Use of Reflectorization to Reduce Truck-Trailer Accidents

WILLIAM J. BURGER AND RUSSELL L. SMITH

Accidents in which vehicles strike large trucks produce a disproportionately large number of fatalities. It is hypothesized that increasing a truck's visibility or conspicuity will reduce the number of vehicles colliding with trucks. The purpose of this project was to thoroughly analyze this specific accident problem, establish information requirements of vehicle drivers, review the state of the art of conspicuity techniques, design and conduct a series of conspicuity experiments, design a new integrated lighting and marking system, design an augmented low-cost reflectorized system for retrofitting on large trucks, and field test the augmented system on fleets of trucks. Augmented systems were fitted on 2,060 trailers, and accident rates were monitored and compared to those of a matched control group of 2,060 nonreflectorized trailers. Both reflectorized and control groups accumulated over 106 million mi. Final accident rates indicated that the reflectorized trailers were involved in conspicuity-related accidents 15.1 percent less frequently than control trailers.

Large trucks weighing 26,000 lb or more constitute less than 2 percent of the total population of vehicles in the United States but are nevertheless involved in accidents yielding nearly 9 percent of all traffic fatalities. The great majority of these fatalities were occupants of passenger cars that collided with large trucks. Therefore, countermeasures aimed at a small percentage of vehicles could lead to a significant reduction in the relatively large percentage of fatalities. One obvious countermeasure would be improving visibility or conspicuity of large trucks. In this paper, a 5-year project designed to develop and evaluate improved-conspicuity systems for large trucks is summarized.

Imposing new federal lighting and reflector system requirements would clearly affect the trucking industry directly and every driver indirectly. Thus, before development and test of proposed new conspicuity systems, every effort was made to provide a thorough statement of the problem.

The project was composed of the following tasks and subtasks:

1. Task 1: Define and analyze the vehicle-into-truck collision problem.
   a. Review relevant literature.
   b. Interview trucking companies.
   c. Analyze accident data.
   d. Develop functional requirements.
   e. Analyze retroreflective and fluorescent material and characteristics.
   f. Evaluate current federal motor vehicle safety standards.
2. Task 2: Design and evaluate augmented (retrofitted) and new integrated lighting and reflector systems.
   a. Design various conspicuity systems and conduct laboratory and field experiments.
   b. Design a specific low-cost augmented system for field testing on truck fleets.
   c. Prepare a detailed plan for conducting the field test of the augmented system.
   d. Design a new, integrated conspicuity system for original equipment manufacture (OEM).
3. Task 3: Conduct field test of the augmented system on selected truck fleets.
   a. Select conspicuity materials.
   b. Select truck fleets.
   c. Install conspicuity materials.
   d. Collect and analyze accident data.

The following sections emphasize major findings, analyses, and considerations with respect to these three tasks. Vastly more detailed accounts can be found elsewhere *(1–3)*.

DEFINITIONS AND ANALYSIS OF THE VEHICLE-INTO-TRUCK COLLISION PROBLEM

Analysis of Accident Data

Reviews of existing extensive analyses of a number of accident data bases reveal that large trucks are struck about equally often in the rear and side, the latter including both sideswipes and perpendicular impacts. They are also equally often struck at night or in dimly lit environments as during the day and are struck about equally often on rural and urban roads that are both level and graded.

Rear impacts tend to occur when the truck is traveling straight ahead and moving slowly, stopping, or stopped on the roadway. The following driver either (a) does not see the truck at all, (b) sees the truck but misjudges its motion or distance, or (c) correctly perceives the truck's dynamics and distance but not within sufficient time to avoid a collision.

Trucks are struck perpendicularly in the side most often when turning or when astride lanes, that is, when backing, making U-turns, and so forth. They are often sideswiped, however, when traveling straight ahead.

The conspicuity problem with large trucks is not restricted to nighttime conditions or specific lighting and marking systems. Trucks are apparently inconspicuous during the day, and both their sides and rear ends need to be made more visible.

Vector Enterprises, Inc., 1550 17th Street, Santa Monica, Calif. 90404.

Development of Functional Requirements

On the basis of the accident analysis, 19 scenarios were established that encompassed nearly every situation in which cars collided with trucks. Each scenario was analyzed at a level of detail necessary to identify the functional requirements of truck communication systems. The scenarios included vehicle locations, movement directions, and varying speeds. Computed stopping distances indicated the distances at which the driver of the striking vehicle would have to apply the brakes to stop or slow sufficiently to avoid a collision.

Scenario analysis demonstrated that existing truck conspicuity or signaling systems communicated general rather than specific information with respect to a truck's dynamics. For example, the current system for indicating changes in velocity has only two states: the brake light is either on or off. The vehicle can be either stopped, accelerating, maintaining a constant speed, or decelerating, and with regard to acceleration and deceleration, the rate of change can vary substantially. Thus the current system relies on the driver to perceive changes in rate of closure. This is an extremely difficult perceptual task, particularly at night, when much of the visual input is severely reduced.

The vehicle-into-truck accident analysis and associated scenarios clearly indicated a need for improved truck conspicuity systems that would provide drivers with the following specific information on the truck's position and dynamics:

- Presence of a vehicle,
- Indication of a truck,
- Distance,
- Speed,
- Whether truck is maintaining constant speed,
- Whether truck is accelerating,
- Whether truck is stopping,
- Whether truck is stopped,
- Whether truck is backing up,
- Whether truck is maintaining a constant direction, and
- Whether truck is turning.

A number of techniques exist for satisfying these functional requirements. Unfortunately, most of these techniques would be too costly to be seriously considered at this time. Thus less-than-optimal solutions must be sought that are nevertheless significant improvements over current systems. Such solutions must derive from an understanding of how drivers detect and identify the presence of a truck and acquire knowledge of its dynamics.

It has often been said that most accidents are wholly or principally caused by inattentive behavior. Thus detection performance depends, at least partially, on target awareness through increased vehicle conspicuity that compensates for car driver inattention by penetrating the driver's field of view.

It is generally believed that luminance contrast is the major cue for detection *(4)*. However, although luminous contrast is certainly necessary for detection, a stimulus may not attract a driver's attention in a cluttered environment. Burg and Hulbert *(5)* and Burg and Beers *(6)* demonstrated that the unique shape of a stimulus is of considerable importance in attracting attention and establishing recognition. For example, reflectors completely outlining wheels on bicycles and motorcycles attract far more attention than do nondistinct, arbitrarily located reflectors.

Drivers use subjective judgment in determining distances and dynamics of other vehicles. Carefully controlled laboratory experiments indicate that size changes of an object moving in depth constitute the dominant cue in judging motion in depth *(7, 8)*. Apparently, the larger the object appears to an observer, the smaller the size change necessary to detect motion *(9)*.

In vehicle following, speed differences become increasingly important the closer the following vehicle approaches the leading vehicle. Ittleson *(10)* noted that although size changes in an object provide motion cues, judgment of distance to an object depends on prior known object characteristics. Thus if an object projects characteristics that provide no cues or ambiguous cues, no basis exists for estimating its distance. An example would be the rear end of a truck. Most drivers are knowledgeable of truck sizes and, when such vehicles are well illuminated, can estimate truck distances by virtue of this knowledge. On the other hand, when trucks are poorly illuminated at night, size cues are degraded, and estimations of distance would be expected to be degraded as well.

In the laboratory, Jannsen *(11)* found that changes in taillight size and brightness were ineffective cues in the relative-motion depth detection. His results indicated that changes in the angular separation between taillights constituted the primary cues for such judgments. Such findings were confirmed by on-the-road studies *(12, 13)*.

In extrapolating from the foregoing, it appears that the perception of movement in depth would be enhanced even more by presenting a larger target to drivers than that inherent in two taillights. In fact, Fisher and Hall *(14)* presented evidence that outlining the entire rear-end of a truck was more effective than the simple angle generated by two taillights. Because driver inattention undoubtedly contributes substantially to degradations in the perceptual process, attention and subjective judgments should be enhanced by improving perceptual cues.

Analyses of Retroreflective and Fluorescent Materials

Reflective materials are obviously far less costly than lighting systems and far more easily retrofitted to trucks to improve conspicuity. Therefore a thorough analysis of reflective materials was performed to determine their characteristics—particularly their effectiveness and durability.

Retroreflective Materials

A retroreflector directs most of the reflected light back along the line of incidence, that is, back towards the light source. Thus the reflector is seen as brightest when the observer's eye is close to the light source. Retroreflectors inherently have narrow beam patterns with respect to observation angle. At an observation angle of 1.0 degree, relative intensity may typically be only one-tenth that of 0.1 degree.

The retroreflective devices relevant to trucks include materials containing (a) spherical glass bead elements or (b) cube corner or prismatic elements. In both cases, it is the elements that reflect the incident light. Glass bead materials include those with beads that are partially imbedded within a supporting surface such as paint and partially exposed to the atmosphere and those with beads that are completely imbedded within a transparent material. Exposed-bead designs generate greater brightnesses but are more easily damaged by abrasion and completely lose their reflectivity when wet. Newer versions of enclosed-bead materials, referred to as encapsulated lens sheeting, have provided greater brightnesses while retaining their protective characteristics.

With regard to prismatic-based materials, the inside of the corner of a cube contains three mutually perpendicular surfaces that reflect light back in the direction of incidence. This principle is used in two types of reflector materials, rigid plastic and sheeting of vinyl, polycarbonate, or other plastic materials. Cube corner reflectors are typically brighter than beaded glass materials at small angles between the cube axis and the observation direction but exhibit a sharper relative decrease in brightness as the angle increases.

A number of conditions reduce the life expectancy of retroreflective materials. The top layer of reflective sheeting can be damaged by abrasion due to dust, sand, and so forth. Oxidation and other chemical reactions can affect the top coat, internal layers, and adhesive backing. Ultraviolet exposure can cause hazing and can discolor and affect properties of plastics, resins, and adhesive backing. Physical impact, any flexing or bending, and extreme temperatures can cause cracking. Moisture can also affect the adhesive backing and, if it penetrates inner layers, can degrade retroreflectivity.

Weather conditions can severely degrade retroreflective materials. Rain, fog, blowing dust and sand, snow, dew, and frost reduce brightness by (a) attenuating and scattering of the light in paths to and from the reflector and (b) forming a degrading optical layer on the reflector surface.

Empirical data regarding the durability of retroreflective materials are severely limited. It is therefore difficult to predict reflector lifetime in truck operations from available data. It would appear, however, that 5 years may be a reasonable expectation for some current materials.

Fluorescent Materials

Fluorescent pigments are organic substances containing dyes that are capable of fluorescing in solid solution, for example, in a paint pigment or resin binder. Such pigments convert light from the shorter wavelengths (violet, blue, green, and yellow) to longer wavelengths. The fluorescent energy is added to normally reflected light, resulting in an effective reflection factor of 200 to 300 percent, compared to 90 percent for a bright, nonreflective color. Several manufacturers produce sheeting materials that are both fluorescent and retroreflective.

Studies on visibility and conspicuity of fluorescent colors agree that such colors are much more easily seen than are nonfluorescent colors. Fluorescent orange appears to be the most conspicuous. Of particular interest, especially when considering application to daytime truck conspicuity, is the fact that fluorescent colors are found to be more attention-getting in peripheral vision than are ordinary pigments.

The most serious drawback to the use of fluorescent materials is their limited lifetime with ultraviolet exposure. About 2 years is a practical maximum in most outdoor situations, and useful lifetime can be as short as 3 to 6 months. Therefore applications to truck conspicuity appear generally impractical.

DESIGN AND EVALUATION OF AUGMENTED (RETROFITTED) AND NEW INTEGRATED LIGHTING AND REFLECTOR SYSTEMS

Task 1 demonstrated that the range of possibilities for improved-conspicuity systems was large and that available empirical data were inadequate for selecting the best of the more cost-effective designs. Therefore Task 2 consisted of a series of experiments for resolving important issues and screening out most of the possible design configurations. Before conducting the experiments, the following design guidelines were established for the augmented and integrated conspicuity systems:

- Truck marking and signaling systems should be standardized as much as possible across all truck body types.
- The augmented system should be restricted to reflectorization treatments to maintain low-cost retrofitting.
- Designs should have acceptable implementation costs and life expectancies.

Six months were allocated to the design phase, limiting the number and types of experiments that could be conducted and the number and types of issues that could be addressed.

Design of Systems and Experimentation

All experiments were concerned with reflectorization designs, as little could have been added to the large body of experimental data on vehicle lighting systems within the current program scope. Thus all recommendations concerning lighting and signaling aspects of the integrated system were based on previous research.

Six experiments were conducted. In some cases, subjects directly observed conspicuity treatments on an actual truck. In other cases, slides were taken of an actual truck and subsequently used in a laboratory setting. In still other cases, slides were taken of miniature vehicles on a 1:25-scale roadway and subsequently used in a laboratory.

The first experiment evaluated 45 rear-end reflector treatments and compared them to conventional configurations specified by the U.S. Federal Motor Vehicle Safety Standards (FMVSS108). Designs outlining the entire rear perimeter and mud flaps were found to be superior to all other designs with respect to conspicuity and ease of detection.

In the second experiment, 12 different patterns involving style and color were presented in pairs on a test truck to subjects at night. Alternating white and colored rectangles were found to be superior in conspicuity, detail, and visible detail. The actual color was less important.

The third experiment replicated the second experiment during the day. Again, the alternating white and colored rectangle design was superior to the other designs. The actual color was again of lesser importance, except when fluorescent materials were used.

The fourth experiment studied the effect of reflectorized rear-end patterns on distance judgments. Seven patterns were used. The design having the perimeter of the rear-end and mud flaps reflectorized was judged by the subjects to be closer than were the other designs. It was also found that the lower the reflectorized area on the truck body, the closer the truck appeared.

The fifth experiment evaluated partial-to-complete perimeter outlines of both the truck rear and side and compared them to the conventional configuration during daytime and nighttime illumination levels. For nighttime conditions, the complete perimeter outlines were found best for both the truck side and rear. Essentially no differences were found among the designs during daytime.

Finally, the sixth experiment evaluated partial-to-complete outlines for their ability to provide rate-of-closure information to subjects. All experimental designs were found superior to the conventional configuration, particularly the complete rear and side outline designs.

Specific Low-Cost Augmented System Design for Field Testing on Truck Fleets

The recommended augmented system design was based on the results of Task 1, the experiments described, previous research by others, and the guidelines discussed earlier. The recommended system consisted of outlining the entire truck rear end and sides. The reflector pattern was a 4-in.-wide stripe of alternating red and white rectangles. In the case of flatbeds, a continuous stripe around the rear and side rails was recommended. A U-shaped outline of the mud flaps was also recommended, using a 2-in.-wide white retroreflective material stripe. Figure 1 shows the recommended configuration.

A variety of retroreflective and reflective materials and devices can be used, including glass bead and prismatic-type sheetings and reflex reflectors. It is considered essential, however, that retroreflective materials be hermetically sealed. Also, reflex reflectors should be of a dispersed-angle-prism design so that a wide angular characteristic is obtained.

Minimum and maximum specific intensity per unit area (SIA) values were recommended on the basis of considerations of minimum intensity necessary for adequate conspicuity and effects of temporary degradation due to dirt, grime, long-term weathering, and glare potential. These values were 250 to 300 and 500 cd/lx/m^2, respectively, for the stripe outlining the truck and 200 and 300 cd/lx/m^2, respectively, for the mud flap stripe.

Detailed materials and installation cost analyses were performed for the recommended retroreflective design and partial configurations such as rail only, partial rail, and broken whole outline. The 1981 estimated costs ranged from a low of $34 for the partial rail treatment to a high of $416 for the complete outline treatment.

New Integrated Conspicuity System Design for Original Equipment Manufacture

The perimeter outline reflectorization design for the augmented system just described was also recommended for the integrated system. Two pairs of four lights each were recommended for the rear lighting system of trucks. Each set of lights could be positioned horizontally or vertically on the lower corners of the truck. The outer (horizontal) or lower (vertical) lights represented red presence indicators. The next light represented amber turn signals. The inner (horizontal) or upper (vertical) two lights were red brake lights. Thus this design not only provides separation of functions, but color and size coding are also involved.

In addition to the two conventionally placed amber turn signals at the front of truck cabs, two additional turn signals were recommended on each side of the truck, one mounted on the truck's cab and the other mounted midway along the body or trailer.

Amber (except for rearmost lights) side clearance lights evenly spaced every 6 to 8 ft, including the corners, were

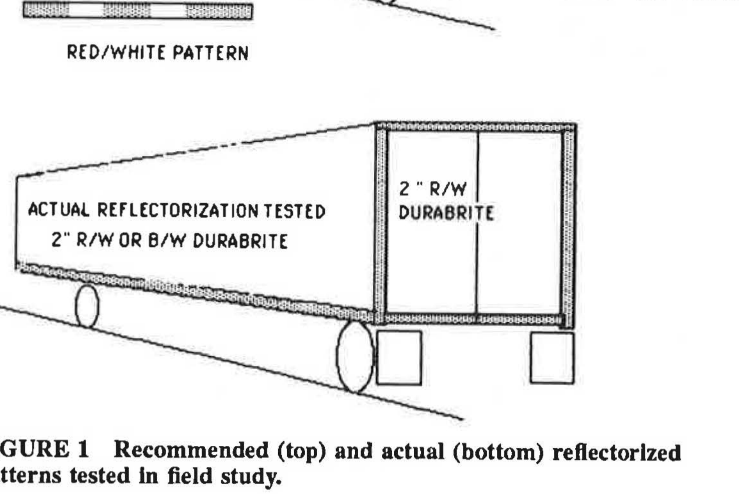

FIGURE 1 Recommended (top) and actual (bottom) reflectorized patterns tested in field study.

recommended along each truck bed or trailer side. The recommended color for the rearmost lights was red.

All of the lights were along or close to the truck's railing. Because of the high-mounted reflectorization, no justification was apparent for high-mounted lights, including the currently required conventional three-light truck identification bar. It was believed that the recommended design amply described and fully identified vehicles as large trucks.

The currently required intensity levels for truck signals and identification lighting appear adequate. However, a minimum area requirement of 12 in.^{2} should be retained for rear signals, and consideration should be given to increasing the minimum area requirements for front and side turn signals. In addition, consideration should be given to a dual-intensity system to adjust brake, presence, and turn signals to different ambient conditions, such as day, night, and fog.

Preparation of a Detailed Field Test Plan for the Augmented System

A detailed test plan was prepared for field testing the recommended augmented system. Sample sizes, fleet compositions, candidate fleets, exposure data, accident rates, existing truck markings, short- versus long-haul operations, experimental and control group matching, and materials and installation costs were discussed and evaluated in detail. In the end, 2,000 trucks were recommended for the augmented system treatment and a matched number was recommended for a control group. A 23-month data collection period was considered adequate to demonstrate significance between the groups at appropriate alpha and beta error levels. As will be noted in the following section, funding was unavailable for field testing the complete augmented system, that is, full truck side and rear outline.

FIELD TESTING OF THE AUGMENTED SYSTEM ON SELECTED TRUCK FLEETS

Selection of Conspicuity Materials

Durabrite prismatic sheeting, manufactured by Avery International, was selected for the field test. This selection was based on four criteria: brightness, ease of installation, durability, and cost. Durabrite satisfied all four criteria more closely than other materials. However, the cost to purchase and install this material on 2,000 trucks according to the recommended design specifications presented in Task 2 still exceeded budget. Therefore the design specifications were modified as follows.

The recommended design was a 4-in.-wide stripe outlining the entire rear and sides of truck trailers. This stripe was reduced to a 2-in. width. Although outlining the entire rear of trucks remained essential, only the side rail was to be treated with the prismatic sheeting. Figure 1 shows the configuration tested. The materials for each vehicle cost $35.00.

As presented in Table 1, the actual photometric characteristics of the Durabrite material closely approached the values recommended in Task 2. The reason that the colored material is labeled Red/Blue in Table 1 is explained in the following section.

Selection of Truck Fleets

The selection of trucking fleets for this study was a difficult and time-consuming task. Many fleets were not able to participate for a variety of reasons. Of those that wanted to participate, many had already installed reflectorized materials on their vehicles. Few fleets remained for which matched groups of control and experimental trucks could be generated. However, 4,162 trucks were ultimately obtained from the Overnite Transportation, Paul's Trucking, and Ruan Trucking fleets. These fleets included short- and long-haul, 40- to 45-ft trailers. Experimental and control groups were matched by assigning trailers to group on a random basis.

Because one trucking fleet used a blue logo, an alternating blue and white stripe was permitted along the side rail instead of the recommended red and white stripe. However, the fleet agreed to have the recommended red and white stripe on the rear of their trucks.

The trucking fleets installed the prismatic sheeting themselves. In addition to receiving the reflector material at no cost, the fleets also received $26 per truck to cover installation costs.

Collection and Analysis of Truck Accident Data

The planned data collection period of 24 months began in the middle of 1983. The 24-month period and 2,081 vehicles per

TABLE 1 RECOMMENDED MAXIMUM AND MINIMUM SIA VALUES AND DURABRITE ACTUAL SIA VALUES IN CANDELAS/lx/m^2

	Observation Angle			
	WHITE		RED/BLUE	
ENTRANCE ANGLE	0.2°	0.5°	0.2°	0.5°
-4°	300-500 (475)	150-400 (325)	75-125 (90)	38-100 (62)
30°	150-500 (220)	75-400 (82)	38-125 (42)	19-100 (16)
45°	75-500 (61)	38-400 (42)	19-125 (12)	9-100 (8)

group were selected to provide a sample size and exposure sufficient to detect a 15 percent reduction in relevant vehicle-into-truck collisions in the reflectorized group, with alpha and beta errors of 0.20 and 0.50, respectively.

During the data collection period, accident reports were obtained from fleet records on a quarterly basis. At the end of each quarter, the fleets' master accident logs were reviewed to identify all trailers for which accidents were reported in that period. Reports were obtained for trailers in both the reflectorized and control groups.

Each accident was coded with identifying information, pre-crash factors, and (to the extent possible) degree to which conspicuity was a likely contributing or causative factor. The conspicuity rating coding was conducted in a blind situation by two highly experienced motor vehicle safety professionals.

All accidents were placed in one of six classifications. The first three classifications were typically vehicle-into-truck accidents and represented high, moderate, and low likelihood that the accidents were conspicuity-related. In a small but significant number of conspicuity-related collisions, the other vehicle did not actually strike the truck-trailer, yet an accident occurred. A common example involved cases where the truck made a radical evasive maneuver to avoid being struck, lost control, and jackknifed. The fourth classification comprised accidents in which the experimental and control trucks typically struck other vehicles. The fifth and sixth classifications were composed of minor incidents and equipment failures that were completely irrelevant to the study.

RESULTS OF FIELD TESTING

Collision Rates

Collisions wherein a tractor-trailer unit struck or was struck by another vehicle or conflicted with another vehicle to cause a single-vehicle collision on a roadway constituted the accident data base that was subsequently analyzed. Overall, 146 controls and 124 reflectorized units were involved in relevant collisions during the 23-month study period, during which each group logged over 106 million mi. The difference represents a 15.1 percent decrease in relevant crashes for reflectorized trailers. Accident frequencies (146 versus 124) were converted to number per million miles for reflectorized (1.372) and control (1.165) groups. The differences between the rates were subjected to a statistical Z test between the two rates, indicating a significance level of 0.09.

Vehicle Damage Costs

It was hypothesized early in the study that enhanced conspicuity might reduce the severity of vehicle-into-truck collisions, whether or not overall frequency of such collisions was affected. Preliminary damage cost estimates were available from most, but not all, of the report forms for vehicles (both tractor-trailer unit and other vehicles) involved in relevant reflectorized and control group collisions. These were summed, and the average damage cost estimate per accident was calculated for reflectorized and control group collisions. The average yearly vehicle damage cost savings for relevant collisions was $175 for trailers logging an average of 60,000 mi/year. Although cost estimates were probably crude, the magnitude of the savings, at a minimum, suggested that a vehicle damage cost savings could be attributed to reflectorization.

CONCLUSION

The field test appears to strongly demonstrate that increasing the conspicuity of large trucks will substantially reduce the number of other conspicuity-related truck accidents. This finding is particularly significant in view of the fact that the conspicuity treatments used in this field test were considerably less emphatic than what was recommended. The 2-in.- rather than 4-in.-wide stripes effectively reduced the recommended SIA values by 50 percent. In addition, the use of rail-only reflectorization of trailer sides equally reduced the recommended conspicuity. Thus there is a strong likelihood that even greater reductions of vehicle-into-truck accidents will occur with the recommended reflectorization treatment.

ACKNOWLEDGMENT

This study was sponsored by National Highway Traffic Safety Administration Contract DTNH22-80-C-07034.

REFERENCES

1. W. J. Burger, R. L. Smith, K. Ziedman, M. U. Mulholland, M. C. Bardales, and T. J. Sharkey. *Improved Commercial Vehicle Conspicuity and Signalling Systems. Task I: Interim Report.* Vector Enterprises, Inc., Santa Monica, Calif., March 1981.
2. K. Ziedman, W. J. Burger, R. L. Smith, M. U. Mulholland, and T. J. Sharkey. *Improved Commercial Vehicle Conspicuity and Signalling Systems. Task II: Analyses, Experiments and Design Recommendation.* Vector Enterprises, Inc., Santa Monica, Calif., Oct. 1981.
3. W. J. Burger, M. U. Mulholland, and R. L. Smith. *Improved Commercial Vehicle Conspicuity and Signalling Systems. Task III: Field Test Evaluation of Vehicle Reflectorization Effectiveness.* Vector Enterprises, Inc., Santa Monica, Calif., Nov. 1985.
4. B. L. Cole. Visual Aspects of Road Engineering. In *Proc., 6th Conference of the Australian Road Research Board,* 1972, pp. 102–148.
5. A. Burg and S. F. Hulbert. *Bicycle Wheel Reflectorization as an Aid to Detection and Recognition.* 3M Corp., Los Angeles, Calif., 1976.
6. A. Burg and J. Beers. *Motorcycle Reflectorization for Nighttime Conspicuity.* University of California School of Engineering and Applied Science, Los Angeles, Calif., 1976.
7. W. M. Smith. Sensitivity to Apparent Movement in Depth as a Function of Stimulus Dimensionality. *Journal of Experimental Psychology,* Vol. 43, 1952, pp. 149–155.
8. W. M. Smith. Effect of Monocular and Binocular Vision on the Sensitivity to Apparent Movement in Depth. *Journal of Experimental Psychology,* Vol. 49, 1955, pp. 357–363.
9. W. C. Steedman and C. A. Baker. *Perceived Movement in Depth as a Function of Stimulus Size.* Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Cincinnatti, 1961.
10. W. H. Ittleson. Size as a Cue to Distance: Radial Motion. *American Journal of Psychology,* Vol. 64, 1951, pp. 188–202.
11. W. H. Jannsen. *The Perception of Maneuvers of Moving Vehicles: Perceptibility of Relative Sagittal Motion on the Basis of Changes in Apparent Size or Brightness of Taillights.* Institute for Perception, the Netherlands, 1972.
12. W. H. Jannsen. *The Perception of Maneuvers of Moving Vehicles: Thresholds for Relative Motion in Depth.* Institute for Perception, the Netherlands, 1973.
13. W. H. Jannsen, J. A. Michon, and L. O. Harvey. The Perception of Lead Vehicle Movement in Darkness. *Accident Prevention and Analysis,* Vol. 8, 1976, pp. 151–166.
14. A. J. Fisher and R. R. Hall. The Effect of Presence Lights on the Detection of Change of Vehicle Headway. *Australian Road Research,* Vol. 8, No. 2, June 1978, pp. 13–16.