EARLY RESULTS OF SEAT BELT LEGISLATION IN THE UNITED STATES OF AMERICA

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I. INTRODUCTION

Laws requiring occupants of motor vehicles to wear seat belts have been enacted in many industrialized nations. However, the United States of America has lagged behind in this regard, perhaps in part due to differences in opinion as to the best means to achieve occupant protection -- belt use laws or automatic restraint systems such as air bags (Campbell, 1984). One concern has been that even with seat belt laws, low compliance rates would significantly reduce the potential benefit.

Marburger (1985) compiled information from many countries and reported that belt use rates almost always increased sharply with the introduction of usage laws -- in some cases a 50 percentage point gain. These initial gains were not always fully sustained, however.

Because the level of compliance is central to the success of any belt use law, it is important to examine the characteristics of users and non-users. Lawson (1985) reviewed findings from several countries, and among other factors reported that belt use tends to be lower among persons with less education and/or lower socio-economic status. The finding is of special interest because it also appears that crash risk is higher in this group.

Even with less-than-perfect compliance, however, several countries have reported casualty reductions associated with the law. Hedlund (1985) reviewed post-law casualty data from several countries including Canada which enacted mandatory seat belt laws in some provinces, but not in others. Canadian occupant deaths declined 10% in provinces with belt laws, but less than one percent in provinces with no such law.

Hedlund's view is that the upper limit of belt law effectiveness in preventing occupant deaths approximates 40%. He projected that number after reviewing casualty reduction in several countries with varying levels of belt use. He found no clear relationship between level of belt use in a country and level of fatality reduction, possibly because of the small numbers of fatalities. On the other hand, he _did_ show such a relationship for _injury_ reduction. Further, the data suggest differentially greater casualty reduction at successively higher levels of compliance, because only then would the highest risk drivers be likely to use belts.

In any event, the USA was late in adopting adult seat belt laws, having only begun in 1985. To date, 26 of 50 states have adopted such laws. It remains to be seen whether the USA can match the use rates and injury reductions reported in other countries, especially since compliance tends to average less than 50% at this point.

II. INJURY DATA FROM THE STATE OF NORTH CAROLINA

To determine the degree to which motor vehicle crashes resulted in injury before and after the introduction of the seat belt law, injury data reported by police in North Carolina (NC) was examined. NC is the tenth largest state in the USA, with a population of about six million. NC's law took effect October 1, 1985. The analysis addresses crash experience during the first three months of the law contrasted to the 21 preceding months.

Crash data in NC are collected statewide on a single standard form. About 160,000 crashes are reported each year, and reports are submitted for non-injury as well as for injury and fatal crashes. The presence of uninjured occupants is reported as well as that of the injured. Additional data elements include vehicle make and model, each occupant's seated location, whether safety belts were worn, and the officer's rating of injury sustained by each occupant:

1. no injury
2. "c" or minor injury
3. "b" or moderate injury
4. "a" or serious injury
5. "k" fatal injury (killed)

From this data set it is possible to define three groups of primary interest and for each to examine injury trends before and after the law:

A. Primary Target Group: Occupants required by law to use the belt (i.e. front seat occupants of vehicles covered by the law).

B. Secondary Occupant Group: Occupants not covered by the law (i.e. rear seat occupants of vehicles covered by the law, plus front seat occupants of other four wheel vehicles not covered by the law).

C. Non-Occupant Group: Pedestrians, motorcyclists, bicyclists, etc.

The NC law requires belt use only by <u>front</u> seat occupants of passenger cars and small trucks, Group A, the group where most effect should be seen. The law would not be expected to produce changes in Group C; therefore it is a "control" group in a sense. On the other hand, it appears that the law <u>may</u> exert some influence on Group B even though the law does not really address this group.

Figure 1 shows the reported levels of belt use in crashes that occurred before and after the onset of the law. As expected, there was a dramatic increase in belt use among front seat occupants subject to the law -- from 31% the month before the law, to 68% during the first month after the law. In addition, reported belt use by vehicle occupants not covered by the law increased to a level approximating 50% after the law took effect.

Increased belt use by rear seat occupants of covered vehicles may result from "follow-the-leader" behavior. Also, some occupants may mistakenly believe they are subject to the law even in situations not so covered. (In addition, <u>part</u> of the reported increase may come from persons falsely telling officers they were using belts. This supposition is supported by the fact that reported belt use in crashes during October and November, 1985, exceeded the levels simultaneously observed in roadside surveys. It is also noteworthy that previous indications were that belt use in crashes was less, not more, than in the population at risk.)

Figure 2 depicts injury among occupants primarily targeted by the law. Two trend lines are shown. The top line represents the percent of occupants who sustained a moderate ("b") or worse injury--roughly 10-12% of occupants. The second trend line is the percent who sustained a serious ("a") or worse injury -- about four percent of the distribution. The lower trend line thus represents the more severe cases of the distribution included in the upper. Fatality numbers were too small for separate analysis.

There seems to be a very clear break in the injury trend corresponding to the onset of the law, with a significant lowering of the injury rate compared to the preceding three months. There is a hint of seasonal variation with the percent injured lower in winter and higher in summer, but the highest and lowest month varies from year to year. Finally, there seems to be a general upward shift in injury percent over the two years, as might be expected given the economic recovery going on during that time.

The injury trends indicate a favorable belt law effect, in that the trend line breaks and resumes at a distinctly lower level.

An identical analysis was performed for Group B, which showed that injury among the non-covered occupants also shifted downward corresponding to the law's onset, although the trend was less clear cut than that for Group A, as would be expected. For Group C, no injury change was expected in association with the law and the analysis showed none.

Thus, it appears that a change in the level of injuries reported has taken place, and the change is most apparent within the group where it <u>should</u> be most apparent.

Figure 1. 1985 North Carolina Police Reported Belt Use in Various Crash Groups

	Target Cars/Trucks	Rear Seat Target Vehicles	Front Seat Other Trucks	Non-Occupants
	% Use	% Use	% Use	% Use
JUL	27	29	19	1
AUG	29	30	21	1
SEP	31	32	23	1
OCT	68	48	47	1
NOV	65	47	42	1
DEC	61	45	40	3

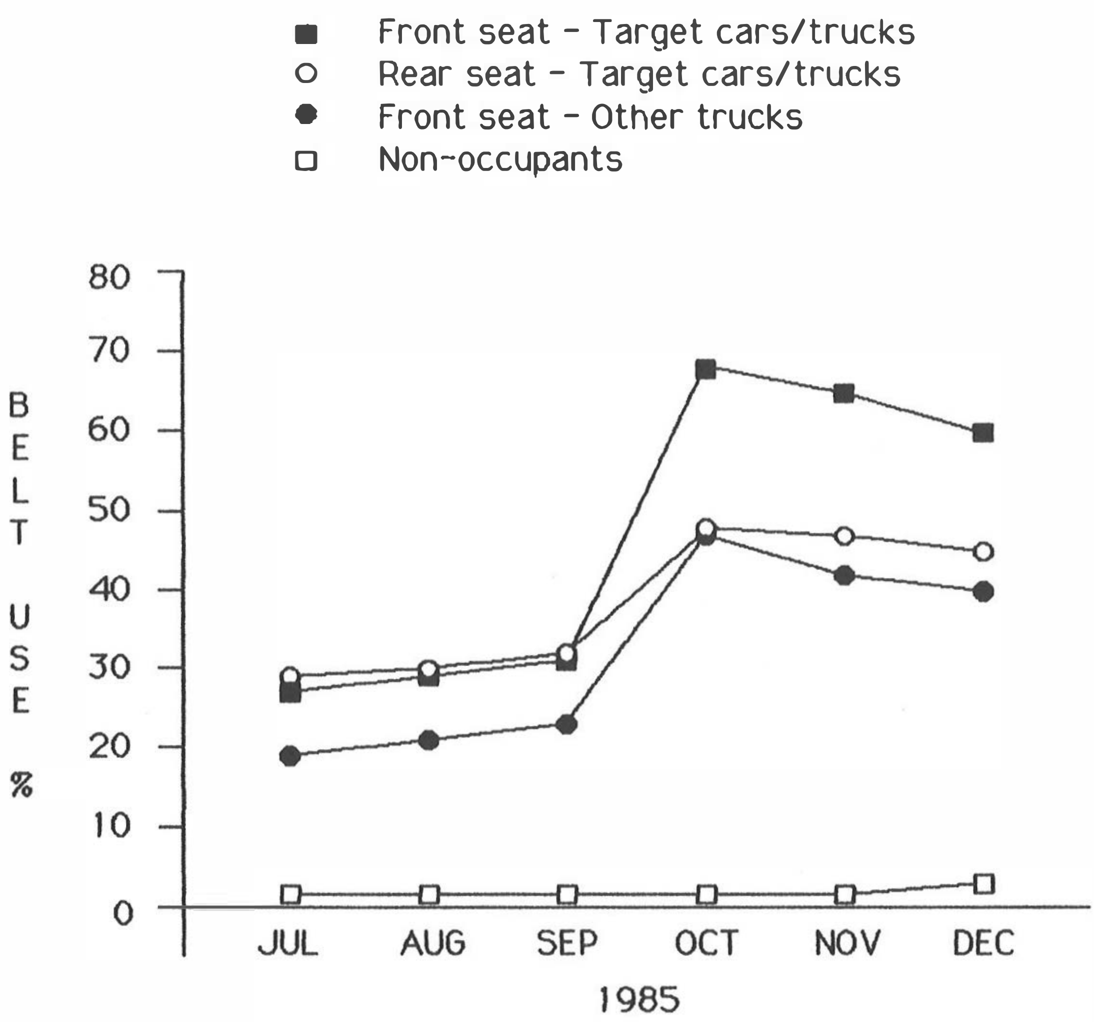
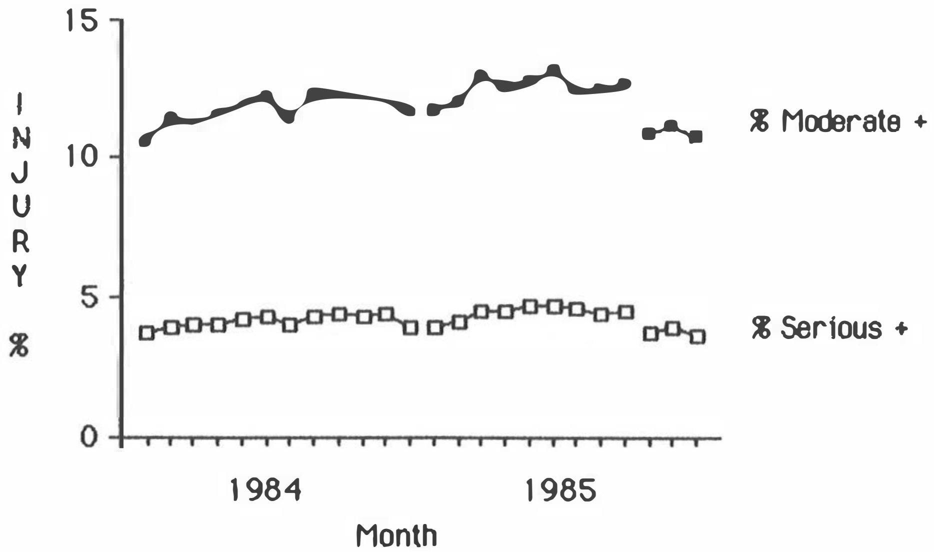


**Figure 2. 1984-1985 North Carolina Crashes
Cars and Small Trucks
Primarily Targeted by the Law**

		Frequency	% Serious +	% Moderate +
1984	JAN	23142	3.7	10.5
	FEB	21555	4.0	11.4
	MAR	22325	4.0	11.2
	APR	23955	4.0	11.4
	MAY	26014	4.2	11.8
	JUN	24671	4.3	12.1
	JUL	25811	4.1	11.4
	AUG	25298	4.3	12.2
	SEP	25743	4.4	12.1
	OCT	26272	4.3	12.2
	NOV	28229	4.4	12.0
	DEC	27390	3.9	11.7
1985	JAN	26723	3.9	11.6
	FEB	20873	4.1	12.0
	MAR	22762	4.5	12.9
	APR	24168	4.5	12.5
	MAY	26263	4.7	12.7
	JUN	25354	4.7	13.1
	JUL	26310	4.5	12.4
	AUG	27808	4.4	12.4
	SEP	24045	4.5	12.6
	OCT	29381	3.7	10.8
	NOV	30872	4.0	11.1
	DEC	28656	3.6	10.7



The next question is how much injury reduction occurred compared to the injury level expected had no seat belt law been introduced. We have not yet completed a detailed forecast of expected trends using time series analysis, but have estimated the Oct-Dec 1985 injury level using 1984 experience as a guide. Table 1 below summarizes the data presented in Figure 2 to give injury percentages for third and fourth quarters of 1984 and 1985:

Table 1
Third and Fourth Quarter Injuries For 1984 and 1985

	number of crashes	moderate or greater injs.		serious or greater injs.	
	N	N	%	N	%
Jul-Sep 1984	76,852	9,130	11.88	3,250	4.23
Oct-Dec 1984	81,891	9,794	11.96	3.457	4.22
Jul-Sep 1985	78,163	9,747	12.47	3,505	4.48
Oct-Dec 1985	88,909	9,662	10.87	3,353	3.77

In 1984 the injury rate varied almost none from the July-September quarter to the October-December quarter. The moderate injuries were 11.88 and 11.96 respectively, and the severe injuries were 4.23 and 4.22 respectively. Based on that, the expected number of October-December 1985 injuries is calculated as if the Oct-Dec experience had persisted at the 12.47% moderate+ and the 4.48% serious+ level observed Jul-Sep 85. When tested by Chi Squared (2df), the distribution of injuries (none plus minor vs moderate vs serious plus fatal) is highly significantly different before and after the law. The direction of the difference is toward lesser moderate and lesser serious injuries. Based on the data in Table 1, the estimated reductions were calculated and are given below in Table 2.

Table 2
Estimated Injury Reductions

		moderate+ injuries	serious+ injuries
Oct-Dec 85	Expected	11,087.0	3,986.9
	Observed	9,662	3,353
	difference	1,425	633.9
	% reduction	-12.8%	-15.9%

To determine how much additional benefit resulted from the increased belt use by occupants not covered by the law, a similar set of calculations was carried out for Group B. Combining the benefits from Groups A and B shows a net savings of 876 moderate ("b") injuries (an 11-13% reduction) and 746 serious+ ("a") injuries (a 16-17% reduction) during the three months. This is a total of 1,622 consequential injuries prevented. Obviously, data must be collected over a longer period before it will be possible to ascertain whether the initial trends will be maintained.

Any early injury trends must be viewed in terms of the unsatisfactory level of compliance with the law in NC. Just before the law took effect (September, 1985), the voluntary wearing rate was about 25%. After the law took effect, observed belt use rose only to 44% (November, 1985) and has increased only to 46% by late spring of 1986.

In sum, a statistically significant injury reduction was observed which was greatest in the covered group of motor vehicle occupants.

III. USA FATAL CRASH DATA FROM EIGHT SEAT BELT LAW STATES COMPARED TO ALL OTHER NON-LAW STATES

This section is based on analysis of data tapes from the Fatal Accident Reporting System (FARS) compiled by the US Department of Transportation (DOT). Under this system an attempt is made to obtain standard information on every fatal motor vehicle crash in the USA. A FARS data tape is now available covering fatalities that occurred during 1985. and we are grateful to NHTSA officials for their assistance in providing the tape. By the end of 1985 eight of 50 states had seat belt laws in effect:

State	Law in Effect:
New York	January through December 1985
New Jersey	March through December 1985
Michigan	July through December 1985
Illinois	July through December 1985
Texas	September through December 1985
Nebraska	September through December 1985
Missouri	October through December 1985
North Carolina	October through December 1985

The data tapes were searched and all reported fatals were allocated to one of two groups:

a. Fatally injured front seat occupants of passenger cars and pickup trucks (i.e. persons covered by the seat belt laws)

b. All other fatals (front and rear seats) plus non-occupants such as pedestrians and cyclists (i.e. those <u>not</u> covered by the laws).

For each of these two groups, time series models were fit to data on fatalities from each of the eight belt law states. The modelling was done using SAS PROC ARIMA, where the acronym ARIMA stands for autoregressive-integrated-moving average.

An autoregressive model for a time series X_t has the form.

$$X_t = \Phi_1 X_{t-1} + \Phi_2 X_{t-2} + \dots + \Phi_p X_{t-p} + A_t \quad ,$$

where $\Phi_1, \dots, \Phi_p$ are the autoregressive coefficient and A_t is a random error term. A moving average model is of the form,

$$X_t = A_t - \theta_1 A_{t-1} - \theta_2 A_{t-2} - \dots - \theta_q A_{t-q} \quad ,$$

and an autoregressive moving average model is given by

$$X_t - \Phi_1 X_{t-1} - \dots - \Phi_p X_{t-p} = A_t - \theta_1 A_{t-1} - \dots - \theta_q A_{t-q} \, .$$

If the series X_t is nonstationary in mean (e.g., if trends, changes in level, or seasonal patterns are present) then the series may be appropriately differenced and a model fit to the differenced series. Typically, the first difference

$$Z_t = \Delta X_t = X_t - X_{t-1}$$

or a seasonal difference such as,

$$W_t = \Delta_{12} X_t = X_t - X_{t-12}$$

might be used. The differenced series can then (after modelling) be summed or integrated back to the scale of the original series.

A model is fit to a series X_t by first identifying an appropriate model form (e.g., autoregressive of order 2). This is done from examinations of the autocorrelations, partial autocorrelations, and inverse autocorrelations of X_t and perhaps ΔX_t or $\Delta_{12} X_t$. After a form is selected the model parameters are estimated, in effect, as the parameter values which minimize the sum of squares of the residuals

$$\hat{A}_t = X_t - \hat{X}_t \quad , \qquad \text{where}$$

$$\hat{X}_t = \hat{\Phi}_1 X_{t-1} + \dots + \hat{\Phi}_p X_{t-p} - \hat{\Phi}_1 A_{t-1} - \dots - \hat{\Phi}_q A_{t-q} \, .$$

That is, $\hat{X}_t$ is the one-step-ahead forecast of X_t. Since the residuals A_t are supposed to be a random sequence, a criterion for the adequacy of a model is that the residual series $\hat{A}_t$ contains no significant autocorrelations. When a model is fit to a data series and significant residual autocorrelations are found, the pattern of these autocorrelations can suggest modifications to the model.

When a model has been fit to the data which accounts for the autocorrelation structure the model can be used to produce forecasts of the data series X_t, namely,

$$\hat{X}_{t_0} + h, \quad h = 1, 2, \ldots, \quad t_0 \leq T,$$

where t_0 is forecast origin and h is the number of steps ahead that are being forecast.

In general, the autoregressive, moving average parameters are determined purely emperically and have no physical interpretation (i.e., they simply make the model fit the data). The SAS procedure also permits models to be fit that contain the effects of certain other independent variables.

In particular, in the analyses of the FARS data intervention effects were included which permitted the series being modelled to shift in level at the time when the relevant seat belt law went into effect.

For each state that had a seat belt law become effective during 1985, a model was fit to the data series.

$$X_t = \frac{N_t}{D_t} \quad t = 1, 2, \ldots, 132 \quad ,$$

where N_t is the number of fatalities in the state during month t, among occupants who would eventually be covered by the law, and D_t was a similar quantity summed over all states that did not ever have seat belt laws in 1985. The series X_t is, in general, a better behaved series than N_t, since in X_t many factors which would produce variation in both N_t and D_t tend to be cancelled out.

By analyzing the fatalities in each state as a ratio relative to fatalities in the aggregated 42 non-law states, the resulting trend reflects changes in the law state relative to ongoing trends in the 42 states. This procedure tends to cancel out the characteristic seasonal rise and fall in fatals, the downward shift in fatal during the recession of the early 1980s, and even any changes in the FARS collection system itself.

For each state a model was fit to the X_t series that contained an intervention parameter for a shift in level at the time the states' law went into effect. Thus, the size, direction and statistical significance of such a shift could be examined. Then the intervention effect was removed from the model and the model was used to forecast values of X_t from the first month the law was in effect through the end of 1985. Actual values of D_t were then multiplied times the forecasted values $\hat{X}_t$ to yield forecasted values $\hat{N}_t$ of

N_t. Both the $\hat{N}_t$ and the actual values N_t were then summed over the months of 1985 when the law was in effect, and compared. Some of the results of these analyses are given in the top half of Table 3. There, the first line shows that the model for New York fatals subject to the belt law contained two autoregressive parameters and one moving average parameter. A parameter indicating a shift in level in January 1985 was marginally significant (i.e., a test of the hypothesis of no shift versus an alternative of a downward shift). Summing the $\hat{N}_t$ and N_t over the entire year (1985) showed that 1059 fatalities would have been expected in New York in 1985, given the data through 1984 and no intervention. The 971 that occurred, thus, represent an 8.3% decrease from the expected number. When actuals and expecteds are summed across the eight states, we see a 9.9% decrease.

The bottom part of Table 3 gives similar results from models fit to occupants not covered by the law.

Table 3. Model Results

Covered Occupants

	State	Model	P-value Intervention	Months	Expected	Actual	Percent Change
1.	NY	Φ_1,Φ_2,θ_2	$.05 < p < .10$	12	1059	971	-8.3%
2.	NJ	Φ_{12}	$p \approx .10$	10	480	452	-5.8%
3.	IL	Φ_1,Φ_2,Φ_3	$p > .75$	6	504	457	-9.3%
4.	MI	Φ_1,Φ_2	$.05 < p < .10$	6	547	458	-16.3%
5.	NB	Φ_1,Φ_4	$p > .75$	4	62	55	-11.3%
6.	TX	Φ_1,Φ_2	$p < .01$	4	818	676	-17.6%
7.	NC	Φ_1	$p > .75$	3	225	224	-0.4%
8.	MO	Φ_3,Φ_4,θ_9	$p > .50$	3	175	192	+4.6%
	Total				3870	3485	-9.9%

Fatalities Not Covered by Laws

	State	Model	P-value Intervention	Months	Expected	Actual	Percent Change
1.	NY	Φ_1,Φ_2,θ_3	n.s.	12	958	989	+3.2%
2.	NJ	$\Delta_1,\theta_1,\theta_{11}$	n.s.	10	364	358	-1.6%
3.	IL	$\Phi_1,\Phi_2,\Phi_5,\Phi_{10}$	n.s.	6	342	367	+7.3%
4.	MI	Φ_1,Φ_{10}	$p \approx .01$	6	301	369	+22.6%
5.	NB	θ_1,θ_3	n.s.	4	31	26	-16.1%
6.	TX	$\Delta_1,\Phi_1,\Phi_4,\theta_1$	n.s.	4	463	449	-3.0%
7.	NC	Φ_2,Φ_3	n.s.	3	116	115	-0.9%
8.	MO	Φ_2,Φ_3,Φ_{11}	$p \approx .02$	3	74	52	-29.7%
	Total				2649	2725	-2.8%

Thus, in the group where a change is expected, the data are consistent with a positive belt law benefit in the form of 9.9% fewer fatals. In the group where the law would be expected to produce little or no effect, the data, indeed, fail to indicate substantial changes (-2.8%).

For "covered" fatals the trend is downward in all but one of the eight states. For "other" fatals, the trend is down in five states and up in three. In Michigan, "covered" fatals are down 16% and "other" fatals are up 22% (risk compensation?). However, in Missouri "covered" fatals are up five percent and "other" fatals are down 30% (reverse risk compensation?).

Based on this analysis, we estimate prevention of about 400 deaths below what would be expected during 1985. This reduction is only from these eight states and only for the applicable part of 1985.

IV. DISCUSSION

The data presented here are based on fragmentary experience. Longer term results from more belt law states must become available before a definitive assessment of injury and fatality trends can be made. However, these preliminary data are consistent with a modestly successful law.

It is worthwhile to consider, however, why the fatal and injury trends are not more favorable. Why not better results than a 10% drop in fatalities and a 13 to 16% reduction in injuries? Certainly research indicates that, with full use, belts are capable of producing a greater casualty reduction (Campbell, 1984). The level of belt use is precisely the answer. In most USA states with laws, belt use is currently reported in the 40-49% range. Thus, it is not surprising that net casualty reduction is attenuated.

In the USA the climate still does not completely favor high levels of compliance. Some police agencies are cool to the law, and enforcement is sometimes casual. Some laws themselves constrict enforcement either by limiting the penalty to a warning or by prohibiting enforcement except after the motorist is stopped for some other offense.

Also, seat belt laws came into being in the USA in the context of a long public dispute both in scientific circles and among policy makers between two approaches to occupant restraint. Certainly the USA has a long way to go. Intense public information and increased enforcement commitment are needed. Further, a special challenge is to design programs to reach persons of lower socio-economic and educational status, among whom belt use is least likely. This may be an even more urgent issue in the USA than in other countries. Because of our dependence on the motor car, and inadequate public transportation, it may be that a greater portion of lower socio-economic citizens drive than is the case in Europe.

Road safety professionals in the USA have urged increased use of passenger restraints for many years. It is gratifying that legislation is now taking effect, following the leadership of other nations. Some lives have already been saved, but the greater challenge lies ahead, both for those who seek to make the programs successful and those whose task is objective evaluation of the results.

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