goal of this analysis is to assess the normality of the estimate of the percent reduction in rear-end crashes. If the distribution is not far from normal, then the standard assumptions about 2 standard deviations from the mean encompassing a 95% confidence interval is appropriate. However, if the distribution is not normally distributed, then calculating p-values based on a normal assumption is not valid.

Exposure Ratio

The rate of conflicts per mile times the VMT is assumed to be Poisson distributed with a rate parameter equal to the number of conflicts for a category. For example, Table 5.1-10a shows that the number of conflicts for the Restricted KME Conflict Definition, conservative threshold, baseline fleet, constant speed category is 31. The VMT associated with the baseline fleet is 395,935.

$$P(S)_{Threshold,\,Fleet,\,Category} \cdot VMT \sim \text{Poisson}(\lambda_{Threshold,\,Fleet,\,Category})$$
$$P(S)_{Conservative,\,Baseline,\,Constant\ Speed} \cdot 395{,}935 \sim \text{Poisson}(\lambda = 31)$$

In the simulation, one million samples are taken from the appropriate Poisson distribution, each sample is divided by the appropriate VMT, and then the appropriate ratios are constructed to create one million samples of the Exposure Ratio.

Prevention Ratio

Restricted KME Conflict Definition

In the Restricted KME Conflict Definition, the mean lag times calculated in the kinematic analysis are assumed to be lognormally distributed. The median of that distribution is equal to the geometric mean lag time. For example, Table 5.1-1 gives the geometric mean lag time for the Baseline fleet, conservative threshold, and constant speed conflict category as 1.220. In practice, it is easier and computationally equivalent to work with natural log transformed values. In this case, the mean of the transformed lag times is 0.198964, the variance is 0.506294, and the number of observations is 41. The calculation of the a_i parameter is omitted because it cancels from the numerator and denominator of the prevention ratio.

$$\overline{\tau}_{Threshold,Fleet,Category} \sim \text{LogNormal}\left(\overline{\ln \tau_{Threshold,Fleet,Category}}, \frac{V(\ln \tau_{Threshold,Fleet,Category})}{N}\right)$$

$$\overline{\tau}_{Conservative,Baseline,Constant\ Speed} \sim \text{LogNormal}\left(\overline{\ln \tau} = 0.198964, \frac{V(\ln \tau)}{N} = 0.506294/41\right)$$

In the simulation, one million samples are taken from the appropriate lognormal distribution and then the appropriate ratios are constructed to create one million samples of the Prevention Ratio.

KME Conflict Definition

In the KME Conflict Definition, the probabilities of a crash given a conflict category are assumed to be gamma distributed. A gamma distribution was chosen because it best fit the data. Table 5.1-2 gives the mean probability of a crash given the constant speed category for the conservative threshold and Baseline fleet as 0.009 and the number of observations as 734. The variance is 0.00206 (calculated separately). The parameters of the gamma distribution are found by the method of moments.

$$\overline{P_{Threshold,Fleet}(C \mid S_i)} \sim \text{Gamma}\left(\frac{N\left(\overline{P_{Threshold,Fleet}(C \mid S_i)}\right)^2}{V(P_{Threshold,Fleet}(C \mid S_i)}, \frac{V(P_{Threshold,Fleet}(C \mid S_i)}{\overline{P_{Threshold,Fleet}(C \mid S_i)}}\right)$$

$$\overline{P_{Conservative,Baseline}(C \mid S_1)} \sim \text{Gamma}\left(\frac{N\left(\overline{P_{Conservative,Baseline}(C \mid S_1)}\right)^2}{V(P_{Conservative,Baseline}(C \mid S_1)} = 31.50, \frac{V(P_{Conservative,Baseline}(C \mid S_1)}{\overline{P_{Conservative,Baseline}(C \mid S_1)}} = 0.22\right)$$

Again, one million samples are taken from the appropriate gamma distribution and then the appropriate ratios are constructed to create one million samples of the Prevention Ratio.

Percent Reduction in Crashes

Finally, the one million samples from each ratio are combined according to the same method as in Section 5.1 for calculating the percent reduction in crashes. Figures D10-1 and D10-2 reproduce Figures 5.1-12 and 5.1-13 for the Restricted KME Conflict Definition and the KME Conflict Definition respectively. Added to these figures are the non-parametric 95% confidence intervals from the results of the simulation. These confidence intervals are not intended to replace the confidence intervals from Section 5.1. However, these confidence intervals do give information about the normality assumption for the confidence intervals in Section 5.1. Similar conclusions are drawn from both Figures D10-1 and D10-2. First, the assumption of normality for the conservative and medium threshold is reasonable. Although differences exist, they are not extreme enough to reject the normality assumption of the percent reduction in crashes. However, for the aggressive threshold, there is evidence that the assumption of normality is not valid. For this reason, Tables 5.1-17 and 5.1-19 do not provide p-values based on the normal assumption for the aggressive threshold.

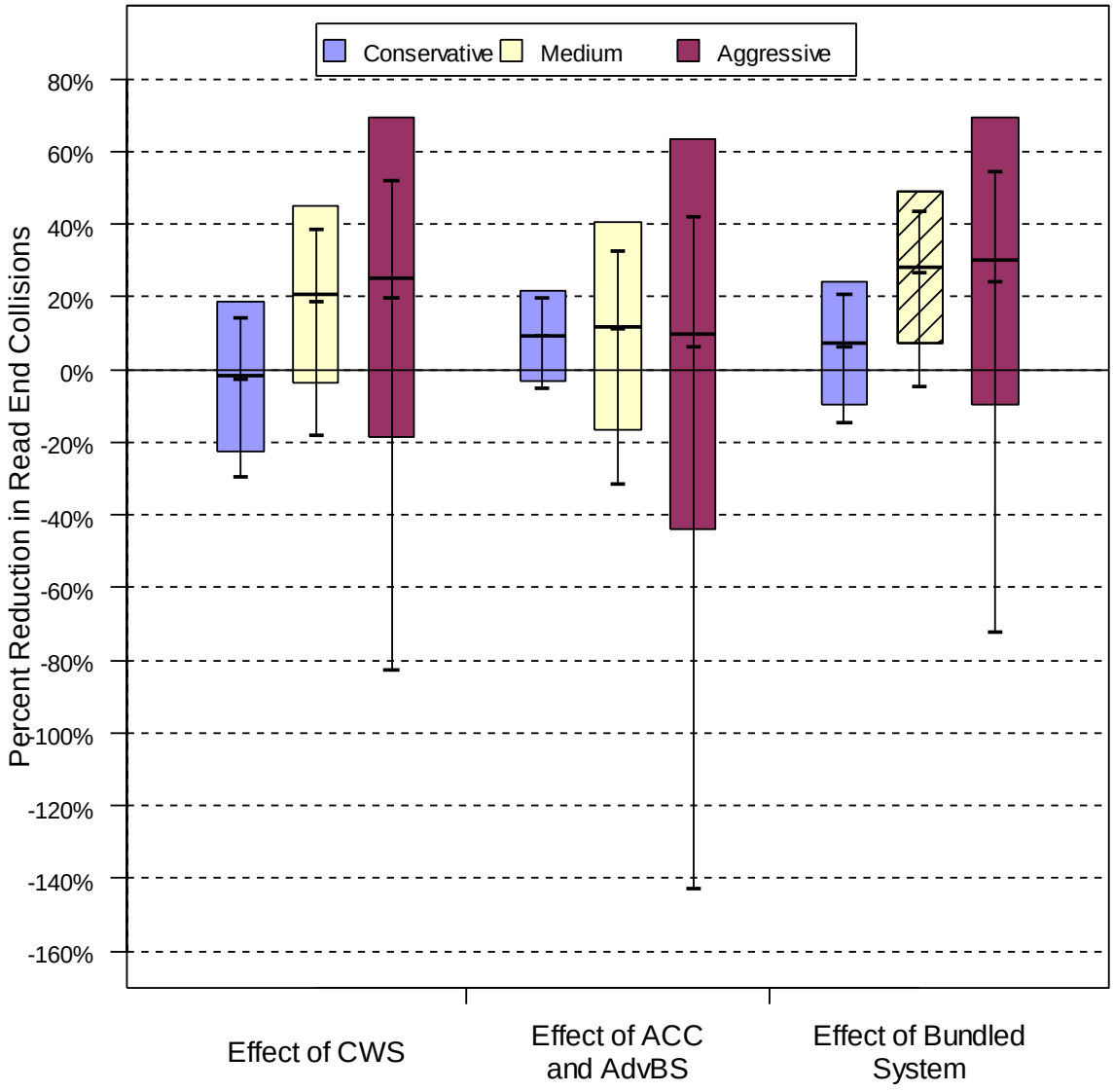

Figure D10-1. Estimated Percent Reduction in Rear-End Crashes Attributable to Deployment of Selected IVSS Technologies (Restricted KME Conflict Definition)

Colored error bars represent +/- two standard deviations

The thin, black error bars represent the results of the simulation

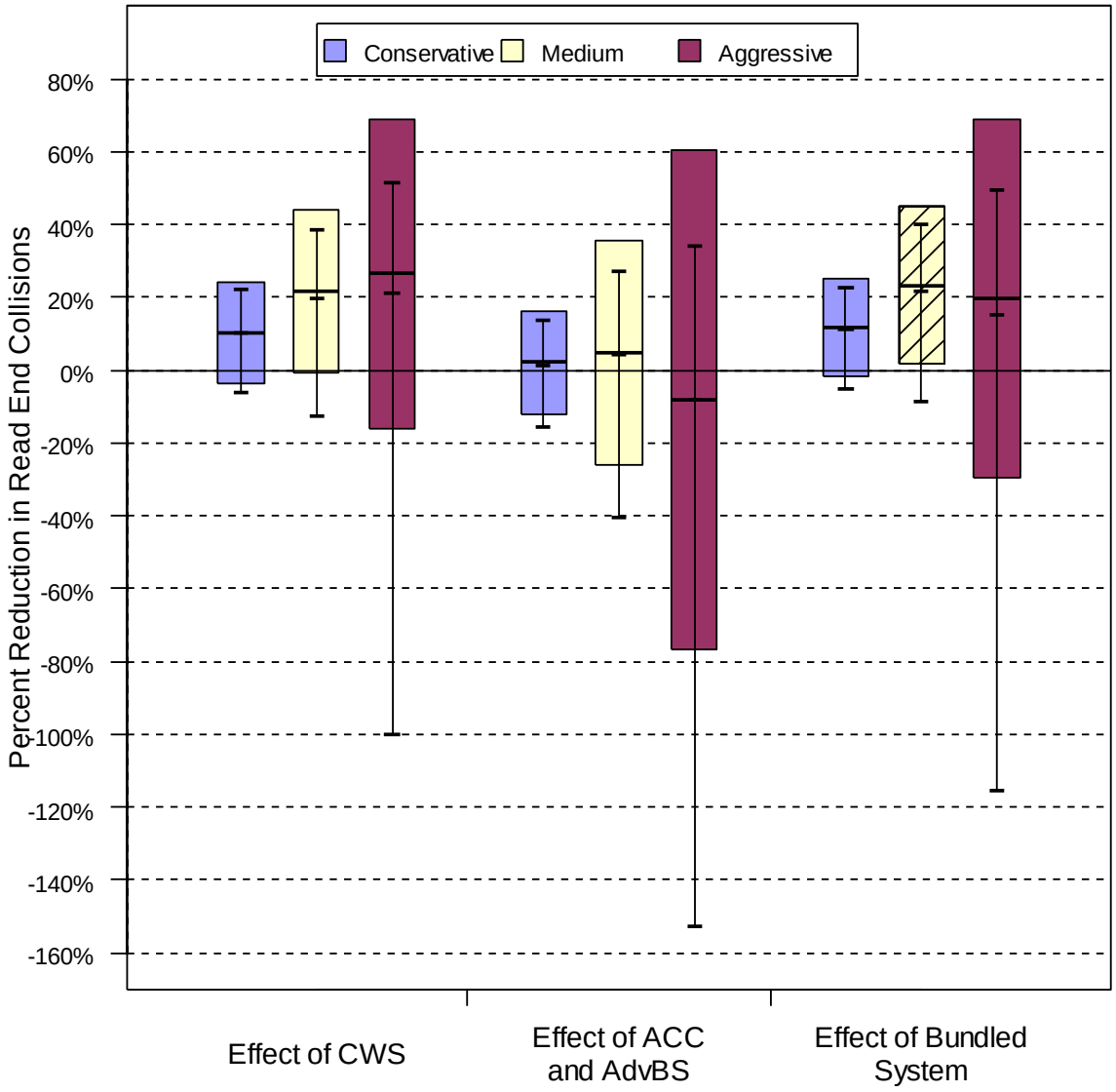

Figure D10-2. Estimated Percent Reduction in Rear-End Crashes Attributable to Deployment of Selected IVSS Technologies (KME Conflict Definition)

Colored error bars represent +/- two standard deviations

The thin, black error bars represent the results of the simulation

Appendix D11. Variance Estimates

The calculation of the variance of non-linear combinations of random variables is often accomplished with a Taylor series approximation, also known as the delta method (Hogg and Craig 1995). The prevention ratio and exposure ratio are both non-linear combinations of random variables, and an estimate of their variance can be calculated in this manner.

The result of the Taylor series approximation is that the variance of a function of a random variable, *f(X)*, is approximated by

$$Var\big(f(X)\big) \approx Var(X)\big[f'(\overline{X})\big]^2$$

where *f'(●)* is the first derivative, and $\overline{X}$ is the mean of the random variable.

In the case of a ratio of random variables, *X* and *Y*, this gives the following approximation

$$Var\left(\frac{X}{Y}\right) \approx Var(X)\left(\frac{1}{\overline{Y}}\right)^2 + Var(Y)\left(\frac{\overline{X}}{\overline{Y}^2}\right)^2$$

where the bar notation over the random variable indicates a mean value.

Exposure Ratio

For the exposure ratio, the variance is approximately equal to

$$Var(ER_i) = Var\left(\frac{P_W(S_i)}{P_{WO}(S_i)}\right) \approx Var\big(P_W(S_i)\big)\left(\frac{1}{\overline{P}_{WO}(S_i)}\right)^2 + Var\big(P_{WO}(S_i)\big)\left(\frac{\overline{P}_W(S_i)}{\overline{P}_{WO}(S_i)^2}\right)^2$$

where ER_i is the exposure ratio for conflict category *i*, $P_W(S_i)$ is the probability that driving conflict S_i occurred with a safety system, and the subscript WO indicates without a safety system. Because the probability that a conflict occurs is a Poisson random variable, the mean and variance are estimated by

$$\overline{P}_W(S_i) = \frac{N_i}{VMT_W}$$

$$Var\big(P_W(S_i)\big) = \frac{N_i}{VMT_W^2}$$

where N_i is the number of conflicts in category *i* which occurred in VMT_W vehicle miles traveled with the safety system. Similar calculations yield $P_{WO}(S_i)$.

Prevention Ratio

For the prevention ratio, KME conflict definition, the variance is approximately equal to

$$Var(PR_i) = Var\left(\frac{\overline{P}_W(C \mid S_i)}{\overline{P}_{WO}(C \mid S_i)}\right) \approx Var\left(\overline{P}_W(C \mid S_i)\right)\left(\frac{1}{\overline{P}_{WO}(C \mid S_i)}\right)^2 + Var\left(\overline{P}_{WO}(C \mid S_i)\right)\left(\frac{\overline{P}_W(C \mid S_i)}{\overline{P}_{WO}(C \mid S_i)^2}\right)^2$$

where $P_W(C|S_i)$ is the conditional probability that a rear end collision occurred given that a driving conflict in category *i* occurred with the safety system. $\overline{P}_W(C \mid S_i)$ and $Var\left(\overline{P}_W(C \mid S_i)\right)$ are calculated from the data obtained in Step 6 of section 4.3.3.

For the RKME conflict definition, the inverse of the geometric mean lag time was used to calculate the prevention ratio.

$$PR_i = \frac{\overline{P}_W(C \mid S_i)}{\overline{P}_{WO}(C \mid S_i)} = \frac{1/\overline{\tau}_W}{1/\overline{\tau}_{WO}}$$

where τ_W is the geometric mean lag time with a safety system.

Algebraic manipulation of this definition indicates

$$\ln(PR_i) = \ln(\overline{\tau}_{WO}) - \ln(\overline{\tau}_W)$$

Assuming independence between the geometric mean lag times

$$Var\left(\ln(PR_i)\right) = Var\left(\ln(\overline{\tau}_{WO})\right) + Var\left(\ln(\overline{\tau}_W)\right)$$

The $Var\left(\ln(\overline{\tau}_{WO})\right)$ is calculated from the variance in the natural logarithm of each lag time simulation.

Again, using the Taylor series approximation:

$$Var(PR_i) = e^{2\ln(PR)} Var\left(\ln(PR_i)\right)$$

Crash Reduction Ratio and Percent Reduction in Crashes

Finally, to find the variance in the crash reduction ratio

$$Var(CRR_i) = Var(ER_i PR_i) \approx ER_i^2 Var(PR_i) + PR_i^2 Var(ER_i)$$

where CRR_i is the crash reduction ratio for conflict category *i*. Assuming independence between the various conflict categories, the variance in the percent reduction in crashes (B) can be calculated in the following manner.

$$Var(B) = Var\left(\sum_{i=1}^{3} P_{WO}(S_i \mid C)(1 - CRR_i)\right) = \sum_{i=1}^{3} P_{WO}(S_i \mid C)^2 Var(CRR_i)$$

where CRR_i is the crash reduction ratio for conflict category i and $P_{WO}(S_i \mid C)$ are the percentages of each conflict category given a collision from GES.

Appendix D12. Comparison of Time History Filtering with the Volvo Partnership Report

A different data filtering procedure was used in the Volvo Partnership Report than is discussed in this report. Figure 6.2-1 of the Volvo Partnership Report shows the data reduction process used in that report. Figure D12-1 gives a comparison between the filtering processes in the two reports.

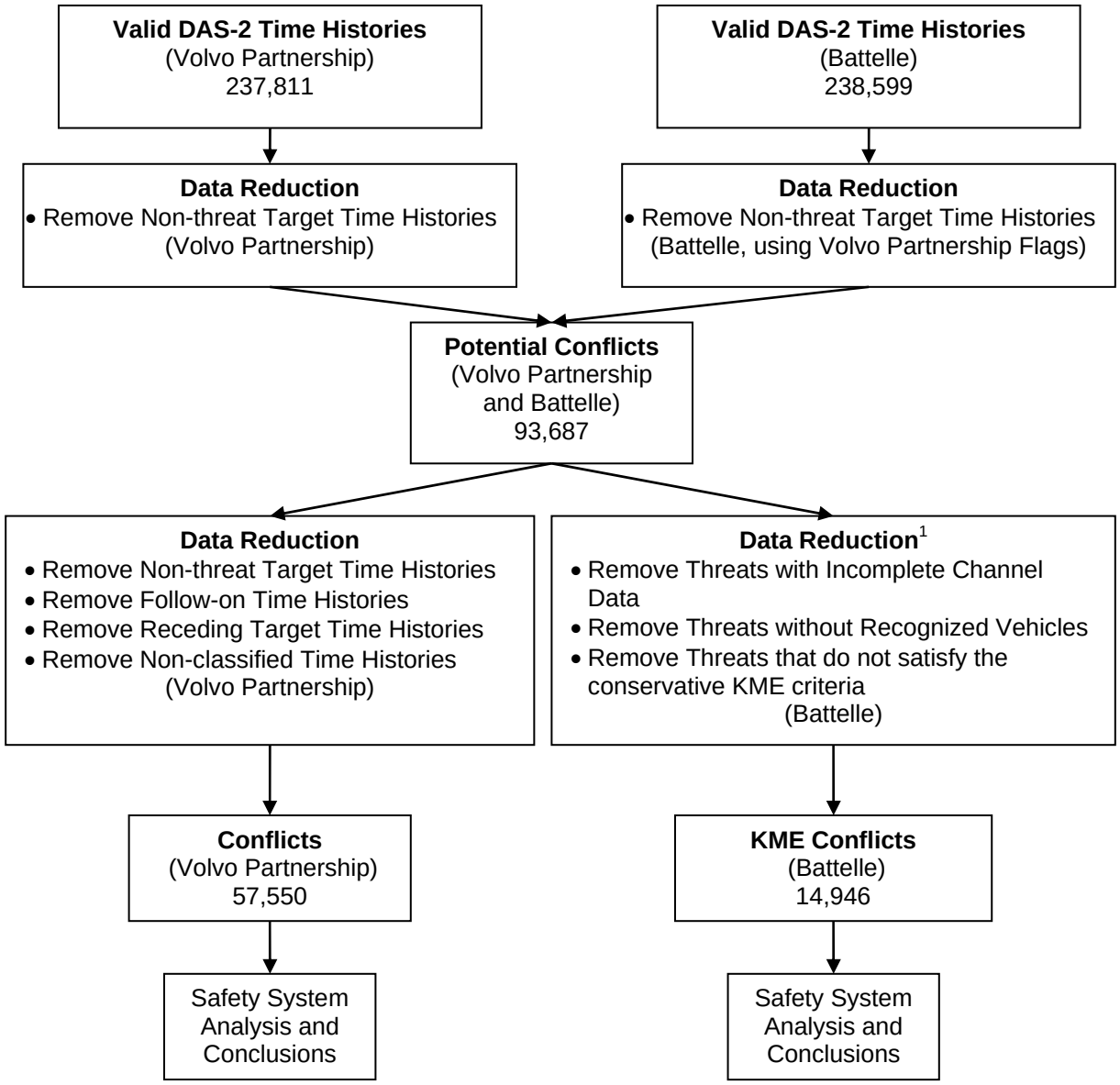

Figure D12-1. Comparison of Data Reduction Procedures in the Volvo Partnership Reports and Battelle Report

[1] See figure 4.3.5 and the associated text for the details of this process.

Both the Volvo Partnership and Battelle reports begin with the set of valid DAS-2 time histories. Valid DAS-2 time histories were identified by Battelle using data validation flags provided by the Volvo Partnership. No explanation for the small difference in reported numbers of valid DAS-2 time histories is given here. Battelle removed the non-threat target time histories using flags provided by the Volvo Partnership. Despite the differences in the starting sets of Valid DAS-2 time histories, both the Volvo Partnership and Battelle found 93,687 time histories before additional data reduction was undertaken.

Figure 6.2.1 of the Volvo Partnership report details the additional data reduction steps that were undertaken by the Volvo Partnership; those steps are summarized in Figure D12.1. The Volvo Partnership report had 57,550 time histories which it used to draw conclusions about the systems. Battelle's data reduction followed a different path as described in Section 4.3.3. The main distinguishing feature between the two methods was that Battelle did not exclude all follow-on time histories and Battelle used the conservative KME criteria to determine if a time history was in the set of time histories to be used to evaluate the safety systems. The 14,946 conflicts that Battelle used were a subset of the 57,550 conflicts in the Volvo Partnership Report.

Appendix D13. Sensitivity of the Lag Time Kinematic Algorithm to Following Vehicle Lane Changes

One of the important features of the kinematic algorithm described in Step 5 of Section 4.3.3 is that when the lead vehicle disappears before the end of a time history, the position of the lead vehicle is not extrapolated beyond that time when calculating the additional lag time available before the following vehicle needs to brake or steer to avoid a crash. If the lead vehicle disappears due to the actions of the lead vehicle, then those same actions are kept constant in the lag process. However, if the lead vehicle disappears due to the actions of the following vehicle, then it would have been more appropriate to predict the position of the lead vehicle when lagging the lane change time of the following vehicle. This analysis was not performed in creating the main results. This appendix explores the effect that these situations (following vehicle lane changes) might have on the results.

The first step was to identify the time histories which may have been excluded due to following vehicle lane changes in the Restricted KME Conflict Definition. Conflicts of interest were those with a lag time equal to 15 seconds, where the following vehicle executed a lane change and where there was a lead vehicle present prior to the lane change. These conflicts were then divided appropriately into fleets, kinematic thresholds, and conflict categories and then were added to the Restricted KME Conflict Definition exposure rates. In all, 1800 conflicts were added to the 2,203 conflicts in the Restricted KME Conflict Definition. The exposure ratio estimates are shown in Figure D13-1. There is no change in the exposure ratios for the KME Conflict Definition, since these 1,800 conflicts are already included in the 12,360 conflicts used to calculate those exposure ratios. Table D13-1 gives the percent increase in the conflict rate for each fleet and conflict category for the Restricted KME Conflict Definition and the conservative threshold.

Table D13-1. Percent Increase in the Conflict Rate for each Fleet and Conflict Category due to Following Vehicle Lane Changes (Restricted KME Conflict Definition, Conservative Threshold)

Fleet	Constant Speed	Slowing	Lane Change	Overall
Baseline	113%	84%	21%	79%
Control	107%	91%	34%	85%
Test	200%	88%	46%	92%

The exposure ratios shown in Figure D13-1 are different from those in Figure 5.1-8. Most notably, the ACC and AdvBS exhibit a significant dis-benefit for the constant speed category for all thresholds in Figure D13-1. Also, the effect of the CWS is significant in Figure D13-1 for the lane change category at the aggressive threshold.

The prevention ratios for both conflict definitions remain unchanged in this analysis. Future work can be performed to change the kinematic algorithm to project the lead vehicle position during following vehicle lane changes after the target has disappeared from the radar. A new

algorithm would be able to estimate the lag time for these conflicts, and this new set of lag times could be used to better estimate the prevention ratios.

Without the additional analysis to estimate the prevention ratios for both the KME and Restricted KME Conflict Definitions for the wider set of time histories considered to be conflicts in this appendix, it is difficult to infer safety benefits. However, the effect of the altered exposure ratios on the overall safety benefits are shown in Figure D13-2. There are two major differences between this figure and Figure 5.1-12. First, Figure D13-2 shows a consistent, although not statistically significant, dis-benefit for the effect of the ACC and AdvBS. Second, the effect of the bundled system is no longer significant for the medium threshold.

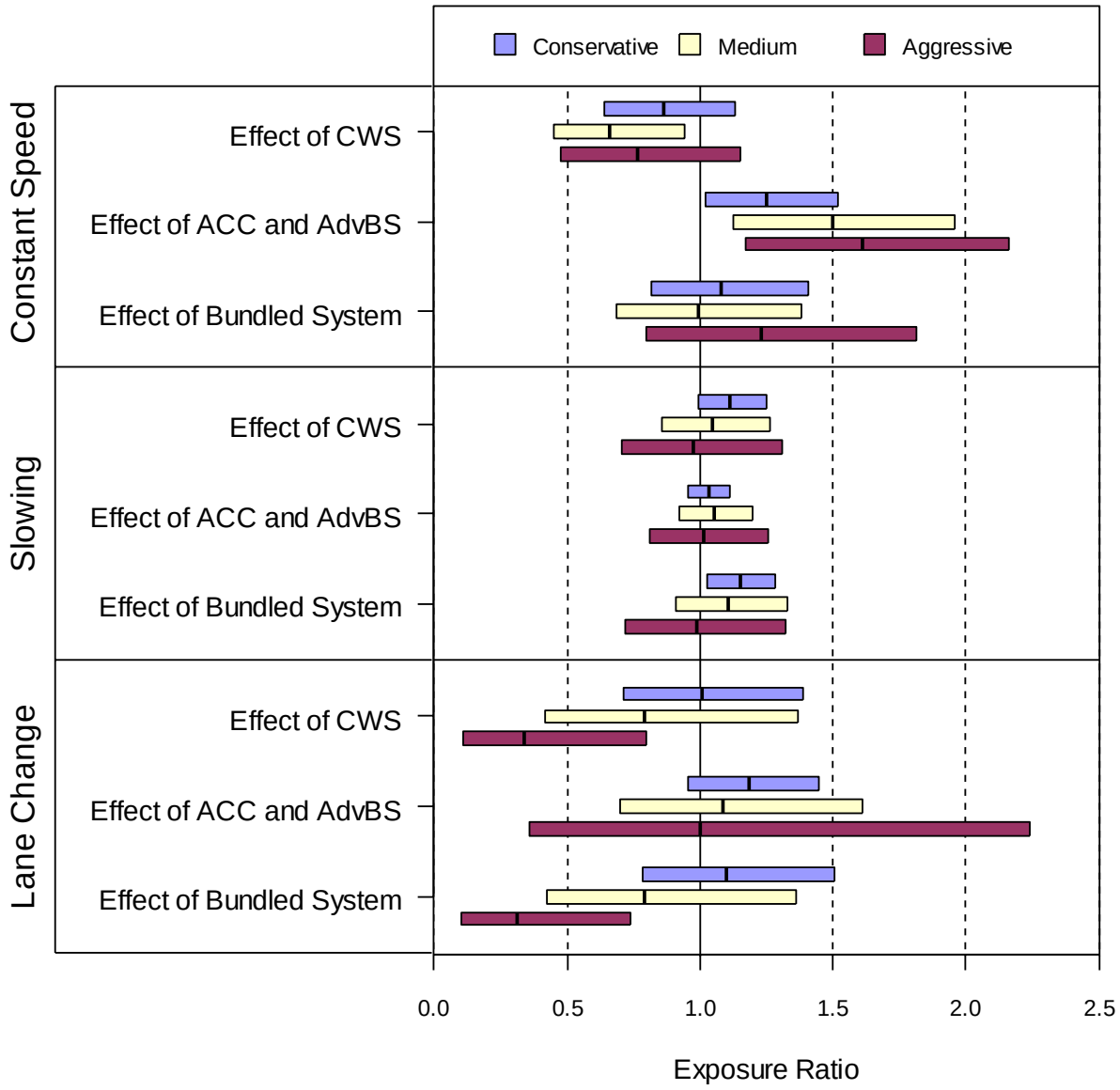

Figure D13-1 Exposure Ratios by Conflict Category, Fleet, and Threshold with 95% Confidence Intervals Including Time Histories where the Following Vehicle Executes a Lane Change to Avoid the Lead Vehicle.

Error bars denote +/- two standard errors; benefits are to the left of 1.00; disbenefits are to the right

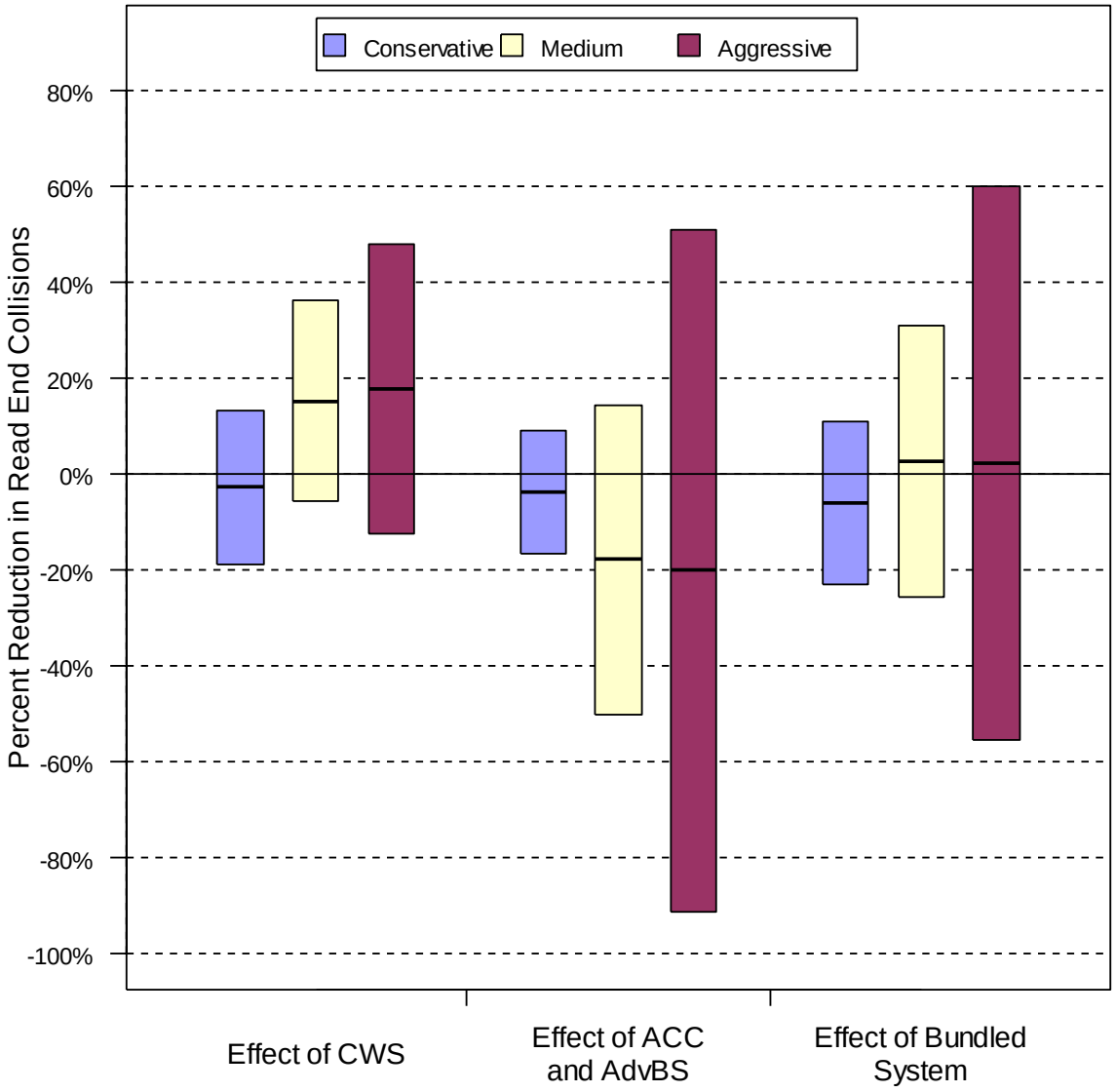

Figure D13-2. Estimated Percent Reduction in Rear-End Crashes Attributable to Deployment of Selected IVSS Technologies using the Restricted Kinetic Motion Equation (RKME) Conflict Definition Method Including Time Histories where the Following Vehicle Executes a Lane Change to Avoid the Lead Vehicle.

(Error Bars Represent Approximate 95% Confidence Intervals)

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APPENDIX E.

ENGINEERING DATA SUPPORTING DOCUMENTATION

Appendix E.

Engineering Data Supporting Documentation

Some of the changes that occurred during the FOT affected the collection of data onboard the vehicles. The Evaluation Team took these changes into consideration in the analyses conducted. However, to assist the readers in understanding the whole process, this appendix summarizes the changes, and documents how they may have impacted the Evaluation. The appendix also presents detailed information on vehicle data management.

Data Changes

The histogram data collected during the Volvo FOT remained consistent over the course of the FOT. The time history data collection triggers as well as the time history data channels changed a number of times due to requests for additional triggers and channels from Battelle and USDOT. When a new configuration file became available, some changes in time history triggers and channels were implemented through simple configuration file changes. All trucks did not receive the new configuration files at the same time. Trucks that called in, got all of their data uploaded, and still had time for a configuration download received the new configuration file. Because the channel azimuth—which was required for inferring the lateral motion of the lead vehicle—was not introduced until the configuration file released on May 31, 2001, only time history data collected based on that configuration file or a later one is appropriate for the safety benefits analysis.

During the course of the Volvo FOT, USDOT, in cooperation with the Volvo Partnership, implemented some changes to the data acquisition system (DAS) for trucks. This effort was initiated to gather new data to evaluate certain performance characteristics of the CWS, as well as to correct errors in the original DAS (referred to as DAS-1). This section details the data collected with the original DAS (DAS-1) as well as data collected with the updated DAS (DAS-2). Differences in time history channels between DAS-1 and DAS-2 are documented in Section 4.2.2.

Decisions concerning the data to be collected by DAS-1, such as which data elements to include and triggering mechanisms, were made jointly by USDOT, ATC, Mitretek, Volpe, and Battelle. The DAS was initially designed to trigger data collection in the form of 15-second time histories every time a VORAD alarm sounded. However, not only was this too costly to implement, due to the volume of data, it was also inadequate because it would not have included situations where a conflict existed but no alarm sounded. In the end, it was agreed that time history data collection would be triggered based on lateral and longitudinal acceleration, steering rate, time to collision, following interval, and kinematic motion equations derived by Battelle and Volpe. Only one of these criteria—less than 0.5-second following interval—corresponds to a VORAD alarm. Time history data collection triggers were not changed between DAS-1 and DAS-2.

Vehicle Data Management

1. Vehicle data bus: Vehicle data bus failures were identified when the ambient temperature reading was -273ºC. These failures caused all data elements collected from the data bus (e.g., vehicle speed) to be missing.

2. VORAD CWS data bus: Failures of the VORAD CWS data bus or sensor were indicated by constant target range data. In such instances, time history files triggered by VORAD conditions (Table 4.2-7) were not created, VORAD data elements recorded in time history files created by other triggers were invalid or missing, and events based on VORAD information could not appear in histogram data.

3. Steering angle sensor: Several measures were used to identify failures of the steering angle sensor.

    a. The primary failure mode for a steering angle sensor was identified by a nearly constant value for an entire time history, resulting in the standard deviation of the steering angle data collected in a history file being zero. The algorithm calculated the standard deviation of steering angle data for each time history file. All time history files collected during a histogram period were also flagged if more than 7% of the files had a standard deviation below 4 degrees.

    b. The steering sensor failure could also be identified by artificial spikes or other noncontinuous events, which would trigger a large number of time history files under the "Steering angle rate >120 deg/s" triggering condition. If 20% or more of the time history files created during a histogram period were triggered by "Steering angle rate >120 deg/s," the files were flagged.

    c. Another characteristic of the data collected by steering angle sensor was a drift over time. The drift was corrected by artificially recentering the steering angle data on a monthly basis prior to use in analyses.

    d. Steering angle data were derived from the VORAD yaw rate data element, when available.

4. Biaxial accelerometer sensor (fore/aft and lateral): Accelerometer failures were indicated by large constant accelerations, which led to the continuous triggering and recording of time history data.

Additional validation checks were performed by the Battelle Team to identify data inconsistency using information stored in the headers of histograms and time history files. Table E-1 summarizes header information for histograms and time history files.

- The Vehicle Miles Traveled (VMT) of each histogram reporting period was calculated by subtracting starting mileage (odometer start) from stopping mileage (odometer stop). When these calculations resulted in negative or unreasonably large numbers, mostly because either starting or stopping mileage was erroneously reported as zero, the VMT for the period was calculated by integrating the speed histogram.

- Header information was also used to match time history data to the histogram period during which the time history file was created.

Table E-1. Header Data Elements for Histogram and Time History Data Files

Channel	Time History	Histogram	
	Start	Start	Stop
Odometer	Yes	Yes	Yes
GPS Coordinates/Time	Yes	Yes	Yes
Ambient Temperature	Yes	Yes	Yes
VORAD Data Snapshots (Range, Azimuth & Relative Speed) for All Identified Targets	Yes	-	-

Various changes implemented throughout the FOT included:

- Changes in the original DAS design (referred to as DAS-1) to correct errors. The new DAS design was referred to as DAS-2.

- Changes in the list of measurement channels collected in time history files (Table 4.2-8):
  - "Target azimuth" data were added to infer the lateral motion of the lead vehicle
  - "ABS Active" data were added
  - "DDU Display Message Update" data were added and replaced "DDU Light" and "DDU Audio" data channels
  - "Following interval" and "Time to collision" data channels were deleted
  - "VORAD yaw rate" data were added to identify steering maneuvers.

- Collection of ATH files to evaluate certain performance characteristics of the CWS.

Because of the multiple requests for changes and because of the limited access to tractors, these changes were not all implemented at the same time. These changes also had consequences on the data analyses performed by the Evaluation Team. For example, only time history data files collected with azimuth information were appropriate for the safety benefits analysis.

DAS-1 Yaw Rate Calculations

Because the yaw rate became the primary measure used to assess lateral movement of the vehicle, only data collected with DAS-2 were validated and analyzed by the Volvo partnership and, thus, are the only data included in this report. DAS-1 utilized steering position for capturing the lateral movement of the truck. The algorithm below (labeled Steering to Yaw Conversion Algorithm) was developed for computing yaw rate from steering position prior to the decision to analyze only DAS-2 data.

Steering to Yaw Conversion Algorithm

1. Centered steering position was computed for each truck by subtracting off average steering position by truck and month

2. Variable calculated yaw was computed as follows:

   Yaw = –(centered steering position)(truck velocity)/(18*truck wheelbase)*

   where truck wheelbase was 18.3 feet

3. A 9-point moving average of calculated yaw was computed

4. This variable was lagged 4 time steps (2/3 of a second) and multiplied by 0.82492.

Average steering position was calculated by month as well as by truck because drift in average steering position over time was noted for many trucks. The 4 time step lag, the damping factor of 0.82492, and the moving average window of 9 were all chosen based on the analysis of an interim dataset available early in the FOT. This dataset consisted of data from trucks that were recording both yaw rate and steering position.