# AN EXAMINATION OF STUDIES WHICH INVESTIGATE THE QUESTION OF ACCIDENT REDUCTION THROUGH FULL LICENSE PLATE REFLECTORIZATION

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## INTRODUCTION

Over the past 35 years, there have been a half-dozen or so investigations into the effectiveness of fully reflectorized license plates. Usually, these investigations have taken place under state auspices and have interpreted effectiveness to mean a 'reduction' in night, rear-end accidents. A reduction, "as compared to what?," becomes, in these studies, an extremely important question. This is because it causes us to focus on the method used to estimate the number of accidents that would have occurred had reflectorization not been introduced. The early studies, in particular, were unscientific and did not control for extraneous factors affecting night accident statistics. The absence of tight, experimental control disallowed the interpretation that observed accident reductions were uniquely the consequence of plate reflectorization. This is admitted by some authors. The point is also made in the literature critiques sponsored by interested parties such as reflective sheeting manufacturers.

Reviews by academic consultants to these manufacturers usually take the position that while not conclusive on an individual basis, collectively the investigations point to a small but real accident reduction potential through full plate reflectorization. Thus, it is generally conceded among consultants and reviewers that while no one study is definitive, the aggregated evidence establishes a favorable case for reflectorization.

> Taken as a group, the present authors feel that these seven studies provide evidence of a significant but not overwhelming safety benefit associated with reflectorized plates. To conclude to the contrary that no benefit exists requires the assumption that the accident reduction shown by all six of the studies [the Virginia study figures show a reduction in accidents, albeit not a statistically significant one in the viewpoint of the author] was in every instance artifactual, and that the behavior change measured in the Sacks study was not safety-related. An assumption of this nature, in the opinion of the present authors, cannot reasonably be defended at the present time (1).

The studies referred to were of vehicle populations that had nowhere near the rear-end lighting of today's cars. Rear lighting and reflectorization have been gradually increasing over the last several decades and, in fact, the 1984 SAE standards specify a third rear light above the trunk level.

At the time these reviews were written, the accident reduction investigations of Virginia, North Carolina, Minnesota, Washington, Iowa, and Maine were on record. Since then, data from Australia and Tasmania have become available and should be included in the corpus of "aggregated

evidence." Some, but not all*, of these investigations appear to show a small safety advantage for full reflectorization. However, none of these findings were statistically significant at commonly used risk levels; which is to say that the element of chance accident fluctuation in accident incidence could not be excluded. Technically, it is not feasible to combine these individual studies and address the question of collective statistical significance. Therefore, reviewers use a more subjective and intuitive argument, rather than a quantitative statistical one, when suggesting that the aggregated evidence supports the proposition.

Subjective evaluation of collective evidence is the usual basis of decision making since more precise and 'objective' rationales are seldom available for complex decisions involving human behavior. In the case of plate reflectorization, reviewers who support the bulk-of-evidence point of view allude to the subjective improbability that other, uncontrolled variables explain the small favorable finding for reflectorization in the majority of investigations. While acknowledging the possibility of alternate explanations in individual cases, they suggest that it would be unlikely for a string of investigations to generally favor reflectorization unless reflectorization was really effective. On the face of it, this argument is plausible. However, it should be pointed out that: a) now that more data are in, not all investigations favor reflectorization; and, b) of those that do, many share the same research defect. Consequently, their results are open to the same alternate explanations, and the common theme argument applies as much against reflectorization as for it. This observation greatly reduces the cogency of the aggregated evidence argument since reflectorization is not the only common factor relating to night accidents of the several studies.

Once having decided, on whatever basis, that reflectorization is effective, some authors and reviewers introduce a cost-benefit rationale to justify the policy of full plate reflectorization. It is pointed out that the accident reduction savings generated by reflectorized plates are greater than the additional cost of reflectorized sheeting itself. This alone, it is alleged, would justify the investment. (It is presumed, of course, that reflectorized plates <u>do</u> reduce accidents—a proposition for which satisfactory proof, most concede, does not to this day exist.) We could not disagree more. Even if a program is cost-beneficial, one would not ordinarily implement it if other programs offering superior benefits at the same cost, or less, were feasible. Until superior alternatives were exhausted, one would defer on a priority basis implementation of the program in question. This point cannot be overlooked if one really is serious about the optimal allocation of resources toward the goal of accident reduction. Thus, to improve decision making, the scope should be broadened to include <u>all</u> realistic alternative courses of action.

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*The Tasmanian study actually found that more reflectorized cars were struck in the rear at night than unreflectorized cars.

## LITERATURE REVIEW

The following is a review of literature on accident reduction with reflectorized license plates.

### Before-After Investigations

Both Minnesota (2) and Maine (3) compared night, rear-end accident statistics before and after introduction of reflectorized plates. Both investigations showed fewer accidents of this type after introduction of the plates. Hulbert and Burg (1) in their critique concisely summarized these works and are quoted here:

> The first attempt to determine whether the use of reflectorized plates led to accident reduction was carried out by Minnesota, which adopted reflectorized plates in 1956. In 1958, as reported by Baerwald, et al (2), an analysis was made of accidents occurring in 1955 ('before') and 1957 ('after'). Accidents of all types were analyzed, and the percent change in number of accidents of each type between 1955 and 1957 was ascertained. The results showed a significant increase in total daytime accidents from 1955 to 1957 while nighttime accidents remained unchanged (total vehicle registrations increased during that period). This means that nighttime accidents represented a smaller percentage of total accidents in 1957 than they did in 1955, in contrast to nationwide figures from the National Safety Council that showed unchanged percentages from 1955 to 1957.
>
> In addition, the Minnesota data showed a significant reduction in night rural non-intersection accidents, and a slight reduction in night rural intersection accidents. As Baerwald, et al, point out, these changes may have been a consequence of the introduction of reflectorized plates, but the evidence is only suggestive not conclusive. In the absence of accurate information as to what other safety-related changes may have been instituted in Minnesota between 1955 and 1957, and because the percentage of night accidents in Minnesota went down steadily from 1954 to 1958 [our italics], without further analysis the results of the Minnesota study thus far reported cannot be considered as convincing evidence of a safety benefit for reflectorized plates.
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> Another 'before-after' study was conducted in Maine (3) in 1964, in which the rural accident data for the before period (1945-1949) were compared with the after period (1950-1963), and the percentage of change

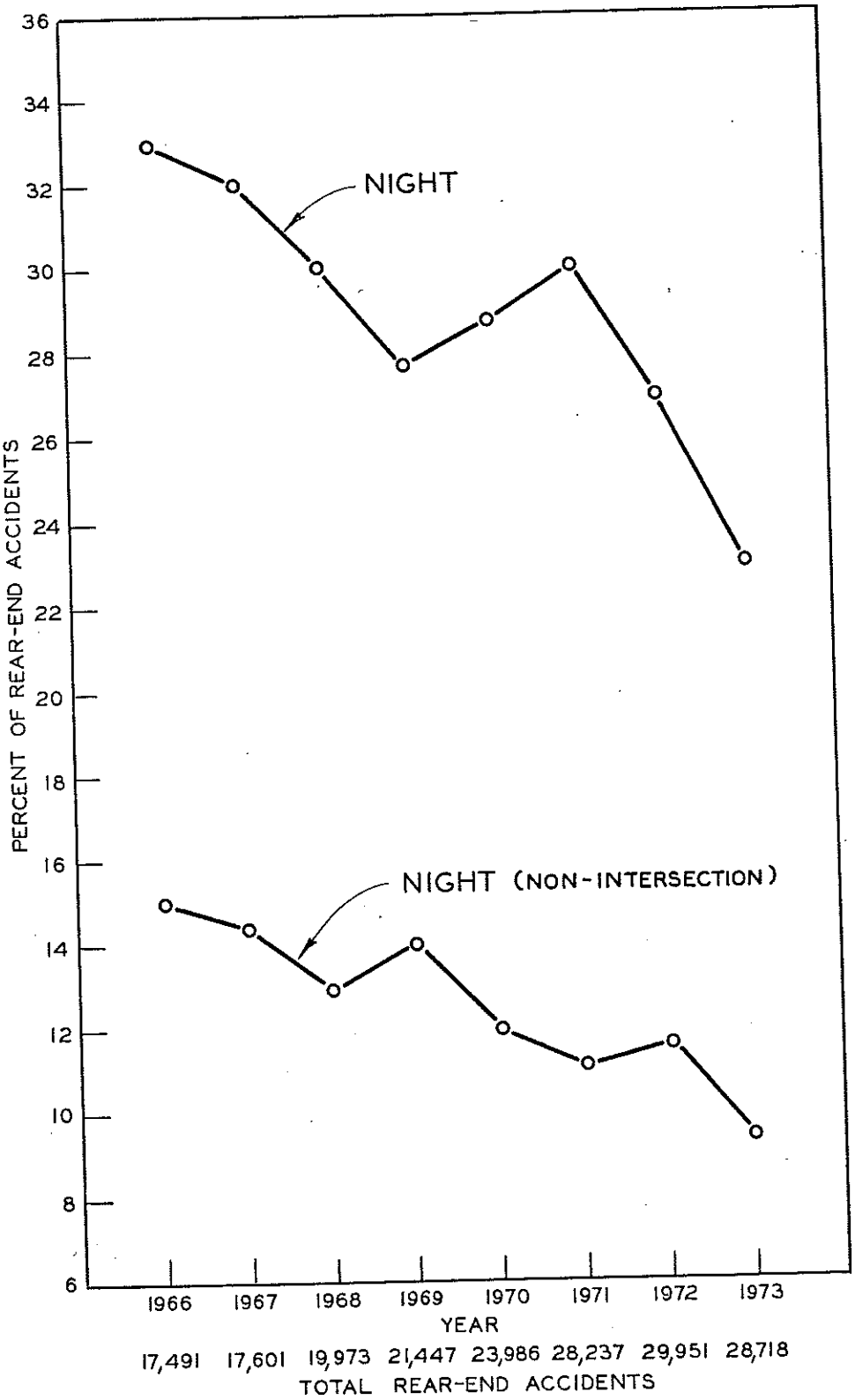


Figure 1. Michigan state trunkline accident experience excluding the City of Detroit for which data were not available.

> in each accident category calculated. The results showed that while total rural accidents increased 154.6 percent, and rural night accidents increased 113.8 percent, rural accidents involving a parked car decreased 57.5 percent. Despite these impressive figures, we are faced with similar problems of interpretation as with the Minnesota data, as there was a downward trend in all rural night accidents [our italics], and we are not presented with enough data to see how other types of night accidents (e.g., head-on) fared during this period. Also, the same questions arise as to whether any other safety-related changes occurred in Maine during the period in question.

It should also be noted that the 1950-1963 period saw considerable increase in rear-end visibility due to larger chromium bumpers and larger tail-lights. In conclusion, Hulbert and Burg state that:

> While the Maine and Minnesota studies both seem to show substantial accident reduction following introduction of reflectorized plates, before-after studies typically suffer from lack of control over other factors that may or may not have an influence on accident reduction. This shortcoming prevents such study results from being interpreted as being anything more than suggestive.

Generally, "other factors" are hopefully eliminated by careful sample selection through randomization and other statistical procedures. Even the courts, which are extremely particular about evidential quality, allow partial data or samples as legal evidence. The admission withstands objections of hearsay provided that samples are drawn in accordance with statistically sound procedures. It is not enough to present sample data or the conclusions drawn from them; one must demonstrate that proper statistical methodology was followed in the data acquisition process itself.

> When a sample is used to project an estimate, the burden of proof rests on the offerer to show that...the sample was selected in accordance with accepted principles of sampling so that it appropriately represents the universe. (4)

The possibility of sample contamination with 'other factors' plagues before-after accident studies, especially since long-term trends in accident statistics are commonplace. For example, Michigan data show a decline during the 1965-1975 decade in certain accident statistics that are relevant to the reflectorization issue. Considering night, rear-end accidents only, we find a decline in the percentage that occur at night both in general and non-intersection roadway sections (Fig. 1). We also find a decline in night, rural, injury, and fatal (Fig. 2). Had fully reflectorized plates been introduced in, say, 1970, the four-year 'after' period

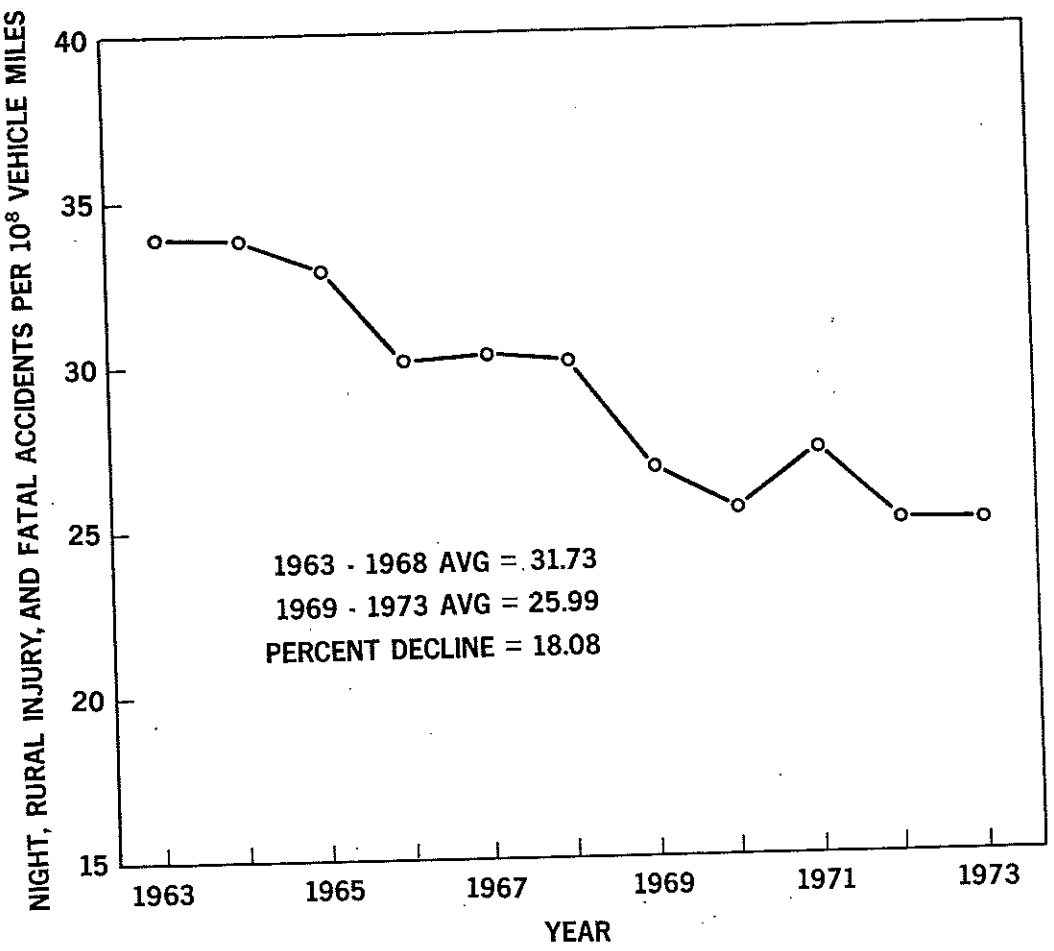


Figure 2. Eleven-year trend of night, rural, injury and fatal accident rate in Michigan.

would have shown a decline of about 15 to 30 percent, depending upon the statistics used. Because of the large number of accidents involved, the 30 percent decline would have been considered statistically significant and could be cited as evidence establishing the safety benefits of fully reflectorized plates. However, since fully reflectorized plates were not introduced, other factors must have been responsible for the trend. Sometimes these factors are overt, as in the case of gradually improved vehicle rear-end lighting and reflectorization. They can also be quite subtle, as in the case of increasing daytime versus nighttime accident exposure (hence, a decrease in relative nighttime exposure) following the growth of two and three-car families.

The Minnesota statistics pertained to deaths from night, rear-end accidents only. Deaths from this type of accident are relatively infrequent (in 1974 they constituted about 5 percent of all highway fatalities

in Michigan), and consequently present an unreliable statistic. In the Minnesota study, the reduction in fatalities would have to be substantial in order to produce statistical significance at customary risk levels. The Minnesota data are not available for this determination. Moreover, during the study of both the Minnesota and Maine Departments, all nighttime accidents decreased; not just rear-end. This fact alone suggests that other, more general causes are at work which tend to reduce head-on, fixed object, etc., as well as rear-end accidents. Therefore, it is difficult to maintain that the use of fully reflectorized license plates in Minnesota and Maine are uniquely responsible for the observed reduction in accident statistics.

Non-Randomized Simultaneous Investigations

Simultaneous studies are inherently superior to before-after studies because they eliminate the interference of extraneous time trends in the data. Time trends are very common in accident data: Michigan's traffic death rates have steadily declined from 15.2 per hundred million vehicle miles in 1933 to 2.3 per hundred million vehicle miles in 1982. If there are time trends, presumably they affect experimental (reflectorized plates) and control (non-reflectorized plates) groups equally and one can still measure any differential effects on accident statistics due to the introduction of the experimental variable. In addition, good design procedures require that simultaneous studies randomize the allocation of experimental and control treatments to the individuals in the study sample. For example, one cannot merely pass out reflectorized plates on a first come, first served basis. If this is done, one runs the substantial risk of introducing into the experiment human behavioral proclivities and thereby biasing the results. In fact, under these conditions, no statistical significance testing is legitimate since these tests assume that samples are selected randomly. The point is absolutely fundamental and is succinctly elaborated by Hulbert and Burg in their review of the Iowa study (5).

> Reflectorized license plates were issued to some 60,000 vehicle registrants, until the supply was exhausted; the remaining registrants, representing some 39.9 percent of the total of 99,831 vehicle registrations, received conventional plates. Subsequent accident data showed that while 61.6 percent of the registered vehicles had reflectorized plates, only 23.3 percent of the parked cars involved in rear-end nighttime accidents had reflectorized plates. The Iowa study used simultaneous study of the accident experience of reflectorized and non-reflectorized groups, a much more powerful design than the "before-after" approach used in Minnesota, and thus the results are more compelling. However, caution must be used in interpreting the Iowa results because of the way in which the reflectorized plates were distributed, on

a first-come basis. It is possible that there were important accident-related differences between people who purchased their plates early and those who bought them later (after the supply of reflectorized plates was exhausted). This question could and should have been resolved by conducting an analysis of the personal and driving record characteristics of the drivers (registered owners) in the two groups. Even had this been done, we still would not have been positive that the 61.1/39.9 split of reflectorized/conventional plates in the population also represented the split for nighttime parked cars. In addition, as with most studies involving driving records, there is a question of how "pure" the criterion data are, due to inadequacies of the accident reporting/encoding/storage process. For example, it is not known how many parked cars were hit by drunk drivers, drivers falling asleep at the wheel, drivers swerving to avoid an obstacle, and so on. Despite these drawbacks, however, the Iowa study remains a strong one.

The same problem occurs in the North Carolina study (6) where the public was allowed to obtain reflectorized plates on a demand basis during a changeover period of six weeks. Again, Hulbert and Burg remark:

> [The North Carolina] effort was an attempt at a simultaneous study of reflectorized and non-reflectorized groups, but suffered from the fact that the study could not be set up properly in advance. Campbell and Rouse fully acknowledge the shortcomings of their study, and are very cautious in interpreting their data. The accident data analyzed were from a six-week period early in 1967, during which there was a changeover in North Carolina from conventional to reflectorized plates and either one could be used legally. Accident-involved cars with and without reflectorized plates were compared during this period; however, the study design suffered from two problems. First of all, there was no plan for distribution of reflectorized plates during the six-week period, so it could not be determined whether there were any significant differences in composition between the reflectorized and non-reflectorized groups. Secondly, it could not be ascertained whether the two groups were equal in their exposure to night accidents during the six-week period. The latter is a problem common to all studies conducted to date, however.
>
> Campbell and Rouse made an attempt to compensate for these shortcomings by comparing daytime as well

> as nighttime accidents, and rear-end vs. non-rear-end accidents. Their data included 1,362 rear-end collisions and 2,096 other collisions, and the breakdowns indicate that whether or not the striking car had reflectorized plates, reflectorized vehicles constituted a smaller percentage of the struck vehicles than did vehicles with conventional plates. Using a one-tailed test of significance (which is entirely appropriate in studying reflectorized plates since there is no reason to anticipate an increase in accidents attributable to the use of such plates), Campbell and Rouse find the differences in favor of reflectorized plates to be of borderline significance. That is, the probability that the differences occurred by chance does not quite meet the 0.05 level commonly used; however, as is pointed out later in this paper, it has not been uncommon to use a less stringent criterion, such as the 0.10 level, to assess the significance of results in behavioral research.

(Here Hulbert and Burg ignore the increased risk of the "other" kind of error, namely of concluding an effect when none exists. This necessarily results whenever we liberalize our 'detection' level; i.e., to 0.10. Associated with the increased risk of this type of error are, of course, the foregone opportunity costs of other safety programs which gave way to one erroneously considered effective.)

> Campbell and Rouse conclude that "In summary, the data support the primary hypothesis, that reflectorized plates are effective in reducing nighttime rear-end collisions. Reasonable alternatives were examined, but the alternatives were not supported by the data." (p. 14). They go on to estimate that this reduction would amount to some 13 percent, or about twice the amount necessary to offset the costs of the reflectorization process.

Both the Iowa and North Carolina studies are sensitive to the possibility that the kind of people who purchase license plates early in the changeover period are less accident prone. A weak correlation of this type could easily explain the small differences in accident statistics. Thus, reflectorized vehicles in both the Iowa and North Carolina studies may experience less accident involvement than non-reflectorized vehicles because the latter group, for economic reasons, may experience more nighttime street parking. Also, nighttime rear-end accidents may involve more intoxicated drivers who, for whatever reason, typically obtain plates late in the changeover period and also tend not to drink in the relative safety of the home. It is commonly known that drinking style (what, where, when, and how much) is associated with family income and age. In addition, if income or age are associated with when people choose to purchase

plates, then those who delayed purchase in Iowa and North Carolina may constitute a high risk group and ultimately experience more accidents of every kind or nighttime, rear-end only.

In research investigations where human behavior is an important factor, subtle, indirect correlations such as the one just discussed can shape or even dominate the research results. This is why randomization is so important; it greatly reduces the chances of unwanted factors creeping in and contaminating the study findings.

The North Carolina study itself contains evidence that a more general social behavior hypothesis is warranted. Consider Table 1. The North Carolina researchers point to the finding that Group 2 is struck less at night than Group 1, and that Group 4 is struck less at night than Group 3. This they interpret to mean that reflectorized plates are responsible for the reduced nighttime accident proportions of these groups.

TABLE 1
Various Reflectorization Accident Categories and their Nighttime, Rear-End Accident Experience; North Carolina Data

| Group No. | Status of Striking Vehicle | Status of Struck Vehicle | Proportion of Collisions Which Occur at Night |
|---|---|---|---|
| 1 | unreflectorized | unreflectorized | 0.351 |
| 2 | unreflectorized | reflectorized | 0.313 |
| 3 | reflectorized | unreflectorized | 0.327 |
| 4 | reflectorized | reflectorized | 0.269 |

Table 1 also reveals that Groups 2 and 3 have comparable night, rear-end accident experience. Thus, reflectorized vehicles are struck by unreflectorized vehicles about as much as unreflectorized are struck by reflectorized (0.313 compared to 0.327). From these data, one cannot conclude that the plate status of the struck vehicle is relevant to the probability of a night, rear-end collision.

The hypothesis that explains the accident experience of all groups in the North Carolina study is that while reflectorized vehicles tend to be involved in relatively fewer night, rear-end collisions, it does not matter whether or not they are striking or struck and hence the reflectorized group is less accident prone, per se, not just at night. But if reflectorized plates reduce accidents, one would expect that fewer reflectorized cars

would be struck in the rear by unreflectorized cars at night than vice-versa. This is not the case in the North Carolina study; exactly 87 cars were struck in each category. A very reasonable hypothesis explains all the North Carolina data (Table 2). If plates were not purchased uniformly during the changeover period, as assumed by Campbell and Rouse, the data in Table 2 would not be as expected. In particular, if people were slow to purchase plates, i.e., more purchases occurred at the end compared to the beginning of the period, unreflectorized vehicles would have more accident exposure since they tended to be on the road a greater percentage of the time.

TABLE 2
North Carolina Accidents During Six-Week Changeover Period
(From Ref. 6)

| Struck Vehicle | | | Striking Vehicle: Rear-End Accidents, Refl. Plates | Striking Vehicle: Rear-End Accidents, Non-Refl. Plates | Striking Vehicle: Other Accidents, Refl. Plates | Striking Vehicle: Other Accidents, Non-Refl. Plates |
|---|---|---|---|---|---|---|
| Day | | Refl. Plates | 196 | 191 | 357 | 315 |
| Day | | Non-Refl. Plates | 179 | 357 | 370 | 483 |
| Night | | Refl. Plates | 72 | 87 | 131 | 139 |
| Night | | Non-Refl. Plates | 87 | 193 | 131 | 170 |

The North Carolina data can be used to estimate the shape of this purchasing function (Fig. 3). This function almost perfectly predicts these data (Table 3).

All North Carolina data can be estimated in this manner, and the results are consistent with the reported findings, using purchasing functions for

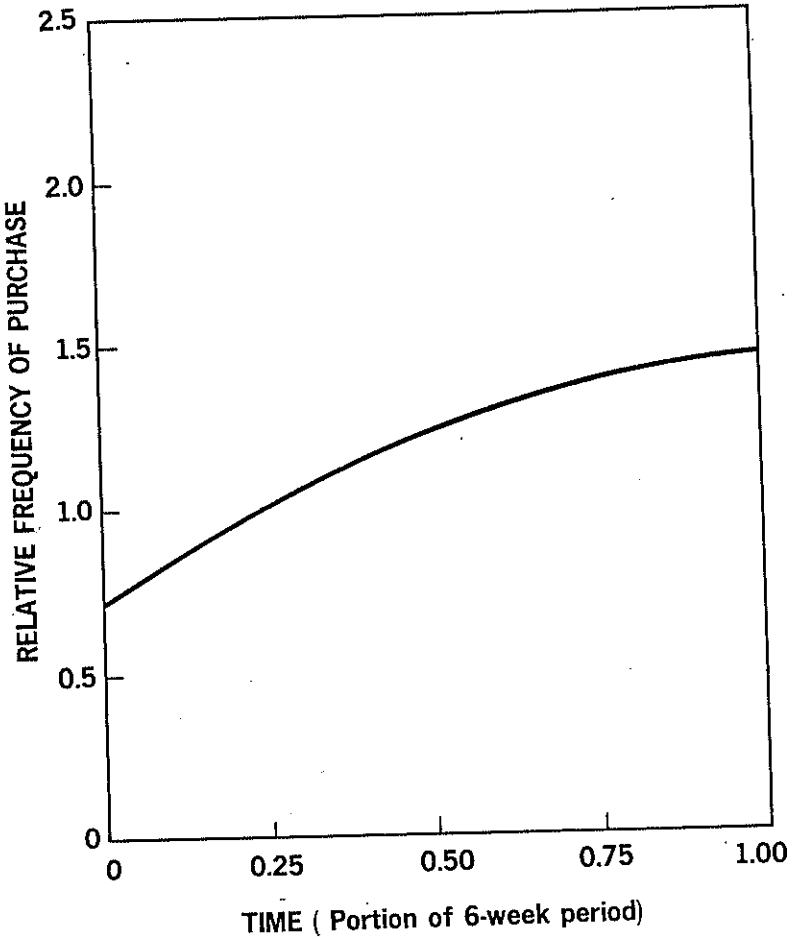


Figure 3. Rear-end, daytime accidents only.

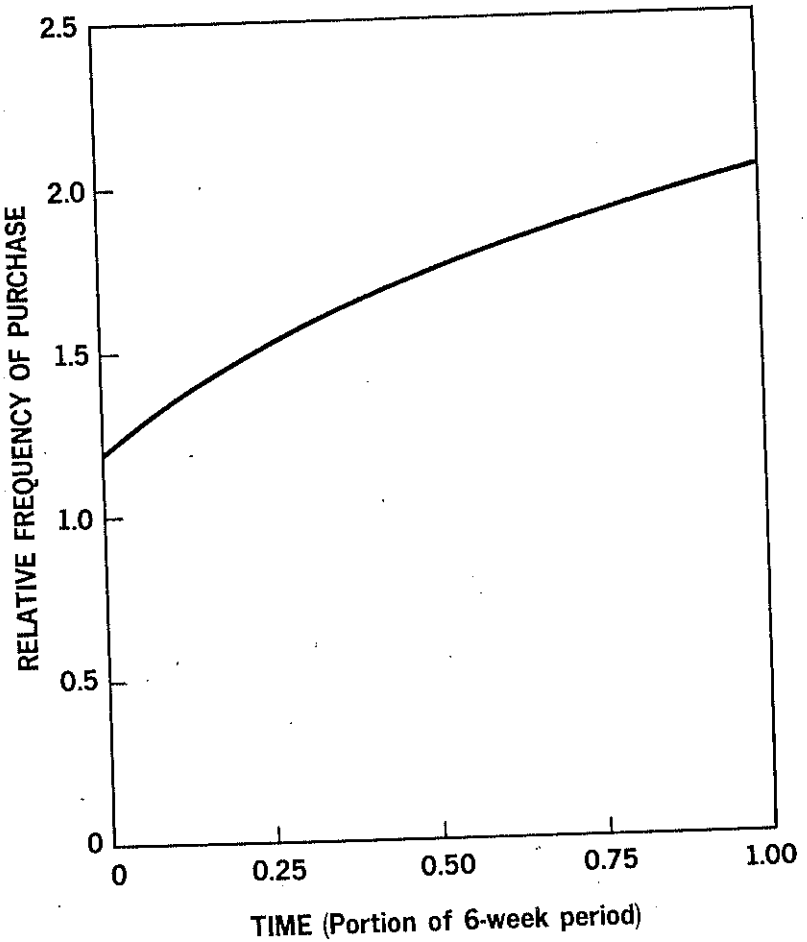


Figure 4. Rear-end, nighttime accidents only.

TABLE 3
Rear-End, Daytime Accidents Only

| Accident Type | Observed | Predicted By Purchasing Function |
|---|---|---|
| Reflectorized Striking Non-Reflectorized | 179 | 185 |
| Reflectorized Striking Reflectorized | 196 | 196 |
| Non-Reflectorized Striking Reflectorized | 191 | 185 |
| Non-Reflectorized Stricking Non-Reflectorized | 357 | 357 |

each of our accident categories (these functions were very nearly identical to the one shown in Figure 3). Of special interest are night, rear-end accidents. These results are shown in Figure 4 and Table 4.

Further, we point out that the purchasing behavioral hypothesis of different accident risk groups resulting from demand purchasing of reflectorized plates predicts the North Carolina accident incidence more accurately than the reflectorization hypotheses. Under these circumstances, it would be difficult to prefer the reflectorization hypothesis since it produces more error in the prediction process.

TABLE 4
Rear-End, Nighttime Accidents Only

| Accident Type | Observed | Predicted By Purchasing Function |
|---|---|---|
| Reflectorized Striking Non-Reflectorized | 87 | 89 |
| Reflectorized Striking Reflectorized | 72 | 72 |
| Non-Reflectorized Striking Reflectorized | 87 | 87 |
| Non-Reflectorized Striking Non-Reflectorized | 193 | 193 |

Since all of the North Carolina data tend to support the more general purchasing behavior hypothesis, it is to be preferred over the more narrow reflectorization hypothesis which is not even consistent with the night, rear-end accident data set. Thus, the North Carolina data do not unambiguously show a safety advantage for reflectorized plates; however, they do demonstrate the pitfalls that bedevil a non-randomized research design.

Only two extraneous factors are needed to explain the apparent accident reduction potential of reflectorized plates discussed previously:

1) Either night accidents have been declining as a percentage of total accidents as in Michigan, or

2) People who purchase license plates early in the changeover period tend to be involved in fewer accidents at night.

These are both very realistic hypotheses in terms of what is known of social behavior and long-term trends in accident statistics.

Randomized Simultaneous Investigations: Australia and Tasmania

In 1975, data from Australia and Tasmania became available (7). As with the North Carolina investigation, the accident statistics were compiled for the samples during the changeover period. Thus, during the survey period, both reflectorized and non-reflectorized vehicles were on the road in proportions which depended upon how much time had elapsed since the onset of the changeover period. However, in contrast to Iowa and North Carolina, these investigations may be considered to have randomly allocated reflectorized plates since there was no choice as to the purchase date of the new plates. New plates were issued only on the vehicle registration date anniversary--a procedure that should at least eliminate purchasing behavior biases that may have affected the North Carolina study.

In the Australian and Tasmanian report the authors correctly decide to consider only night, rear-end accidents for which one vehicle had reflectorized plates and the other did not. Thus we have two possibilities: 1) a reflectorized vehicle strikes a non-reflectorized vehicle; and, 2) a non-reflectorized vehicle strikes a reflectorized vehicle. If reflectorization is effective in reducing night, rear-end accidents, a greater proportion of reflectorized vehicles should strike non-reflectorized vehicles than vice-versa. The combined Australian and Tasmanian data show that slightly more (four) reflectorized vehicles were struck. Therefore, the authors conclude that there was no evidence to support the conclusion that reflectorized plates reduce night, rear-end accidents.

Of the investigations thus far discussed, the Australian and Tasmanian experiment designs are the most satisfactory since they probably eliminate the influence of extraneous factors. This is substantiated by statistical estimation of the same kind of plate purchase functions as used in

the North Carolina study. These functions were essentially flat as they should be if reflectorized vehicles appeared on the road in a uniform manner. However, the data set was small (1,315 collisions) so that no definitive conclusion is possible.

The largest and most conceptually thorough of all the investigations to date is that conducted by Virginia (8). The accident experience of 100,000 without reflectorized plates and 100,000 with reflectorized plates were compared. All vehicles were selected in a manner intended to guarantee random allocation of the reflectorized plates. From this study group, it was found that during the study year, 497 non-reflectorized vehicles were involved in night, rear-end accidents while 475 reflectorized vehicles shared the same fate. The difference of 22 was not considered statistically significant by the author.

Most of the controversy over the Virginia report concerns its finding that the difference of 22 accidents between the two groups was not statistically significant at the 0.05 level. Critics (1, 9), while not able to show that the difference is statistically significant at 0.05, disagree with the formulation of the research hypothesis. The validity of this criticism notwithstanding, the Virginia report fails to find anything other than a small difference in the accident experience of the two groups. Some critics argue that if this difference is real (it would have been considered real if statistical significance had been demonstrated) the effect is large enough to warrant reflectorized plates on a cost-benefit basis (10, 11). This conclusion is based on a cost-benefit analysis in which the cost of reflectorization is compared with the cost of accidents presumeably prevented with plate reflectorization. The conclusions are particularly sensitive to the cost inputs; a point which engenders considerable controversy, particularly in this day of matching fund potentials.

## CONCLUSIONS

We find that the presumed safety benefits of full plate reflectorization have not been unambiguously demonstrated. Early studies (Maine, Minnesota) tended to suggest benefits; however, these studies are seriously flawed by very poor research designs which probably capitalized on known accident reductions caused by factors other than plate reflectorization. As subsequent studies (Iowa, Virginia, North Carolina) became more sophisticated and sought to eliminate extraneous causal factors in accident statistics, benefits attributed to reflectorization were reduced or found to be non-existent. However, several (Iowa, North Carolina) of these interim studies were still not methodologically satisfactory in that they allowed plates to be purchased on a demand basis, thus introducing the possibility of human behavior differences into the research design. Finally, the latest studies (Australia, Tasmania) attempted to eliminate both time trend in accident data and behavioral biases. These studies found no safety benefit for reflectorized plates.

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