EPA-420-S-75-900

"STUDY OF POTENTIAL FOR MOTOR VEHICLE FUEL ECONOMY IMPROVEMENT"

SAFETY IMPLICATIONS PANEL REPORT

REPORT NO. 2 OF SEVEN PANEL REPORTS

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PREPARED BY
THE
U. S. DEPARTMENT OF TRANSPORTATION
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PREFACE

This Safety Implications Panel Report is Number Two (2) of a group of seven (7) prepared by special panels of the Task Force established under the joint chairmanship of DOT and EPA to conduct a study of the practicability of a fuel economy improvement standard of 20% for new motor vehicles produced in the 1980 time frame. Each panel addressed a major impact area and drew on a variety of sources in preparing its report, including previous DOT and EPA research, and industry and public comments.

Materials developed by the various study panels were used in preparing the Report to Congress entitled "Potential for Motor Vehicle Fuel Economy Improvement", dated 24 October 1974 (second printing, 18 November 1974). Assumptions and conclusions expressed in the panel reports, however, are those of the respective panels and do not necessarily reflect official positions or policies of the U.S. Department of Transportation, the U.S. Environmental Protection Agency, or the study Task Force.

The complete Panel Reports set consists of the following:

Report No. 1: Policy Assessment Panel Report
Report No. 2: Safety Implications Panel Report
Report No. 3: Air Quality and Emissions Panel Report
Report No. 4: Technology Panel Report
Report No. 5: Economics Panel Report
Report No. 6: Fuel Economy Test Procedures Panel Report
Report No. 7: Truck and Bus Panel Report

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1.0 FUEL ECONOMY AS A FUNCTION OF WEIGHT, PERFORMANCE, AND DRIVING SCHEDULE

The sensitivity of fuel economy to automobile weight depends strongly on the population or subpopulation of automobiles chosen for the determination of the sensitivity, and on the driving schedule under which the fuel economy is determined. The subject has been examined in several contexts and the main findings are summarized below:

In the context of the total U.S. auto fleet, information has been examined and assembled from generally available automobile statistics* and from EPA certification data based on simulated urban driving. The results are summarized in Tables** 1, 2, and 3 for model years 1974, 1973, and 1970 respectively. These findings are presented as a function of automobile market class and of manufacturer.

Further compression of this information may be obtained by a reasonable simplification. Specifically, the automobiles in the market classes of Standard, Intermediate and Specialty can be grouped together in a simple class under the label of "Large". Automobiles within this class of course differ appreciably in fuel economy, weight and other characteristics, but these differences are small compared to the differences observed between Large and Compact or, Subcompact automobiles. Such a compression scheme may be applied to any major entry in Tables 1, 2, and 3. As an example, it is offered here for the total U.S. fleet, in years 1973 and 1974. The results, appear in Table 4 which provides simplified baseline data.

The baseline data of Table 4 may be used for the evaluation of various scenarios regarding changes in the mix of

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*Wards Automotive Yearbook and Automotive News Almanac.

**Note that all data appearing in these tables are sales weighted averages, except the fuel economy data, which are sales weighted harmonic averages.

TABLE 1. FUEL ECONOMY (EPA CERTIFICATION DATA) AND OTHER STATISTICS BY AUTOMOBILE MARKET CLASS AND MANUFACTURER (MODEL YEAR 1974).

MKT CLASS / MFR	1974 *	STANDARD	INTERMED	COMPACT	SUBCOMPACT	SPECIALTY	ALL
GM	% SALES	16.8%	8.8%	4.9%	4.6%	7.2%	42.3%
	FUEL ECON	9.1	9.1	14.3	20.4	8.6	10.0
	INERTIA WT	4850	4307	3666	2782	4568	4327
	C.I.D.	405	332	303	140	387	346
	WT/C.I.D.	12.0	13.0	12.1	19.9	11.8	13.0
	AXLE RATIO	2.84	2.88	3.04	2.53	3.05	2.87
FORD	% SALES	6.9%	4.8%	3.4%	4.5%	4.7%	24.3%
	FUEL ECON	9.4	10.5	15.2	19.2	14.4	12.3
	INERTIA WT	5031	4500	3500	3000	3938	4124
	C.I.D.	401	329	258	122	276	291
	WT/C.I.D.	12.5	13.7	13.6	24.6	14.3	15.5
	AXLE RATIO	2.81	2.86	2.91	3.47	3.21	3.03
CHRYSLER	% SALES	3.8%	2.9%	6.0 %		0.3%	13.0%
	FUEL ECON	8.9	10.1	14.6			11.3
	INERTIA WT	4828	4000	3500		3753	4002
	C.I.D.	409	309	229		380	303
	WT/ C.I.D.	11.8	12.9	15.3		9.9	13.6
	AXLE RATIO	2.74	3.06	3.15		--	3.00
AMC	% SALES	0.3%	0.7%	1.5%	1.3%	0.3%	4.1%
	FUEL ECON	10.4	11.3	13.9	14.9	11.8	13.2
	INERTIA WT	4160	4022	3230	3039	3487	3394
	C.I.D.	332	298	250	250	304	268
	WT/C.I.D.	12.5	13.5	12.9	12.2	11.5	12.6
	AXLE RATIO	3.15	3.19	3.20	3.54	3.54	3.30
VW	% SALES				4.2%		4.2%
	FUEL ECON				21.6 **		21.6**
	INERTIA WT				2350 **		2350 **
	C.I.D.				96 **		96 **
	WT/C.I.D.				24.5**		24.5**
	AXLE RATIO				3.90 **		3.90**
TOYOTA	% SALES				2.6%		2.6%
	FUEL ECON				19.8 **		19.8**
	INERTIA WT				2375 **		2375 **
	C.I.D.				106 **		106 **
	WT/C.I.D.				22.4**		22.4**
	AXLE RATIO				3.90 **		3.90 **
OTHER IMPORTS	% SALES			1.6%	7.9 %		9.5%
	FUEL ECON			16.1**	17.4 **		17.2**
	INERTIA WT			3050**	2525 **		2613**
	C.I.D.			121**	104 **		107**
	WT/C.I.D.			25.2**	24.3**		24.4**
	AXLE RATIO			4.10**	3.68 **		3.75**
TOTAL DOMESTIC	% SALES	27.8%	17.2%	15.8%	10.4%	12.5%	83.7%
	FUEL ECON	9.2	9.7	14.6	19.0	10.3	10.9
	INERTIA WT	4884	4292	3522	2908	4283	4169
	C.I.D.	403	325	260	153	342	320
	WT/C.I.D.	12.1	13.2	13.5	19.0	12.5	13.5
	AXLE RATIO		2.91	3.18	3.06	3.10	3.07
TOTAL IMPORTS	% SALES			1.6%	14.7%		16.3%
	FUEL ECON			16.1	18.9		18.6
	INERTIA WT			3050	2450		2509
	C.I.D.			121	102		104
	WT/C.I.D.			25.2	24.0		24.1
	AXLE RATIO			4.10	3.79		3.82
ALL	% SALES	27.8%	17.2%	17.4%	25.1%	12.5%	100%
	FUEL ECON	9.2	9.7	14.7	18.9	10.3	11.8
	INERTIA WT	4884	4292	3506	2642	4283	3904
	C.I.D.	403	325	260	123	342	287
	WT/C.I.D.	12.1	13.2	13.5	21.5	12.5	14.9
	AXLE RATIO		2.91	3.18	3.48	3.10	3.17

Source: Sales & specs from Automotive News *7 months ** Estimate

TABLE 2. FUEL ECONOMY (EPA CERTIFICATION DATA) AND OTHER STATISTICS BY AUTOMOBILE MARKET CLASS AND MANUFACTURER (MODEL YEAR 1973).

MFR \ CLASS	1973	STANDARD	INTERMED	COMPACT	SUBCOMPACT	SPECIALTY	ALL
GM	% SALES	19.0%	11.4%	4.6%	4.0%	6.7%	45.7%
	FUEL ECON	10.0	10.7	12.7	19.4	9.5	10.8
	INERTIA WT	4848	4357	3546	2500	4299	4308
	C.I.D.	391	350	315	140	392	351
	WT/C.I.D.	12.4	12.4	11.3	17.9	11.0	12.6
	AXLE RATIO	2.91	3.13	3.07	2.63	3.05	2.98
FORD	% SALES	8.0%	5.1%	3.2%	4.3%	3.1%	23.7%
	FUEL ECON	8.9	8.7	12.9	19.2	8.3	10.2
	INERTIA WT	4635	4000	3000	2750	4282	3889
	C.I.D.	396	336	271	119	388	315
	WT/C.I.D.	11.7	11.9	11.1	23.1	11.0	13.6
	AXLE RATIO	2.75	3.15	2.98	3.49	2.86	3.02
CHRYSLER	% SALES	4.5%	3.0%	5.2%		0.4%	13.1%
	FUEL ECON	10.0	9.9	16.2		10.0	11.8
	INERTIA WT	4671	4000	3376		3500	3968
	C.I.D.	375	323	246		360	311
	WT/ C.I.D.	12.5	12.4	13.7		9.7	12.9
	AXLE RATIO	3.12	3.23	3.23		3.23	3.19
AMC	% SALES	0.3%	0.5%	1.2%	1.2%	0.2%	3.4%
	FUEL ECON	11.2	12.2	18.9	18.0	12.9	15.9
	INERTIA WT	4379	4214	3427	3259	3434	3568
	C.I.D.	332	306	251	251	304	269
	WT/C.I.D.	13.2	13.8	13.7	13.0	11.3	13.3
	AXLE RATIO	3.15	3.15	2.73	2.73	3.54	2.88
VW	% SALES				3.9%		3.9%
	FUEL ECON				22.0		22.0
	INERTIA WT				2316		2316
	C.I.D.				96		96
	WT/C.I.D.				24.1		24.1
	AXLE RATIO				3.83		3.83
TOYOTA	% SALES				2.0%	0.5%	2.5%
	FUEL ECON				20.4	19.0	20.1
	INERTIA WT				2398	2600	2438
	C.I.D.				106	120	109
	WT/C.I.D.				22.6	21.7	22.4
	AXLE RATIO				3.8	3.7	3.78
OTHER IMPORTS	% SALES		0.4%	0.6%	6.2%	0.5%	7.7%
	FUEL ECON		13.3	16.2	19.9	18.6	19.0
	INERTIA WT		4000	--	2470	2500	2558
	C.I.D.		168	--	100	143	107
	WT/C.I.D.		23.8		24.7	17.5	24.1
	AXLE RATIO		3.92	--	3.63	4.43	3.70
TOTAL DOMESTIC	% SALES	31.8%	20.0%	14.2%	9.5%	10.4%	85.9%
	FUEL ECON	9.7	10.0	14.3	19.1	9.2	10.9
	INERTIA WT	4925	4456	3389	2738	4090	4219
	C.I.D.	389	341	274	124	387	329
	WT/C.I.D.	12.3	13.1	12.4	22.1	10.6	13.5
	AXLE RATIO	2.90	3.15	3.08	3.02	3.01	3.01
TOTAL IMPORTS	% SALES		0.4%	0.6%	12.1%	1.0%	14.1%
	FUEL ECON		13.3	16.2	20.6	18.8	19.9
	INERTIA WT		4000	--	2415	2500	2468
	C.I.D.		168	--	99	130	103
	WT/C.I.D.		23.8	--	24.4	19.2	24.0
	AXLE RATIO		3.92	--	3.36	4.01	3.42
ALL	% SALES	31.8%	20.4%	14.8%	21.6%	11.4%	100.0%
	FUEL ECON	9.7	10.0	14.4	19.9	9.6	11.6
	INERTIA WT	4925	4447	3389	2557	3963	3979
	C.I.D.	389	337	274	110	366	298
	WT/C.I.D.	12.7	13.2	12.4	23.2	10.8	14.8
	AXLE RATIO	2.90	3.17	3.08	3.15	3.09	3.06

Source: Sales & specs from Automotive News, Wards Automotive

TABLE 3. FUEL ECONOMY (EPA CERTIFICATION DATA) AND OTHER STATISTICS BY AUTOMOBILE MARKET CLASS AND MANUFACTURER (MODEL YEAR 1970).

MKT CLASS / MFR	1970	STANDARD	INTERMED	COMPACT	SUBCOMPACT	SPECIALTY	ALL
GM	% SALES	20.0%	12.0%	2.9%	0.3%	5.5%	40.7%
	FUEL ECON	10.9	13.1	13.7	--	11.7	11.6
	INERTIA WT	4720	4041	3500	2500	4005	4320
	C.I.D.	389	334	264	140	358	358
	WT/C.I.D.	12.2	12.1	13.3	17.9	11.2	12.2
	AXLE RATIO	3.07	3.10	3.09	2.53	3.52	3.12
FORD	% SALES	12.5%	5.4%	4.8%	0.9%	3.6%	27.2%
	FUEL ECON	11.1	11.7	19.2	--	11.5	12.2
	INERTIA WT	4526	4000	2814	2250	3938	3967
	C.I.D.	359	293	177	110	323	323
	WT/C.I.D.	12.6	13.7	15.9	20.5	12.2	13.7
	AXLE RATIO	3.13	2.81	2.84	3.55	2.98	3.01
CHRYSLER	% SALES	6.4%	3.1%	5.3%		1.6%	16.4%
	FUEL ECON	12.3	13.3	15.3		12.0	13.3
	INERTIA WT	4587	3755	3500		3850	4007
	C.I.D.	346	302	244		321	302
	WT/ C.I.D.	13.3	12.4	14.3		12.0	13.3
	AXLE RATIO	3.08	3.07	3.22		3.23	3.14
AMC	% SALES		1.2%	1.0%	0.5%	0.4%	3.1%
	FUEL ECON		13.1	16.5	17.9	15.2	15.0
	INERTIA.WT		3913	3000	3000	3500	3419
	C.I.D.		284	207	199	298	247
	WT/C.I.D.		13.8	14.5	15.1	11.7	14.0
	AXLE RATIO		2.94	2.96	2.73	3.15	2.95
VW	% SALES				7.0%		7.0%
	FUEL ECON				21.4 *		21.4 *
	INERTIA WT				2379		2379
	C.I.D.				97		97
	WT/C.I.D.				24.5		24.5
	AXLE RATIO				4.13		4.13
TOYOTA	% SALES			0.1%	2.2%		2.3%
	FUEL ECON			14.7	23.0 *		23.0
	INERTIA WT			3500	2412		2459
	C.I.D.			138	100		102
	WT/C.I.D.			25.4	24.1		24.2
	AXLE RATIO			4.11	3.90		3.91
OTHER IMPORTS	% SALES			0.5%	2.9%		3.4%
	FUEL ECON			--	20.0 *		20.0 *
	INERTIA WT			3072	2343		2450
	C.I.D.			130	83		90
	WT/C.I.D.			23.6	28.2		27.6
	AXLE RATIO			4.11	4.01		4.03
TOTAL DOMESTIC	% SALES	38.9%	21.7%	14.0%	1.7%	11.1%	87.4%
	FUEL ECON	11.2	12.7	16.1	--	11.8	12.2
	INERTIA WT	4636	3979	3230	2500	3941	4116
	C.I.D.	372	317	222	140	339	326
	WT/C.I.D.	12.5	12.6	14.5	17.9	11.6	12.9
	AXLE RATIO	3.08	3.01	3.08	3.16	3.28	3.09
TOTAL IMPORTS	% SALES			0.6%	12.1%		12.7%
	FUEL ECON			--	21.3		21.3
	INERTIA.WT			3128	2364		2400
	C.I.D.			131	94		96
	WT/C.I.D.			23.9	25.1		25.0
	AXLE RATIO			4.11	4.03		4.03
ALL	% SALES	38.9%	21.7%	14.6%	13.8%	11.1%	100%
	FUEL ECON	11.2	12.7	16.1	21.0	11.8	12.9
	INERTIA WT	4636	3979	3225	2381	3941	3902
	C.I.D.	372	317	218	100	339	297
	WT/C.I.D.	12.5	12.6	14.8	23.8	11.6	14.3
	AXLE RATIO	3.08	3.01	3.12	3.91	3.28	3.20

Source: Sales & specs from Automotive News

* Estimate

TABLE 4. SIMPLIFIED BASELINE DATA FOR 1973 AND 1974 U.S. AUTO FLEETS

	1973				1974			
	LARGE	COMPACT	SUBCOMP.	ALL	LARGE	COMPACT	SUBCOMP.	ALL
% SALES	63.6	14.8	21.6	100	57.5	17.5	25.0	100
FUEL ECONOMY MPG	9.8	14.4	19.9	11.6	9.6	14.7	18.9	11.8
INERTIA WT LBS	4600	3390	2560	3980	4580	3510	2640	3910
C.I.D.	368	274	110	298	366	260	123	287
WT/C.I.D.	12.5	12.4	23.3	14.8	12.5	13.5	21.5	14.9

SOURCE: TABLE 1 AND 2.

the U.S. fleet. The three appearing classes, namely Large, Compact and Subcompact may be thought of as six, five and four passenger cars respectively. A further entry, if desired, may be made regarding a safety figure of merit as a function of the automobile weight. Thus, simple trade-offs can be exercised.

In the context of individual automobiles, no significant test data are available regarding the effects of automobile weight, performance and driving schedule on fuel economy. Thus, the approach followed here consists of utilizing extensively test data available for engines, drive trains and other automobile components of the 1973 model year. Such data have been used in conjunction with simulated automobile travel under various driving schedules of current interest.

Table 5 gives the values of the sensitivity coefficient of fuel economy to:

(1) a weight change (without other changes)
(2) a weight change accompanied by a proportional change in engine displacement, (weight/CID ratio unchanged)
(3) an engine displacement change (without other changes)

The sensitivity coefficient in each case gives the percent change in fuel economy per one percent change of weight or other parameter as shown. Alternatively the sensitivity coefficient may be visualized as the slope of the percent variation of fuel economy plotted against the percent variation of automobile weight, or engine size. The three cases are shown in Figures 1 and 2. These illustrations correspond to the entries made under EPA Composite Driving Schedule, in Table 5.

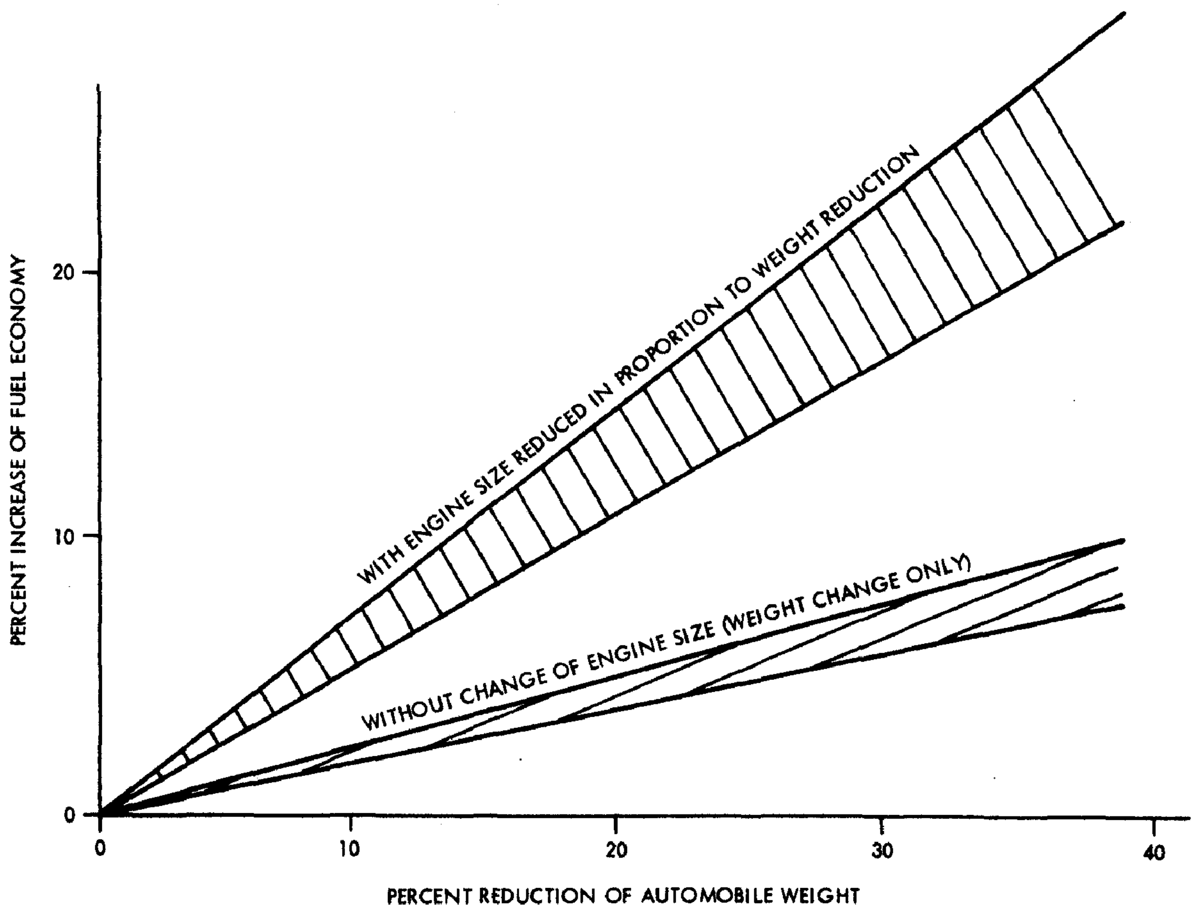
Note that various driving schedules of current interest have been considered. The results appearing under composite schedules are suggested as fair indicators of fuel economy under conditions of nation-wide mileage accumulation. Specifically, the EPA Composite is a harmonic average of EPA Urban

TABLE 5. SUMMARY OF RESULTS REGARDING THE SENSITIVITY COEFFICIENT OF FUEL ECONOMY TO VARIOUS CHANGES AND DRIVING CONDITIONS

DRIVING TYPE SCHED OF CHANGE	EPA URBAN	EPA HIGHWAY	SAE URBAN	SAE SUBURBAN	SAE(55 MPH) INTERSTATE	SAE(70 MPH) INTERSTATE	EPA COMPOSITE	SAE(55 MPH) COMPOSITE	SAE(70 MPH) COMPOSITE
WT. CHANGE ONLY*	.26 ±.04	.21 ±.04	.31 ±.06	.31 ±.08	.15 ±.04	.20 ±.05	.25 ±.04	.26 ±.04	.27 ±.03
WT. CHANGE; (WT/C.I.D.) CONSTANT*	.70 ±.09	.65 ±.13	.75 ±.11	.74 ±.10	.54 ±.08	.57 ±.15	.68 ±.10	.68 ±.08	.68 ±.10
C.I.D. CHANGE ONLY*	.43 ±.09	.44 ±.13	.41 ±.11	.44 ±.12	.37 ±.08	.38 ±.15	.44 ±.09	.41 ±.08	.41 ±.10

*CHANGE IN FUEL ECONOMY PER ONE PERCENT PARAMETER CHANGE.

and EPA Highway, weighted respectively 55% and 45%, to reflect FHWA statistics of nation-wide driving. Similarly the SAE composites include 27.5% SAE Urban, 27.5% SAE Suburban and 45% of SAE Interstate at either 55 MPH or 70 MPH. It is evident that when composites are used, the differences between driving schedules are minimized.



Source: Table 5, EPA Composite

Figure 1. Bounds of Fuel Economy Improvement From Automobile Weight Reduction With and Without Engine Resizing

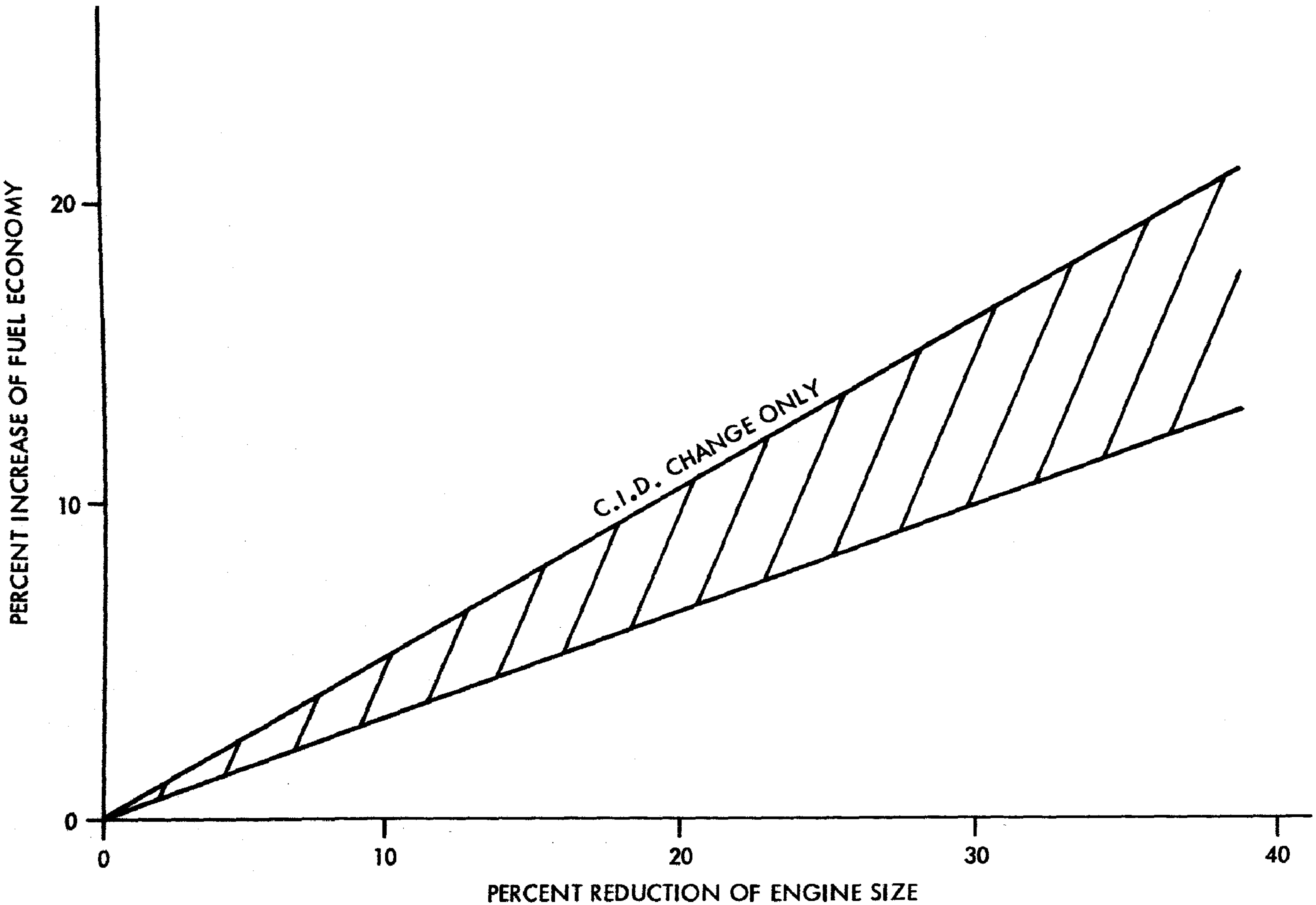


Figure 2. Bounds of Fuel Economy Improvement From Reduction of Engine Size

Source: Table 5, EPA Composite

2.0 TRAFFIC CONTROL FOR SAFETY AND FUEL ECONOMY

The primary emphasis of the U.S. Department of Transportation is to promote the safe and efficient movement of both people and goods throughout our country. Safety is usually measured in the number of accidents, injuries and/or fatalities along with their associated social and monetary costs. Efficiency can be indicated by travel times, fuel consumption, comfort, convenience and other user costs associated with the operation of the facilities involved. Because of the recent energy crisis, the measure of fuel consumption has become one of the more prominent measures of efficiency. Therefore it behooves the Department of Transportation to embark on a major effort to improve the safety and fuel conservation of our transportation systems.

One of the major potential methods to improve the operational safety and efficiency of our street and highway system is through the improvement of the operational controls for the traffic using these facilities. Studies have shown that motor vehicles traveling at a uniform speed of about 35 miles per hour provide the highest mileage rates per unit of fuel consumed.(1) At approximately 35 mph our controlled-access roadways operate at their peak potential capacity and we obtain maximum throughput.(2) Uniform speed without vehicle or pedestrian conflicts also provides the safest traffic flows.(3) Therefore, the application of appropriate traffic surveillance, communication and controls, can substantially improve the movement of people and goods over our roadways network.

The traffic signal is one of the basic traffic control devices used on our urban streets. Its function is to assign the right-of-way to conflicting streams of traffic at roadway intersections. In cities of 1/2 to 1 million people, 60 percent of the signalized intersections are periodically congested.(4)

With modern technology, the timing of these traffic signals can be adjusted and coordinated to promote continuous movements for major platoons through the street network thus providing travel time saving and fuel conservation. Through the proper timing of traffic signals, the number of stops can be minimized thus saving fuel and improving safety by reducing the chance for rear-end accidents. Through vehicle detectors located on the approaches to signalized intersections, traffic flow information can be collected and traffic signal timing patterns can be determined by electronic computer traffic signal controllers to assign green times to keep most of the traffic moving at all times. The fluctuation of traffic demands requires a flexible traffic control system to best serve these demands.

The electronic digital computer can best supply this control flexibility. It is estimated that the implementation of modern urban traffic control signal systems can generally provide a 20 percent reduction in travel time, about a 15 percent savings in fuel and a 10 percent improvement in accidents.[5]

Our freeway system was initially conceived to promote the rapid safe movement of motor vehicles by minimizing traffic conflicts through the control of access to the freeway. The access control was obtained by limiting the number and the spacing of entrance and exit ramps to the freeway and spacially separating the crossing roadways. In most of our urban areas, however, the traffic demand for use of freeways periodically exceeds the traffic capacity of the facilities and the smooth flow of traffic breaks down into a stop-and-go operation. Such traffic congestion creates a hazardous situation as well as wastes vehicle fuel. Through the electronic traffic surveillance of freeways and the adjacent roadway facilities, freeway entrance ramps can be controlled more positively to limit the traffic using the freeway in order to assist in maintaining smooth flow operations. The metering of entrance ramp vehicles, one-at-a-time, has also improved the safety of the vehicle merging operation into the freeway traffic stream by eliminating the rear-end collision hazard between ramp vehicles. Ramp metering in Atlanta decreased ramp rear-end accidents by 85 percent.(6) Freeway controls in general have increased average peak period speeds by about 15 percent and reduced accidents by some 40 percent.(7) Fuel savings from freeway control projects may range from 10 to 20 percent.(8)

Because of the traffic surveillance capabilities of freeway control projects it is possible to rapidly detect capacity-reducing incidents and therefore quickly dispatch emergency aid. Twenty-one million emergency stops per year occur on urban freeways of which 10 percent occur on the traveled way and require removal.(9) The delay due to incidents totals to 750 million vehicle hours per year on U.S. urban freeways.(10) Thus it can easily be shown that incident detection and rapid response can more quickly aid the needy motorist, clear away the capacity reducing obstacle and return the freeway to normal operations in a shorter time than if a freeway surveillance and control system were not in operation. The quick response to injury producing accidents will save lives.(11) In addition, when a freeway stoppage is detected, drivers upstream can be warned of the congestion ahead and advised to use an alternate route. It is estimated that 400 million gallons of fuel are wasted per year because of delays caused by urban freeway incidents.(12)

Through the selective use of controls on our streets and highways, certain types of vehicles can be given preference over the movements of the rest of the traffic. The use of exclusive bus lanes on city streets and freeways and the granting of priority for providing green lights to buses at traffic signal controlled intersections can improve the operation of mass transit which may in turn promote more ridership on transit vehicles.

In areas that have installed exclusive bus lanes as part of a comprehensive traffic management program that includes improved signalization, vehicle accidents have been reduced by 15 to 20 percent, and pedestrian accidents have been reduced by 35 percent and bus passenger injuries have been reduced by more than 40 percent.[13] The limiting of some freeway entrance ramps for the use of bus and carpools and the reservation of a high speed freeway lane for bus and carpool use can encourage drivers to divert to multi-occupancy vehicles. Parking controls favoring carpool vehicles can also provide carpool incentives. The more drivers who can be enticed to join a carpool or to ride a bus decreases the number of vehicles on the road during peak hours which results in improved traffic operations, saves fuel and reduces chances for accidents. If the average automobile occupancy were increased from 1.4 to 1.6 persons per vehicle through carpooling, there would be a savings of 3.2 billion gallons of fuel a year.[14]

Traffic safety and fuel savings can be obtained through the prudent application of traffic control techniques which have been proved to be successful in pilot research studies that have been conducted in various parts of the country. Although many cities are installing or are planning to install computer controlled traffic signal systems, many of the systems proposed are not capable of taking advantage of advanced traffic signal control strategies. The computers selected for control purposes should be able to utilize programs written in a common language such as FORTRAN. More engineers should be trained in the design, operation and maintenance of advanced electronic traffic control systems so that city and state agencies can adequately implement and operate the new sophisticated systems. The DOT should promote and assist State and local governments in implementing the needed traffic control improvements to save both lives and fuel.

FOOTNOTES (SECTION 2.0)

(1) Fuel consumption tables in Paul J. Claffey's NCHRP Report 111 on "Running Costs of Motor Vehicles as Affected by Roadway Design and Traffic," Highway Research Board, 1971 show that passenger vehicles use less fuel at speeds between 30 and 40 miles per hour (See Table 6 on page 17). Other vehicles have minimum fuel consumption around the same speed range or a little below (See Table 10, page 21 and the figures in appendix A).

(2) Many studies have confirmed the fact that the highest volumes can be obtained if traffic is moving at about 35 mph. A typical example is shown in figure 3.44 on page 66 of the *Highway Capacity Manual - 1965*, Special Report 87 of the Highway Research Board.

(3) Many studies have shown that controlled access highways are safer than surface roadways, that "T" type intersections are safer than four legged junctions, that minimum accident involvement rate occurs for those traveling from the average speed to 10 mph above it etc. which all come down to the less the number of conflicts the less chance of accident occurrence. The series of chapters on "Traffic Control & Roadway Elements Their Relationship to Highway Safety/Revised" published by the Highway Users Federation for Safety and Mobility from 1968 to 1971 summarizes the literature very well to point out this finding.

(4) The fact that up to 60 percent of the signalized intersections are periodically congested is pointed out in the final report by the Polytechnic Institute of Brooklyn in their final report for NCHRP Project 3-18(2) on "Traffic Control in Oversaturated Street Networks." This finding is a result of a nationwide survey they conducted which is shown in figure 2-2 on page 45 of their report.

(5) An analysis of cities which have installed computer traffic control signal systems was presented by Charles R. Stockfisch in his report on "Selecting Digital Computer Signal Systems" published by FHWA in 1972. These reported findings presented in Table 3 on page 60 show that for 307 intersections studied, delay was reduced 20 percent, stops reduced 27 percent, accidents reduced by 13 percent and travel time was reduced 28 percent. Considering the reduction of the number of stops and the travel time, it is safe to assume fuel saving will be about 15 percent considering just one stop-start cycle requires 19 percent more fuel per mile than a steady state driving speed of 30 mph.

(6) The results of the Atlanta ramp metering experience are reported in Paul E. Everall's report on "Urban Freeway Surveillance and Control-The State of the Art" published by FHWA in 1972. The Atlanta results can be found on page 119 of the report.

(7) Paul Everall's report on "Urban Freeway Surveillance and Control" also presents the accident results for a number of freeway control projects in table 34 on page 144. The increase of freeway speeds reported for various freeway control projects includes an increase of 34 percent in Detroit, 50 percent in Los Angeles, 60 percent in Houston and 70 percent in Chicago. Dallas has experienced about 15 percent increase in speeds. It is felt that the more conservative 15 percent might be expected for general application since the pilot research studies were installed at problem areas whereas the more general application would cover larger systems such as is installed in Dallas.

(8) The fuel saving is based on an estimate that the level of congestion would be reduced through freeway controls and therefore the stop and start situation would be reduced. As noted before, the stop and start movement of vehicle consumes a significant amount of fuel.

(9) The number of emergency stops per year on U.S. roads was estimated in a report on "Post-Crash Communications" prepared by AIL, a Division of Culter-Hammer for the National Highway Safety Bureau in 1970. The figures quoted was obtained from Tables 4-26 and 4-27 on page 4-34 of the report.

(10) The delay due to incidents was obtained from the same report by AIL from the Table 4-29 on page 4-36.

(11) It has been pointed out by several experts that quick response to injury accidents can save lives. Dr. Haddon quoted a report by the California State Health Department in a Spring 1966 Symposium on "Traffic Safety a National Problem" (See Eno publication of 1967 page 156) which "shows that patients with exactly the same injuries have four times the probability of dying if those injuries occur in automobile accidents in rural areas instead of an urban area." The AIL report mentioned above in (9 & 10) points out in pages 6-4 and 6-5 that the number of fatalities could be reduced if delays in receiving proper medical care were reduced.

(12) The gallons of fuel used because of delays was determined from the 750 million vehicle hours of delay and using an idling fuel consumption rate of 0.54 gallons per hour; the

rate is about 400 million gallons of fuel. Claffey in NCHRP Report 111 uses 0.63 as the composite automobile gallons per hour fuel consumption rate.

(13) The figure used for the effectiveness of bus lanes was obtained from a report entitled "Bus Priority" published by the Transport and Road Research Laboratory of England, TRRL Report LR 570. It is a summary of several studies presented in table 2 on page 15.

(14) The average automobile occupancy rate of 1.4 was obtained from several publications. This rate is quoted anywhere from 1.2 to 1.6 in different reports. The fuel savings was determined from the following analysis

5.55 billion barrels of petroleum in 1971
46 percent is gasoline
71 percent of the gasoline is used for autos
34 percent of auto usage is for the work trips

5.55 (.46)(.71)(.34) = 0.615 billion barrels for auto work trips

with 42 gal per barrel, 42(.615) = 25.8 billion gallons

Using a 12.5 percent reduction due to increased passenger/veh 1.4-1.6

25.8 x .125 ≈ 3.2 billion gallons per year

Or as reported 106 billion gallons of gasoline used in 1973

106 x .71 x .34 = 25.6

25.6 x .125 ≈ 3.2 billion gallons of gas saving if average auto occupancy increased from 1.4 to 1.6

3.0 WEIGHT VERSUS SAFETY

The relationship between automobile weight and safety is difficult to quantify, but qualitative conclusions can be drawn. Automobile size classes provide a convenient scheme for general conclusions; however, these classes are not well defined and the weight variation within a class can be quite large. One of the most universal definitions for class distinctions is that of the Motor Vehicle Manufacturers Association which separates the classes by wheelbase, (Ref. 1, p. vii). The following table shows the classes, wheelbase range and a typical, but not totally inclusive, curb weight range for each size class:

Size Class	Wheelbase Range (in.)	Curb Weight Range (lb.)
Subcompact	94-101	1,800-2,750
Compact	102-111	2,875-3,575
Intermediate	112-118	3,550-4,100
Full Size	119-up	3,950-5,100

It is common practice to equate car size with car weight. While this relationship is generally true, the above table shows that weight may overlap, though wheelbase does not. Smaller cars commonly have somewhat lighter construction than large cars; the weight overlap usually occurs when one compares the largest and/or most expensive cars in a given class with the smaller less expensive cars in the next bigger class.

Car weight varies for a given make and model year depending upon optional equipment. This tends to increase the amount of overlap between classes. Foreign cars and full size cars tend not to vary so much, on the order of 6 percent or less for 1974 models, because there is less relatively heavy optional equipment available. Domestic subcompacts can easily vary 8 percent, compacts 12 percent and intermediates 10 percent.

Weight changes can be particularly critical with the smaller cars because of the smaller crush distances and interior volume. The basic car structure which absorbs crash energy is usually the same regardless of options, and the absorption capability is probably related to the curb weight. The weight that determines the energy which must be absorbed is the weight at the time of the accident. This weight is affected by payload, passengers and baggage, as well as equipment; the effect can be greater in small cars than in large cars. Three passengers increase the weight of a 2,000 pound car by 20 percent over the weight of the car and a driver; the corresponding factor for a 4,500 pound car is about 10 percent. Fortunately, this effect is mitigated somewhat by low passenger density, however, a subcompact car can easily weigh 25 to 30 percent more than curb weight at the time of the crash.

3.1 WEIGHT IMPACT OF CURRENT AND ANTICIPATED FUTURE SAFETY STANDARDS

1. Current standards have added approximately 260 pounds to automobiles as shown in Table 6.
2. Future bumper standards may add 45 pounds (subcompact) to 100 pounds (full size) if steel designs are used. "Soft-nose" designs may decrease present system weights by 50-100 pounds.
3. New brake system requirements may add 5-25 pounds depending upon whether antilock is required on a particular car.
4. The 30 mph passive restraints may add 55 to 80 pounds to a car with no weight change considered for mounting structure or increased length to provide deceleration space. The weight change may be greater for small cars. The 45 to 50 mph passive restraints may add an additional 150 to 270 pounds to car weight.

5. Probable weight increases for future standards are:

Subcompact	250-375 pounds
Compact	325-450 pounds
Intermediate	525-450 pounds
Full Size	325-450 pounds

The major reason for the large range is the relatively undefined effect of "soft-nose" bumper designs. The effect; i.e., weight reduction, will probably be greater on larger cars.

TABLE 6. MAJOR PASSENGER CAR SAFETY RELATED WEIGHT CHANGES

Standards in Effect	Weight Increase (lbs)
100 Series	5
201 - 204, 207, 210	32
208 (Belts)	35
214 (Side Door Strength)	50
215 (Bumper)	141
	263
Issued Standards Not Yet In Effect	
215 (Bumper Corner Requirements) 9/1/75	9
105-75 (Hydraulic Brakes) 9/1/75	5 -25
Possible Future Standards	
Before 1980 FMVSS 208 (30 mph)	~ 55 - 80 lbs.
Part 581 No Damage Bumper	~ 45 - 100 lbs.
After 1980 FMVSS 208 (45-50 mph)	~150 - 270 lbs.
Total	~250 - 450 lbs.

3.2 ACCIDENT STUDIES

There have been a limited number of studies using accident data to investigate the relationship between car weight and safety. Unfortunately each investigator established his own weight classes so results are not directly comparable. Also, each investigator assigned the makes and models to his classes by using some average weight. The effect is not too serious for generalized results, but absolute numbers cannot be obtained.

Another factor clouding accident data analysis is that accident data are primarily collected for purposes other than assessing crashworthiness, e.g., police reports are primarily for roadway traffic control and law enforcement and insurance reports are primarily for damage claims.

The question of involvement rate also clouds the issue; do large and small cars have difference accident involvement rates and, if so, why? Some evidence indicates that small cars do have a higher involvement rate than large cars. The Highway Loss Data Institute (HLDI) studies first party claims and derives claim frequency per 100 insured vehicle years; they attempt to standardize the data by adjusting for driver age, under or over 25, and amount of deductible, $50 or $100. Their results for 1972 and 1973 models as reported by the Insurance Institute for Highway Safety (IIHS) show that compacts and intermediates have a claim frequency approximately 20 percent greater than full size cars and subcompacts have a claim frequency 33 percent greater than full size cars (Ref. 2; p. 3).

The Highway Safety Research Institute, University of Michigan, has published data indicating that small cars are over-involved in "out-of-control" single car accidents (Ref. 3, p. 11) and in collisions with other small cars (Ref. 4, p. 5). In part, this over-involvement has been attributed to average driver age with small cars having younger drivers. The evidence is not yet conclusive so it is not unreasonable to assume a constant involvement rate regardless of size in any study to determine the effect of a reduction in average vehicle size.

The relationship between car weight and safety has been studied intensively on various samples, but such studies have not been extensive. As mentioned above, each investigator devises his own weight classes. O'Day, et/al, studied "small cars" with a licensing weight of 3,100 pounds or less and "large cars" with a licensing weight of 3,300 pounds or greater; the 200 pound gap was intentional to provide separation. They found (Ref. 5, p. 5) that the chance of a car being involved in an accident was not highly related to its weight, but once involved the chance of injury in the car increases 2.5 percent for each 100 pound decrease in weight.

Mela studied a set of 32,980 two-car crashes which occurred in New York State during calendar years 1969-71. He divided the cars into five weight classes (Ref. 6, p. 48-7). He found that the driver's chance of serious injury increased or decreased by about 5 percent for each 100 pound increase or decrease in his car weight; his chance of serious injury increased or decreased approximately 2 percent for each 100 pound increase or decrease in the weight of the other car in the collision (Ref. 6 p. 48-8). The data also implied that if all cars involved in two-car crashes weighed 3,170 pounds, the overall injury rate would be the same as it was for the population studied which had an average weight of 3,360 pounds. The effect of a given weight change on safety may vary with car population. Figure 3 shows one relationship between changes in the average weight of the vehicle population and the chance of serious injury to unbelted drivers in two-car crashes. Mela concludes that a shift in the U.S. passenger car population from its present weight distribution to one composed largely, i.e. 50 to 60 percent, of subcompact and compact cars with no cars exceeding 3,250 pounds could produce up to 25 percent more serious and fatal injuries. Doubling of safety belt usage would enable smaller cars to be used with about the same injury rate as now exists (Ref. 6, p. 48-11, 17, 18).

Scott also investigated a New York State accident file and found that when the primary vehicle shipping weight is

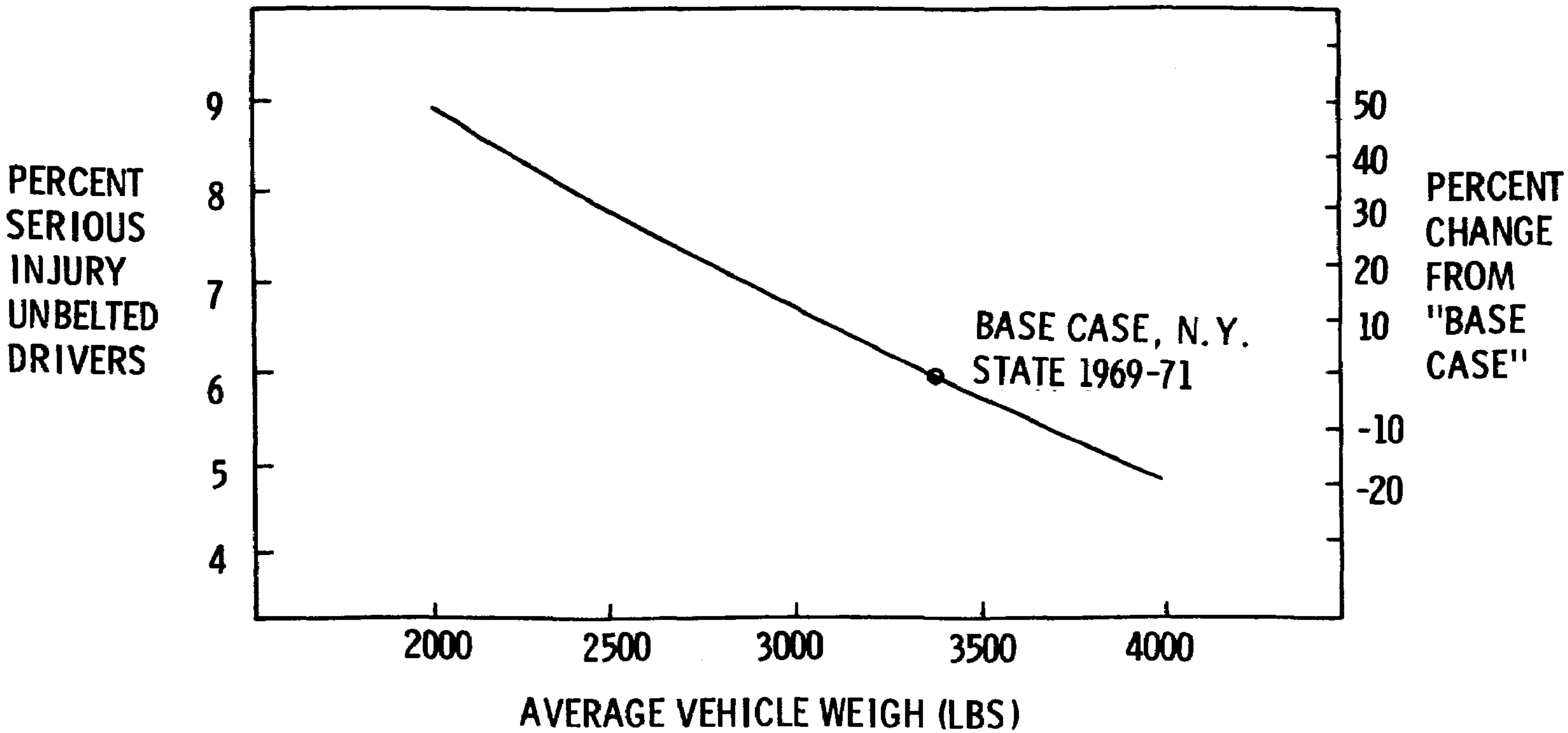


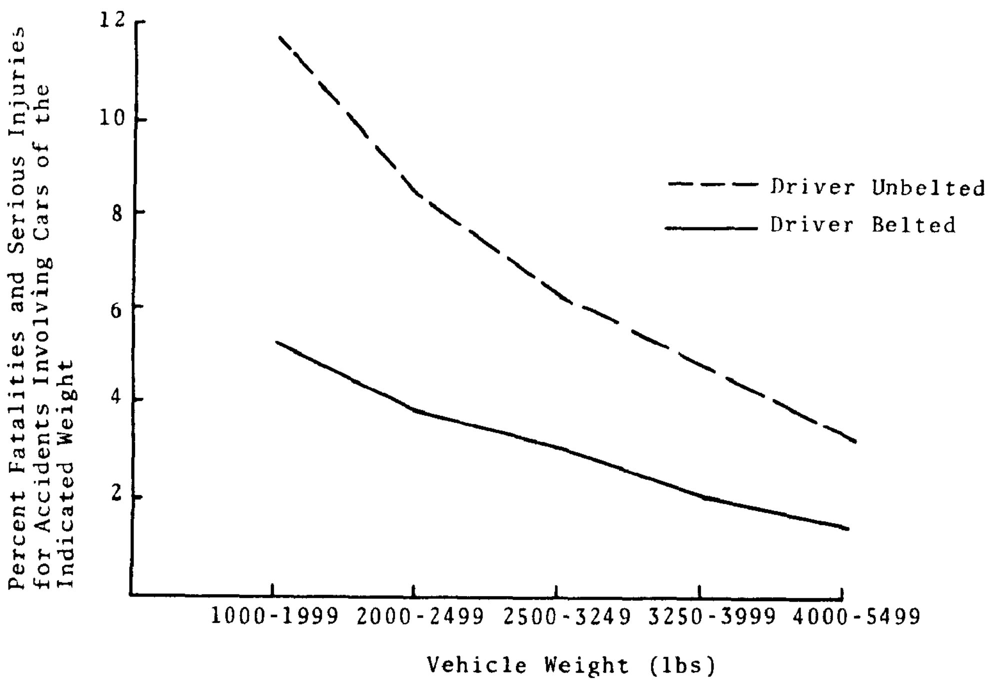
Figure 3. Relationship Between Vehicle Weight and Chance of Serious Injury to Unbelted Driver in Two-Car Crash

under 2,500 pounds the severity is essentially the same regardless of the weight of the secondary vehicle; this severity is 2 to 3 times that of a larger car, above 3,250 pounds, striking another large car (Ref. 7, p. 13-15 and 13-22). He also found that (Figure 4) belted drivers of cars in the 1,000 to 1,999 pound class have about the same percent of serious and fatal injuries as unbelted drivers of cars in the 3,250 to 3,999 pound class (Ref. 7, p. 13-16). These findings correspond well with those of Mela.

Campbell and Reinfurt studied accidents occurring in North Carolina in 1966 and 1968-71. They established an injury index with 100 as the average value. An index of 120 means 20 percent more frequent serious injury to a driver than average and, an index of 80 means 20 percent less frequent serious injury than average. In car vs. car crashes the index chart crosses 100 at approximately 3,000 pounds for the two cases: (a) all injuries and (b) serious and fatal injuries (Ref. 8, p. 21 and 22).

In later work Campbell, O'Neill and Tingley studied crashes of 1970-73 model cars dividing them into five categories: full size, intermediate, compacts, subcompacts and import cars. Their data show that the smaller cars, including imports, tend to have twice as many single car, predominately ran-off-road, accidents as the combination of full size and intermediate cars. This holds true for both belted and unbelted drivers (Ref. 9, p. 12-3). This supports the findings of the Highway Safety Research Institute mentioned above.

Using an index system similar to that described above the data show that belted drivers in subcompact and compact cars have approximately the same chance of injury as unbelted drivers of intermediate and full size cars (Ref. 9, p. 12-6). This also implies that greatly increased usage of seat belts would enable smaller cars to be used with about the same injury rate as now exists. This supports the Mela findings. Current national policy is that the present rate is



Source: "A Safety Comparison of Compact and Full-Size Automobiles," by Basil Y. Scott, N.Y. State Department of Motor Vehicles, presented at 3rd International Congress on Auto Safety, Vol. I, 15 July 1974 in San Francisco.

Figure 4. Percentage Fatal/Serious Injury vs. Vehicle Weight

unacceptable and must be reduced. On that basis any change to a higher percentage of smaller cars would be self-defeating.

Efforts to increase belt usage have met with well publicized resistance. Interlocks have increased usage somewhat, but laws may be necessary to achieve the usage level required to accommodate a switch to smaller cars. Passive restraints may be the solution; however, matching passive restraints to smaller cars is at present an unresolved problem. Even with universal passive restraints equivalent to present belts, the injury rate for a population of smaller cars would remain approximately the same as the present level for all cars.

The above findings indicate that injury levels become a problem if the curb weight of an automobile drops below 3,000 to 3,200 pounds. This conclusion is based upon accident data and is, therefore, a measure of the capability of cars using present designs and manufacturing techniques.

The National Highway Traffic Safety Administration is sponsoring the Research Safety Vehicle (RSV) Program which has as a goal a 3,000 pound car with crashworthiness at speeds up to 50 mph. This program is currently in Phase I; the results of Phase III are to be applicable to cars of the mid-1980's. Such cars would not represent a significant portion of the automobile population until 1990.

3.3 MATERIALS SUBSTITUTION

More significant from a near term point of view would be material substitutions enabling production of relatively large, light weight cars. Aluminum and plastic are commonly mentioned substitutes. Aluminum prices are increasing; aluminum production requires large amounts of energy; and there are valid questions as to the availability of aluminum in sufficient quantities. Recent unpublished findings under a DOT contract indicate that increasing aluminum usage from the present 81 pounds per car to 200 pounds per car would require increasing the industry capacity by 15 percent. Such an increase would reduce car weight about 120 pounds. Plastics used in automobiles are largely petroleum products so a major limitation on their use is self-evident.

Likely near term substitutes are the various high strength low alloy (HSLA) steels. These steels have significant strength advantages, but require larger forming equipment as the punch forces must be higher. Another problem is variation in weldability from run-to-run and batch-to-batch. An in-service problem exists because the thinner sections will be less tolerant of corrosion (Ref. 10, p. 30-32). Recent unpublished findings under a DOT contract indicate that extensive use of HSLA steels could reduce the weight of a standard size passenger car by 300 to 400 pounds.

Increasing the use of aluminum and incorporating HSLA steels could conceivably reduce the weight of a standard size car by 10 percent by 1979 or 1980. A similar reduction appears possible for intermediates; the reduction for the smaller size classes would be somewhat less. Such cars could represent a significant proportion of the automobile population by 1985. The effect of materials changes on injury rate may not be commensurate with the magnitude of the reduction in curb weight because the weight of the payload is unchanged. Cars in the various size classes would have the same relative strength that they now have, but crash energy levels based upon weight at impact would be reduced by a smaller percentage than the reduction in curb weight.

3.4 SUMMARY

1. The relationship between automobile weight and safety is difficult to quantify, but qualitative conclusions can be drawn. As it is common practice to equate car size with car weight, automobile size

classes provide a convenient scheme for general conclusions; however, the weight/size relationship is not exact. For any given make/model the basic car structure which absorbs crash energy is usually the same regardless of options. The weight that determines the energy that must be absorbed is the weight at the time of the accident and is affected by payload and equipment. The effect of loading can be greater in small cars than in large cars. Consequently it is mandatory that any legislation on "size" or "weight" of cars define these terms rigorously.

2. Various investigators have studied accident data to determine the relationship between weight and safety. Their findings are not directly comparable, but it appears that the chance of serious to fatal injury increases considerably at curb weights less the 3,000-3,200 pounds. Doubling seat belt usage would enable these smaller cars to be used with about the same injury rate as now exists, recognizing that present national policy is that this rate is unacceptable.

3. The above conclusion is a measure of the capability of cars using present designs and manufacturing techniques. Material substitutions are the most likely means of maintaining car size while reducing car weight. Such substitutions must preserve structural strength if injury rates are to be maintained. High strength low alloy steels appear to be the most promising materials; extensive use of these steels could reduce the weight of a standard size passenger car by 300 to 400 pounds. Combined with some increased use of aluminum the weight reduction should approach 10 percent for a standard size car by 1979

or 1980. The weight reduction will be somewhat less for the smaller size classes.

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4.0 EFFECT OF SPEED LIMITS ON FUEL ECONOMY AND SAFETY

4.1 FUEL ECONOMY

During the recent oil crisis a national speed limit of 55 mph was established in order to decrease fuel consumption. It was indeed expected that by lowering the speed limit to 55 mph there would be appreciable savings in fuel. Limited data available indicate that nationwide gasoline consumption for the period November 1973 through March 1974, when compared to the same period for the year before, is down about 3.8 percent; at the same time the data show that motor vehicle travel has also been reduced by the amount of 3.7 percent which is close to the reduction in fuel consumption. A similar estimate of reduction in fuel consumption is also obtainable from the well publicized figure of 200,000 barrels of fuel being saved every day. These estimates are based on very gross data which may be obscuring the small effects of lower speed, but until more accurate information becomes available we must conclude that the lower speed limits have had a small relative effect on fuel consumption.

4.2 SAFETY

The lower speed limit went into effect for the primary purpose of saving fuel and little or no major consideration was given to the substantial safety results which could be achieved by implementing a lower speed limit. The effect that the travel speed has on both the frequency and the severity of highway accidents has been the subject of many research studies. The general conclusions of these studies have been that the probability of a collision is greater for any vehicle which travels at speeds increasingly different from the average speed of all traffic and that the severity of accidents increases as speed increases.

More recently, many European countries have adopted some type of speed limits outside urban areas and reports are becoming available on the positive effects that this reduction in speed is having on safety. In Germany the results show that in the month of January 1974, after adjustment for traffic volumes, that country experienced a 61 percent reduction in both fatalities and injuries. Denmark experienced a 50 percent reduction in fatalities and a 40 percent reduction in both injuries and accidents for the month of November. The month of December showed a preliminary reduction of 30 percent for all three. France shows a 23 percent reduction in fatalities and a 12 percent reduction in injuries. During the 4 month period of December 1973 through March 1974, Luxemburg experienced a slight increase in number of accidents but a 40 percent reduction in fatalities. Only one fatal accident was recorded during the first 2 months, but there was no noticeable reduction in the remaining two. These and similar results have induced the European Council of Ministers of Transport to conclude that the new speed limits have led to a reduction in the number and seriousness of road accidents, and to consider that it is unwarranted, from a road safety standpoint, to reintroduce freedom of speed on the road.

Some of these reductions in fatalities are much larger than the ones found in the United States but we must be aware that in most cases these European countries went from unlimited speed to a reasonable speed limit, while the United States has lowered the speed limit by approximately 10 mph on a small portion of the highway system which already was controlled by reasonable speed limits.

Nevertheless, the results experienced in this country during the energy crisis period are just as significant as the ones reported in Europe. Since the adoption of the 55 mph speed limit, various analytical efforts have been initiated to assess the contribution of speed to the improved safety level. It is still too early to arrive at definite conclusions as to the true benefits of lower speed limit, however, it is undeniable that, whatever changes have occurred, the results are that approximately 6000 lives have been saved, representing a 25 percent reduction in the number of highway fatalities over the first 6 months of 1974 when compared to the same period in 1973. This represents a potential saving of 12,000 lives per year (if the reduction is maintained.

Figures 5-7, which cover the period from July 1973 through March 1974, provide a summary of the level of reduction experienced in travel, fatality and fatality rate. These figures show that:

1. There has been a reduction in travel,
2. The percent reduction in travel is about the same in both rural and urban areas,
3. The percent reduction in fatalities is much greater than the reduction in travel,
4. The fatality rate (number of fatalities per 100 million vehicle miles of travel) has shown a percent reduction similar to the percent reduction in fatalities.

It becomes aparent from Figures 5-7 that reduction in travel accounts for less than half of the reduction in fatalities; the remainder must be associated with other changes in type and condition of travel. Some of these changes are the reduction in speed limit, more uniform flow of high speed travel, reduction in the number of high risk recreational trips, vehicle occupancy, changes in driver attitude, etc. To isolate the effect that lower speed limits alone have had on road safety may not be possible, but a conservative estimate can be obtained by assuming

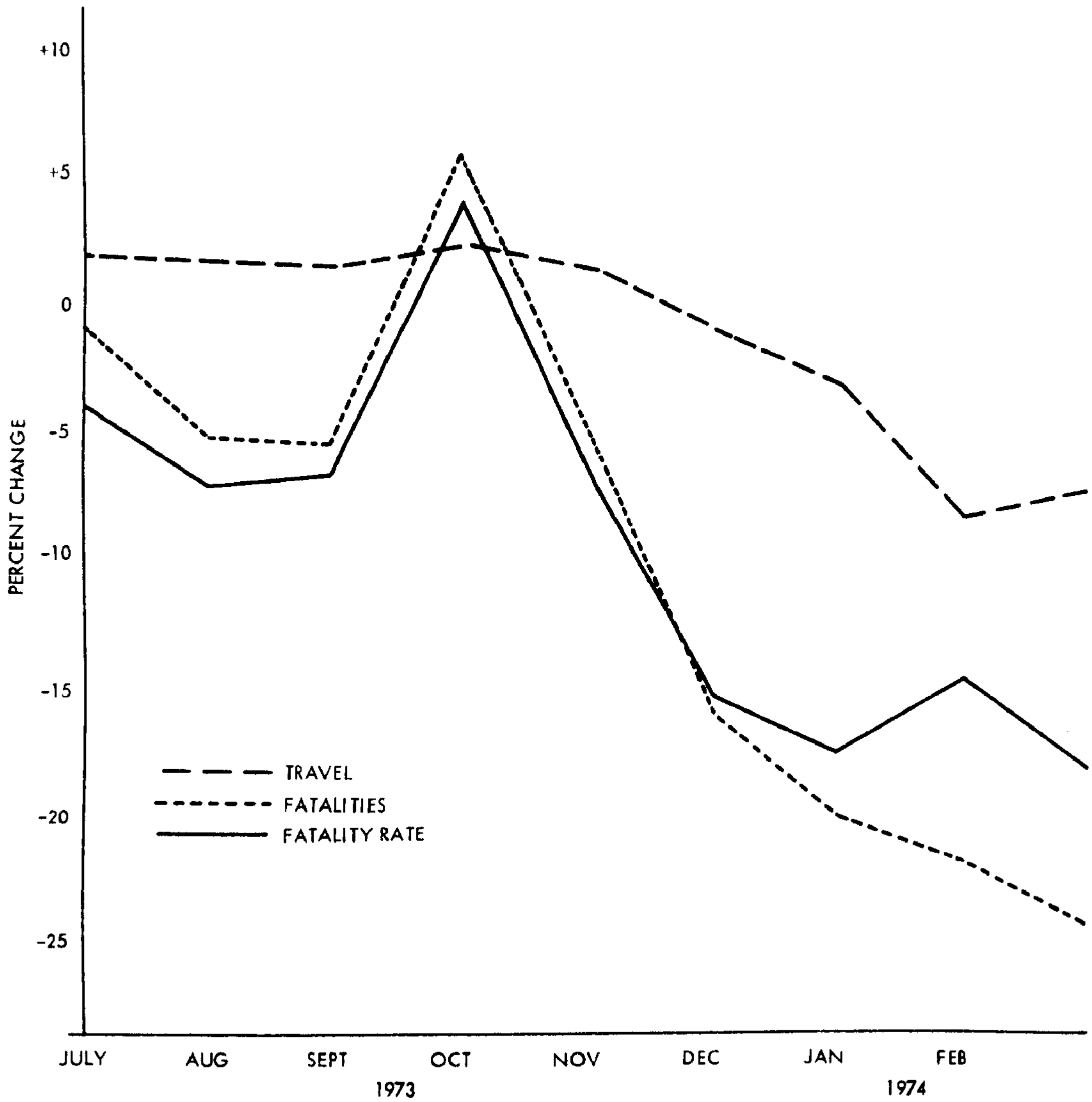

Figure 5. Fatality Statistics in Urban Areas

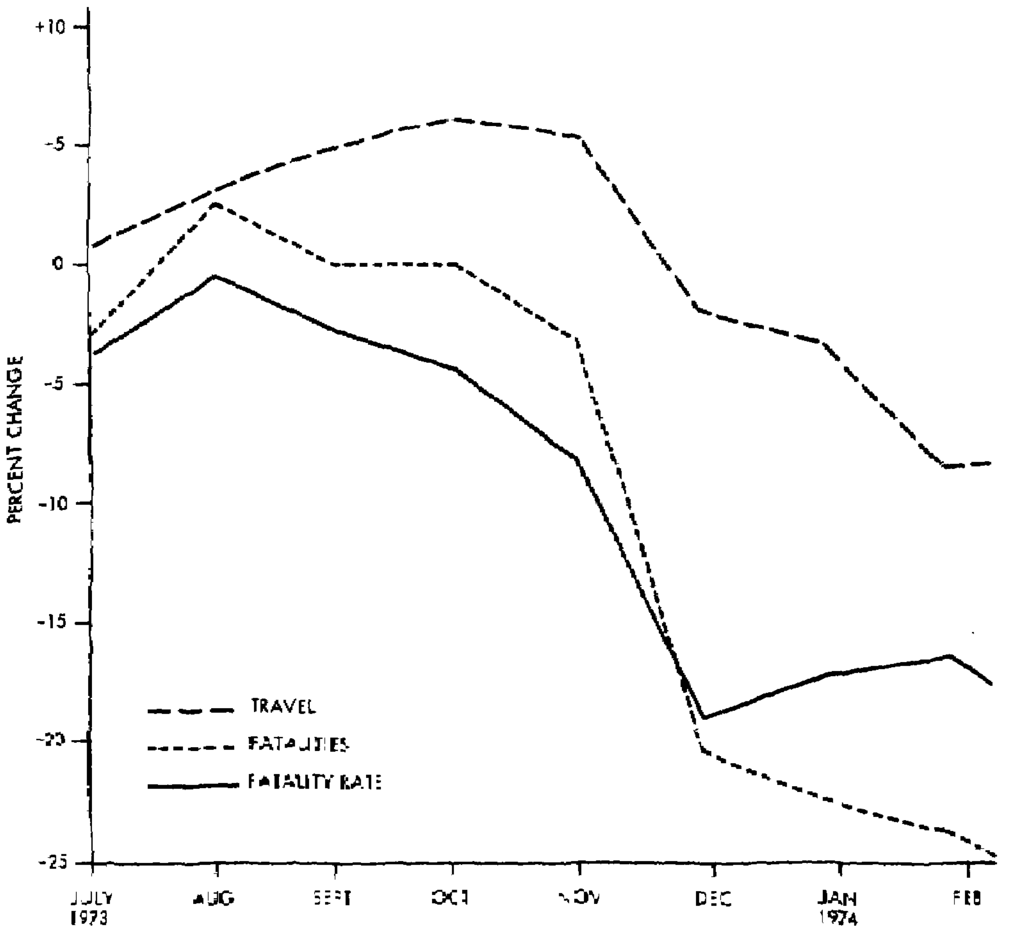

Figure 6. Fatality Statistics in Rural Areas

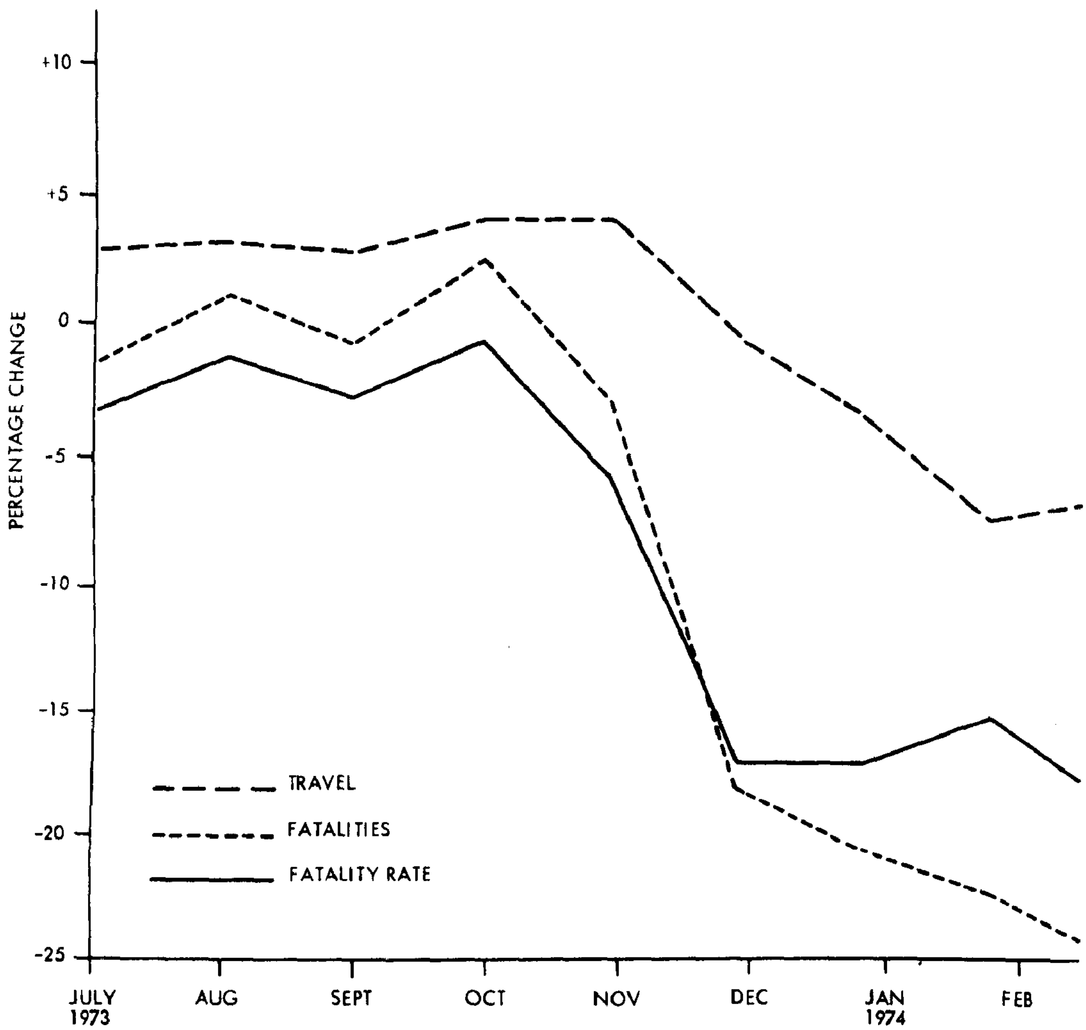

Figure 7. Fatality Statistics in All Areas

(1) that lower speeds have had no effect on the frequency of road accidents and (2) that this is the only change which has affected the severity of accidents that do occur. With this background, an analysis was undertaken of the accident data available from seven states covering a period of 3 months after the adoption of the lower speed limit. The seven states which published monthly accident summary reports for the minimum period of 3 months are Delaware, Georgia, Idaho, Kentucky, North Carolina, South Carolina and Texas. The month during which a lower speed limit was implemented differed among these states but the analysis for each state began with the month and included the next two months and compared them to the corresponding months from the previous year.

The results show that these states experienced a 13.6 percent reduction in the total number of road accidents. Based on assumption (1), the reduction can be entirely attributed to changes in both quantity and type of exposure. All other things being equal, it would be expected that this 13.6 percent reduction in accidents would result in a similar reduction (13.6 percent) in all types of injury.

Assumption (2) implies that the effect of lower speeds is to lower the severity level of the remaining accidents; it would be simple, but incorrect, to take the difference between the actual and the expected (13.6 percent) reduction for each injury class and attribute it to the effect of lower speeds on that injury class. A more plausible result is obtained if we hypothesize that lower speeds do not prevent injuries but reduce their severity. That is, some accidents that might have produced fatalities have now caused serious injuries, some serious injuries (A-Inj.) have become moderate, some moderate injuries (B-Inj.) have become minor, and some minor injuries (C-Inj.) have been prevented.

Using this hypothesis to estimate the reduction in each of the injury levels due to lower speeds, an analysis of the accident data from the seven states produced the following results:

- Reduction in quantity and type of exposure accounted for 13.6 percent reduction in accidents, fatalities, and injuries at each severity level.
- Lower speed may account for an additional reduction of 12 percent in fatalities, 20 percent in serious injuries, 5 percent in moderate injury, and less than 1 percent in minor injuries.

The same type of analysis was conducted on the set of multiple vehicle, single vehicle, and pedestrian accidents to investigate whether the energy crisis is having a different effect on these different types of accidents. Results for each case are presented in a tabular form in Table 7.

The three major findings of this analysis were:

- The reduction in number of accidents was essentially the same for all three types (13.8 percent for multiple vehicle; 14.1 percent for single vehicle; and 12.9 percent for pedestrian).
- The severity of single vehicle accidents was not affected by lower speeds.
- The severity of multi-vehicle accidents was reduced by more than 20 percent due to lower speeds.

There is no available explanation for the last finding and additional efforts will be required to both verify and interpret the results.

In summary, the <u>tentative</u> conclusions which could be drawn from the analysis are that changes in travel exposure have uniformly reduced accidents and associated injuries by approximately 14 percent; that lower speeds are having a large effect in the additional reduction of 12 percent in fatalities and 20 percent in serious injuries; and that the reduced injury severity occurred primarily in multiple vehicle crashes.

TABLE 7. HIGHWAY ACCIDENT STATISTICS FOR SEVEN STATES (Delaware, Georgia, Idaho, Kentucky, No. Carolina, So. Carolina, and Texas)

MULTIPLE VEHICLE ACCIDENTS

	Prior Year	Expected (13.8%) Reduction	(E) Expected Totals	(A) Actual Totals	(E - A) Difference	(R) Reduction	(R/E) Reduction (Percent)
Fatalities	967	133	834	643	191	191	22.9
A-Injuries	10,405	1,435	8,970	6,761	2,209	2,400	26.8
B-Injuries	14,219	1,961	12,258	13,106	-848	1,552	12.7
C-Injuries	17,386	2,398	14,988	15,406	-418	1,134	7.6
Accidents	147,759			127,385			

SINGLE VEHICLE ACCIDENTS

	Prior Year	Expected (14.1%) Reduction	(E) Expected Totals	(A) Actual Totals	(E - A) Difference	(R) Reduction	(R/E) Reduction (Percent)
Fatalities	687	97	590	621	-31	-31	-5.3
A-Injuries	6,225	879	5,346	4,754	592	592	11.1
B-Injuries	6,858	968	5,890	6,885	-995	-403	-6.9
C-Injuries	3,910	552	3,358	3,668	-310	-310	-9.2
Accidents	37,719			32,392			

PEDESTRIAN ACCIDENTS

	Prior Year	Expected (12.9%) Reduction	(E) Expected Totals	(A) Actual Totals	(E - A) Difference	(R) Reduction	(R/E) Reduction (Percent)
Fatalities	370	48	322	261	61	61	19.6
A-Injuries	951	123	828	723	105	166	20.0
B-Injuries	957	124	833	981	-148	18	2.2
C-Injuries	563	73	490	494	-4	14	2.8
Accidents	2,673			2,327			

ALL ACCIDENTS

	Prior Year	Expected (13.6%) Reduction	(E) Expected Totals	(A) Actual Totals	(E - A) Difference	(R) Reduction	(R/E) Reduction (Percent)
Fatalities	2,223	302	1,921	1,697	224	224	11.6
A-Injuries	19,060	2,580	16,480	13,438	3,042	3,266	19.8
B-Injuries	24,417	3,310	21,107	23,399	-2,292	1,974	4.6
C-Injuries	23,752	3,220	20,532	21,370	-838	136	0.7
Accidents	214,807			185,638			

Note: See the following page (4-10) for an explanation of the column headings.

LEGEND FOR TABLE 7

- Prior year - This first column contains the totals during the based period for the specified type of accident.

- Expected reduction - The second column contains the stated percentage of the previous column. The percent figure represents the actual percent reduction in total accidents and is obtained from the given totals for all accidents.

- Expected totals - This column contains the difference between the first two columns and represents the totals which would be found if the reduction in injuries of various types were proportional to the reduction in accidents.

- Actual Totals - In this column the totals for the current three months period are listed.

- Difference - This column contains the values of the difference between expected and actual totals.

- Reduction - This column contains what is believed to be the true value of the reduction experienced in each injury class. The value for each class is obtained by adding to the computed difference (Col. 5) the reduction found for the next higher injury class. The value represents the number of injuries of a given class, the severity of which has been lowered by one level.

- Reduction (Percent) - This last column expresses the reduction in each class as a percent of the expected totals. Negative values in this column reflect the fact that the reduction in injuries was lower than the reduction in accidents, while positive values reflect the additional reduction which is tentatively associated with lower speeds.