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Analysis of the Dismountec Motorist and Road-Worker Model Pedestrian Safety Regulations

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16. Abstract

Two pedestrian model regulations previously developed by NHTSA were studied to determine their potential safety benefits. One regulation was concerned with the disabled-vehicle situation and called on motorists to position themselves and their vehicles as safely as possible and to employ conspicuity enhancing devices and materials. This regulation was studied in an experimental field setting in which the operational features of the regulation were examined. The results of the study showed that deploying fusees or warning triangles in conjunction with four-way flashers significantly reduced the speed and shifted the placement of vehicles passing a simulated disabled vehicle during daytime and nighttime conditions. No substantial evidence was found to indicate that wearing fluorescent and retroreflective materials influenced the course or speed of passing motorists. It is recommended that the portions of the model regulation concerned with the positioning of vehicles and deployment of hazard warning devices be made available to locales seeking counter-measures against this accident type. Provisions related to wearing conspicuous materials should be deleted as mandatory requirements.

The second model regulation studied, involved persons performing road work and called for workers to wear approved fluorescent and retroreflective materials, for standard traffic control devices to be employed, for permits and inspection of road work sites and for drivers to yield to workers and workers to avoid sudden move-ments into the path of vehicles. Detailed analyses of accident reports for cases where road workers were struck, indicated that there were a variety of precipitating factors involved and that rather than being an unitary accident type, these crashes were made up of several sub-types. It was concluded that even if the portions of the model regulation related to worker conspicuity and dart-out behavior were fully effective, only a minority of road worker accidents would be affected.

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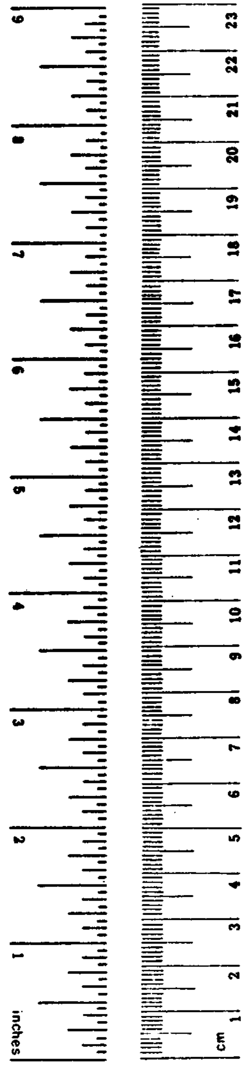
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

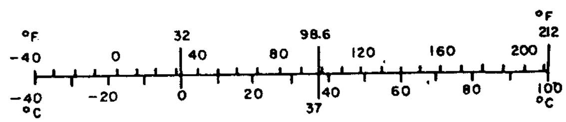
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



The Dismounted Motorist Model Regulation sought to reduce the pedestrian accident potential of the disabled-vehicle situation by directing safe behavior on the part of the disabled motorist and passengers and requiring the employment of devices to enhance the conspicuity of the setting. Specifically, the major provisions of the regulation involved:

- o Prohibiting stopping on controlled-access highways except under specifically defined circumstances.
- o Requiring placement of disabled vehicles off the roadway whenever possible.
- o Prohibiting standing or walking in the roadway.
- o Requiring a driver to actuate the vehicle's four-way flashers if it is so equipped.
- o Mandating the carrying and use of retroreflective/fluorescent materials.
- o Requiring deployment of fusees (flares) or emergency warning triangles.

The present study addressed the potential safety benefits of the dismounted motorist regulation. Using a simulated disabled-vehicle, the effects on the behavior of overtaking motorists was assessed by systematically varying the key elements of the model regulation.

In the field test, the speeds and lateral-positions of vehicles passing a simulated disabled vehicle were employed as the primary dependent measures. The relationships of these measures to a safety benefit was postulated to lie in the fact that the main elements of the regulation can be viewed as intended to enhance the conspicuity of the disabled vehicle and motorist setting, with this enhancement improving driver detection of the scene and bringing about vehicle courses and anticipatory responses which would increase the lateral separation of passing vehicles.

Field testing was conducted during the daytime and at night on straight and level sections of a four-lane, limited-access highway designed to interstate highway standards and on a two-lane rural roadway. The speed limit on the controlled access highway was 55 mph and was 45 mph at the rural site.

From the content of the model regulation, and the findings of previous research, four specific disabled-vehicle conditions were examined. These were:

o A bare vehicle (no conspicuity enhancing devices or materials were used)

o A vehicle with its four-way flashers activated

o A vehicle with its four-way flashers activated and three reflective warning triangles deployed

o A vehicle with its four-way flashers activated and three fusees deployed

To test the elements of the model regulation related to pedestrian conspicuity, five pedestrian conditions were employed. These were:

o No pedestrian present

o A pedestrian wearing gray coveralls

o A pedestrian wearing gray coveralls and a commercially-available sash made of red-orange fluorescent and retroreflective material

o A pedestrian wearing gray coveralls and a commercially-available vest made of red-orange fluorescent plus retroreflective striping material

o A pedestrian wearing a locally fabricated white three-quarter length coat striped with yellow fluorescent and retroreflective material

The vehicle and pedestrian conditions were examined in a factorial design. That is, testing was conducted for each cell of the following matrix:

Pedestrian Conditions \ Vehicle Conditions	Bare Vehicle	Four-Way Flashers	Triangles & Flashers	Fusees & Flashers
No pedestrian				
Pedestrian in street clothing				
Pedestrian wearing sash				
Pedestrian wearing vest				
Pedestrian wearing coat				

Measurements of speed and lateral-position of overtaking vehicles were made using electronic-recording equipment and coaxial sensor cables mounted on the roadway surface. The simulated disabled vehicle was parked on the shoulders of the test sites several inches off the travelled way. When the pedestrian was present, he stood at the center rear of the vehicle facing approaching traffic. (For safety reasons, at night, a life-size mannequin was employed as the pedestrian.)

The testing sequence for each condition involved measuring speeds and lateral-positions when just the bare vehicle was in place, then measuring with a particular test condition in place and then measuring again with just the bare vehicle. In this way, the effects of the test conditions were compared with the baseline of the bare vehicle as determined just before and just after the test condition was deployed.

The main findings of the field test are shown in the following table.

Summary of Findings

	Two-Lane Road		Limited-Access Highway	
	Daytime	Nighttime	Daytime	Nighttime
Pedestrian Conditions	8.8% Speed Reduction No Lateral Position Effects	No Effects	3.4% Speed Reduction No Lateral Position or Lane Changing Effects	No Effects
Vehicle Conditions	8.7% Speed Reduction 10.6% Greater Lateral Separation	14.4% Speed Reduction 16.6% Greater Lateral Separation	3.4% Speed Reduction No Lateral Position or Lane Changing Effects	4.9% Speed Reduction 12.0% More Vehicles Changing Lanes No Lateral Position Effects
Percentage entries are averages over the four conditions where the pedestrian was present and the three active vehicle conditions. Noted changes are from the baseline of the bare vehicle.				

It can be seen that the pedestrian conditions produced effects only during the daytime and only on passing vehicle speeds. Additional analyses of the data also showed that these effects were due to the presence versus the absence of the pedestrian rather than the employment of fluorescent/retroreflective materials.

The vehicle conditions brought about speed and lateral-position changes on the two-lane road during the day and at night, and speed changes, day and night, on the limited-access highway. In addition, the vehicle conditions produced increased lane-changing behavior at night on the limited-access roadway. Within the vehicle conditions, the significant effects were as follows:

	Two-Lane Road		Limited-Access Highway	
	Daytime	Nighttime	Daytime	Nighttime
Fusees and Flashers	10.8% Speed Reduction 16.7% Greater Lateral Separation	21.4% Speed Reduction 21.8% Greater Lateral Separation	4.4% Speed Reduction No Lateral Position or Lane Changing Effects	9.5% Speed Reduction 33.0% More Vehicles Changing Lanes No Lateral Position Effects
Triangles and Flashers	9.2% Speed Reduction 12.1% Greater Lateral Separation	13.6% Speed Reduction 21.0% Greater Lateral Separation	2.8% Speed Reduction No Lateral Position or Lane Changing Effects	3.9% Speed Reduction No Lateral Position or Lane Changing Effects
Flashers	6.2% Speed Reduction No Lateral Position Effects	8.2% Speed Reduction No Lateral Position Effects	3.0% Speed Reduction No Lateral Position or Lane Changing Effects	No Speed, Lateral Position or Lane Changing Effects

It can be seen that the fusees/flashers condition produced the greatest effects including speed reductions on both road types during the day and at night, increased lateral separation on the two-lane road during daytime and nighttime, and an increased frequency of lane changing at night on the limited-access highway. The triangles/flashers condition generally produced the same pattern of effects but of lesser magnitude; the triangles/flashers, however, did not affect lane-changing frequency on the limited-access highway. Finally, the flashers-only condition brought about speed reductions during the day and at night on the two-lane roadway and during the day but not at night on the limited-access highway. The flashers produced no effects on lateral-position or lane-changing behavior.

The results of the field test are interpreted as providing evidence for the effectiveness of the portions of the model regulation dealing with the deployment of fusees or warning triangles in conjunction with the activation of four-way flashers. Similar evidence for the wearing of fluorescent and retroreflective materials was not obtained, however. It is recommended, therefore, that the portions of the model regulation dealing with the use of conspicuous garments be eliminated as a mandatory requirement. The modified regulation would then appear appropriate for dissemination to communities and organizations seeking countermeasures for this accident type. In terms of the method of such dissemination, it is recommended that consideration be given to the development and distribution of a brochure containing information on the accident type, the language of the revised regulation and related annotations. The brochure could also contain informational material on the potential desirability of wearing fluorescent and retroreflective materials in the disabled vehicle and other pedestrian situations in which enhanced conspicuity appears logically appropriate.

Regarding the Road Worker Model Regulation, at the time it was developed the available evidence suggested that the primary factors contributing to pedestrian accidents among persons performing roadway construction and maintenance activities were their proximity to passing traffic, their appearance in unexpected locations, their preoccupation with their tasks and the distraction of motorists brought about by encountering the work site (lane drops, construction vehicles, temporary barriers, signs, etc.).

The main provisions of this model regulation involved:

- Permits required for all road work sites.
- Drivers to yield to workers, and workers to exercise care to avoid sudden movements into the path of a car.
- Workers to wear approved retroreflective and fluorescent materials to be provided by their employers.
- Traffic control devices at road work sites to comply with standards contained in the Manual on Uniform Traffic Control Devices and every work site to have at least one such device or an approved flashing yellow light.

Initial analyses were conducted to examine the details of road-worker accidents as described in existing rural and freeway pedestrian accident data bases. The outcome of this process suggested that rather than being a unitary-accident type, road-worker accidents could be classified into several subtypes with different predisposing and precipitating factors. To amplify upon this finding, systematic searches were then carried out over multi-year periods in the state accident record systems of Florida and New York. In all, 290 usable accident reports were obtained. The classification of these accidents yielded highly similar results for the reports from the two states. The combined results were:

- 24 percent of the accidents involved vehicles hitting items of construction equipment which were propelled at workers and cases where multiple vehicle crashes occurred, with one of the vehicles then striking a worker.
- 18 percent of the accidents involved flagmen being struck.
- 12 percent involved poor worker conspicuity as a primary predisposing factor.
- 9 percent involved workers darting-out into traffic.
- 7 percent involved poor path prediction by drivers (commonly the right hand minor on trucks, vans, etc. striking workers).
- 6 percent involved vehicles running off the roadway or through barriers and striking workers.
- 6 percent involved workers being struck by construction vehicles.
- 3 percent involved surveyors being struck.
- 3 percent involved other, often unusual, circumstances.
- 11 percent were not classifiable because of insufficient descriptive information.

These results suggest that worker conspicuity and dart-out behavior are factors in only a relatively small percentage of road-worker pedestrian accidents. Thus, even if the model regulation was fully effective, the expectation is that it would impact only about one-quarter of road-worker accidents (or approximately one-half of one percent of all pedestrian accidents). It is believed that rather than pursuing the model regulatory approach with its limited potential payoff, on-going efforts to reduce the vehicle crash problem in construction and maintenance zones, such as fostering compliance with the Manual on Uniform Traffic Control Devices, should be encouraged. A reduction in the frequency of these vehicular crashes would be desirable in itself and also would be expected to reduce worker injuries stemming from these accidents. In addition, it is recommended that future attention be directed toward encouraging: 1) practices at construction and maintenance sites which minimize worker exposure to secondary impacts; and 2) use of adequate physical barriers to prevent vehicles from entering work areas and which would discourage worker dart-out behavior. Also, developing and encouraging training and other steps to enhance the safety of flagging activities, such as employing flags made of fluorescent material, appear desirable.

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to the Connecticut State Traffic Safety Commission for granting us permission to use the state roadways employed in the study. We also thank the Connecticut State Police Department and the local police departments in the towns in which the test sites were located for their cooperation with the testing.

Valuable support and assistance were received from Dr. Alfred J. Farina, Mr. William C. Wheeler, Jr. and Dr. Marvin M. Levy who served as Contract Technical Managers for the National Highway Traffic Safety Administration. Our thanks also go to Mr. Maurice Lanman, formerly with the Federal Highway Administration, for the information he provided on methods of measuring vehicle placement on roadways.

Mr. Charles A. Goransson and Dr. Peter Zeidler of our staff safely carried out the field experimentation associated with the Dismounted Motorist Model Regulation.

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I. INTRODUCTION

In 1971 Snyder and Knoblauch provided a classification system for urban pedestrian accidents based on analyses which identified distinct causal accident types. Each type was described according to a model which identified the precipitating factors which immediately preceded and led to the accidents, and the predisposing factors--characteristics of the individuals involved and the environmental setting--which contributed to the development of the accidents. Work on accident typing and the identification of precipitating and predisposing factors was subsequently extended to rural and suburban pedestrian accidents (Knoblauch, 1976) and to pedestrian accidents occurring on freeways (Knoblauch et al., 1976).

The availability of a systematic accident typing schema and identification of the behavioral errors and contextual factors associated with each accident type have made a significant contribution to NHTSA-sponsored pedestrian accident research conducted over the past decade. For example, Blomberg et al. (1974) used the findings of Snyder and Knoblauch to structure countermeasures intended to prevent specific types of accidents by interrupting the situational and behavioral sequences known to lead to these accident types. This study developed nine model regulations aimed at reducing pedestrian accidents. These were:

1. Model Ice Cream Truck Ordinance
2. Model Road Work Site Law
3. Model Freeway Stop Law
4. Model Bus Stop Ordinance
5. Model Ordinance or Law on Parking Near Intersections and Crosswalks
6. Model Vehicle Overtaking Law
7. Model On-Street Parking Ordinance
8. Model Pedestrian Accident Information Ordinance
9. Model Backing Signal Law

Development of the regulations began with a review of the predisposing and precipitating factors identified in earlier research as being associated with the relevant accident types. This review resulted in a threat analysis for each accident type and an initial conceptualization of potential countermeasures. A detailed literature review was carried out to locate other possibly relevant countermeasure approaches and municipal ordinances and state laws were searched to locate any which addressed the pedestrian accident types under study. Following a review by a multidisciplinary team, the countermeasures deemed potentially viable were converted into legal/regulatory content and format. These, in turn, were evaluated in a nationwide survey among segments of the population concerned with the enactment and enforcement of new regulations (traffic engineers, police, legislators, National Committee on Uniform Traffic Laws and Ordinances committee members, special interest groups and members of the general public).

The final forms of the nine model regulations were intended to satisfy several major criteria. These were:

- o To reduce the frequency of pedestrian accidents.
- o To specify the physical and operational requirements in sufficient detail to insure uniform application across jurisdictions, expeditious and complete implementation, and sensitivity to local needs and special requirements.
- o To be most conducive to legislative approval and enactment.
- o To be capable of enforcement within the constraints of existing or reasonably contemplated enforcement resources.
- o To be maximally acceptable to the public to gain compliance and minimize confusion.
- o To be acceptable to the official community including judges, elected officials, traffic engineers, and police officers.

A natural outgrowth of the development of the model regulations has been the question of whether they can, in fact, reduce pedestrian accidents. The Model Ice Cream Truck Ordinance, for example, has been formally field tested in a major city which enacted the model ordinance, and has been shown to reduce child pedestrian accidents associated with on-street vending by about three-quarters (Hale et al., 1978). Others of the regulations have been field tested in settings where the major operational elements of the regulation were found to be in place but where the regulation itself had not been adopted (c.f. Leaf and Blomberg, 1981).

The present study was concerned with collecting evidence on the behavioral effectiveness of two of the model regulations: The Dismounted Motorist Safety Regulation* and the Model Road Work Site Law. The text and annotations of these two regulations as proposed by Blomberg et al. (1974) can be found in Appendix A. The basic provisions of the Dismounted Motorist Regulation involved:

- o Prohibiting stopping on controlled access highways except under specifically defined circumstances.
- o Requiring placement of disabled vehicles off the roadway whenever possible.

*"Model Freeway Stop Law" is the terminology originally used by Blomberg et al. (1974). Accumulating evidence such as that provided by Knoblauch (1976) indicates that the problem of drivers and passengers being struck in the vicinity of disabled vehicles extends to various types of roadways. The term "Dismounted Motorist Pedestrian Safety Regulation" has been adopted to expand the original countermeasure/regulation beyond just the freeway context.

- Prohibiting standing or walking in the roadway.
- Requiring a driver to actuate the vehicle's four-way flashers if it is so equipped.
- Mandating the carrying and use of retroreflective and fluorescent materials.
- Requiring deployment of fusees or emergency warning triangles.

The main provisions of the Model Road Work Site Law require:

- Permits for all road work sites.
- Drivers to yield to workers and workers to exercise care to avoid sudden movements into the path of a car.
- Workers to wear approved retroreflective and fluorescent materials to be provided by their employers.
- Traffic control devices at road work sites to comply with standards contained in the Manual on Uniform Traffic Control Devices and every work site to have at least one such device or an approved flashing yellow light.

Section II of the report contains the study's results regarding the Dismounted Motorist Safety Regulation. The material in the section includes a description of the accident type, a review of relevant previous research and a presentation of the rationale, method, findings and conclusions of the field test of this model regulation.

Section III of the report presents the study's findings regarding the Road Worker Model Regulation. Included are a description of the accident type, the results of analyses of numerous road-worker accident reports and a discussion of the implications of these analyses on the future utility of this model regulation.

II. DISMOUNTED MOTORIST SAFETY REGULATION

A. Background

When a motor vehicle becomes disabled or stops unnecessarily on an expressway or other high-speed roadway there can be considerable risk to any of the occupants who choose to exit the vehicle. The basic accident hazard posed by this situation is the proximity of the persons on foot to traffic passing the scene and the possible preoccupation of the pedestrians while attending to the vehicle or seeking assistance.

In a California study, Johnson (1965) found that approximately 30 percent of the state's pedestrian accidents on freeways stemmed from the disabled-vehicle situation. The study noted that when vehicles are disabled, the occupants generally do one of three things: 1) Walk off along or across the freeway to summon assistance; 2) Work on their vehicle; or 3) Stand around (sometimes in the roadway) and wonder what to do. Johnson also reported that the dismounted motorist situation was a greater proportion of all freeway pedestrian accidents in high traffic volume areas (generally in urban locales) and that the accidents tended to occur in the nighttime hours.

In a study of 236 pedestrian accidents on limited-access highways in five states, Knoblauch et al. (1976) found that 20 percent of their accident cases were related to the disabled-vehicle situation. They noted that this type of accident:

> "typically involves a pedestrian standing next to or working on a disabled-vehicle at night on freeways passing through open areas in city or country locations. The collisions most frequently occurs on the shoulder or the edge of the traveled way, although the vehicle occasionally runs off the road striking the pedestrian. The pedestrian is basically not attending to on-coming traffic, but working on, looking at, or standing next to his automobile." (pp. III-65)

In a study of pedestrian accidents outside of urban areas, Knoblauch (1977) found that 5.6 percent of 1,531 accidents which occurred on various types of roadways in six states were related to the disabled-vehicle situation. The report noted that, "this type typically involves a young man working on or standing next to a disabled vehicle at night on a secondary or primary highway in an open, country location. The collision most frequently occurs on the edge of the traveled way although the vehicle occasionally runs off the traveled way and strikes the pedestrian." (pp. III-93).

Non-freeway, urban pedestrian accidents appear to involve the disabled-vehicle situation less frequently than do freeway pedestrian accidents or rural pedestrian accidents. Various studies suggest that in non-freeway urban locations, disabled-vehicle related pedestrian accidents account for approximately one-half of one percent to two percent of all pedestrian accidents (c.f., Dunlap and Associates, Inc., 1977; Knoblauch and Knoblauch, 1976). This lower frequency of disabled-vehicle related accidents in urban areas is likely due to several factors including the predominance of other pedestrian accidents in urban settings (e.g., dart-outs and dashes), the greater likelihood of finding a "parking place" for a disabled vehicle, lower vehicle speeds and better urban street lighting.

The rural and freeway pedestrian accident studies by Knoblauch (1977) and Knoblauch et al. (1976) provide considerable data on the characteristics of the disabled-vehicle related pedestrian accident. A summary of a number of descriptive variables is contained in Table 1. These data suggest that the majority of the disabled-vehicle related pedestrian accidents in the rural and freeway settings tended to occur under relatively benign environmental and accident site conditions. That is, most of the accidents occurred in dry weather, on straight and level roadways, with shoulders at least several feet wide.

The majority of the crashes, however, did take place during the hours of darkness, frequently on unlighted roadways. Also, the speed limits at the sites tended to be high, with the large majority of sites zoned over 50 mph.

Other data from the rural and freeway studies (Knoblauch, 1977 and Knoblauch et al., 1976) indicate that the drivers' vision to the accident site was not obscured--in 85 percent of the cases the driver had at least 300 feet of sight distance to the scene. Similarly, the pedestrian's vision of traffic was indicated as being unobscured in 86 percent of the accidents. In approximately 61 percent of the accidents, the vehicle involved was proceeding straight ahead; in 83 percent of the rural accidents the driver was said to have been looking straight ahead or enaged in general search activity.

Among the freeway accidents, in 50 percent of the cases the pedestrian was not in a lane of travel when struck (the most common location was on the right hand shoulder), in 27 percent of the cases the pedestrian was struck at the roadway edge while in 23 percent of the accidents the pedestrian was in a lane of travel. In 38 percent of the accidents the pedestrian was described as standing near the vehicle. Other behaviors included pushing the vehicle (ten percent of the cases), entering or exiting the vehicle (eight percent), flagging other vehicles (eight percent) and "other" (eight percent).

Among the rural accidents, 26 percent were described as having taken place at sites which had no shoulders. Overall, in 67 percent of the accidents the pedestrian was on the traveled portion of the roadway, while in 33 percent of the cases the struck pedestrian was not on the roadway. In 57 percent of the rural cases the pedestrian was described as working on or pushing the disabled vehicle when the accident occurred, in 27 percent of the cases the pedestrian was standing by the vehicle, while in 16 percent of the accidents the pedestrian was engaged in other behavior.

These data suggest that the majority of disabled-vehicle related pedestrian accidents are precipitated by a combination of pedestrian and driver failures. The pedestrian is often located in an unexpected place and is subject to a distraction. Drivers appear to have difficulty detecting the pedestrian or in adopting courses which will insure avoiding the pedestrians.

Table 1. Situational Characteristics of the Disabled-Vehicle Related Pedestrian Accidents

	Rural (N=86)	Freeway (N=48)
Weather Conditions		
Clear	58.8%	81.3%
Cloudy	22.4	12.5
Precipitation	16.5	4.2
Reduced Visibility	2.4	2.1
Road Surface Conditions		
Dry	68.2%	86.7%
Wet	15.3	11.1
Snow/Ice	16.5	2.2
Light Conditions		
Daylight	34.9%	41.3%
Dark—no lighting	47.7	39.1
Dark—road lighting	11.6	17.4
Dark—some lighting	5.8	2.2
Time of Accident		
Midnight - 4 a.m.	19.8%	29.2%
4 a.m. - 8 a.m.	7.0	8.3
8 a.m. - Noon	3.5	4.2
Noon - 4 p.m.	16.3	18.8
4 p.m. - 8 p.m.	18.6	16.7
8 p.m. - Midnight	34.9	22.9
Roadway Speed Limit		
30 mph or less	5.9%	2.1%
35 mph	15.3	2.1
40 mph	4.7	6.3
45 mph	8.2	0
50 mph	3.5	8.3
55 mph or more	62.4	81.3
Number of Lanes (in direction of travel)		
One	50.0%	10.4%
Two	32.6	37.5
Three or more	17.4	52.1
Shoulder Width		
None	25.6%	4.3%
1 - 3 feet	10.5	0
4 - 6 feet	16.3	14.9
7 - 9 feet	27.9	48.9
10 feet or more	19.8	31.9
	Rural	**Freeway**
Vertical Placement		
Level grade	65.9%	50.0%
Uphill	21.2	33.3
Downhill	12.9	16.7
Road Curvature		
Straight	64.7%	52.1%
Curve	11.8	20.8
At intersection/interchange	23.5	27.1
Estimated Traffic Volume Per Hour		
5 or less	11.3%	0%
6 - 15	5.7	4.2
16 - 30	13.2	4.2
31 - 60	9.4	6.3
61 - 120	11.3	18.8
121 - 240	13.2	10.4
241 - 480	17.0	10.4
481 - 960	7.5	12.5
961 - up	11.3	33.3

Sources: Knoblauch (1976) and Knoblauch et al. (1976)

In reviewing the components of the Dismounted Motorist Safety Regulation, the following commentary is believed relevant:

- Disabled vehicles shall be parked as far from the traffic lane(s) as practicable. This is a common sense requirement, but one which often is not followed by drivers who experience sudden failure of their vehicles. It was included in the regulation as a statement of desirable practice rather than as a new, unique stipulation.

- Disabled vehicles should be marked by four-way flashers if they possess them. Because of Federal vehicle standards, almost all vehicles on the road have such flashers. The existence of flashers has not been enough to insure their use, however. Drivers often fail to use them, perhaps through oversight, a feeling that the vehicle is adequately visible or that the flashers will drain the battery.* Particularly in poor visibility conditions, the flashing emergency signal was believed to be important to warn other motorists of the presence of the stopped vehicle.

- Warning triangles, fusees, or flares should be positioned behind the disabled vehicle. The purpose here was to alert on-coming drivers early enough so that they could react safely to the actual vehicle, by slowing in advance, or by moving away, and by being aware of the presence of an unusual hazard.

- Retroreflective/fluorescent materials are to be worn by anyone who is not inside the disabled vehicle. When the survey was performed during the original proposal of this regulation, this feature met with the most negative reactions. Provision of such materials was felt to be expensive and, therefore, unlikely to be done voluntarily. Also, whether people would wear the materials even if they were available is uncertain. Compliance with this provision was beleived to be best accomplished through public education and the requirement that all new vehicles be delivered with such materials.

- Walking/standing on roadways is prohibited unless absolutely necessary. This, too, is a common sense requirement, though one which can be overlooked in emergency situations. This provision was also believed be best handled through public education efforts.

From the preceeding material it may be noted that there are two basic features to the model regulation. These are: 1) to encourage motorists to position their vehicles and themselves as safely as possible; and 2) to enhance the conspicuity of the setting. In addition, there are cost and safety considerations related to the use of the conspicuity enhancing items (beyond the vehicle's four-way flashers) which suggest that their benefits should be clearly demonstrated before the model regulation is promulgated for possible adoption. The test of the Model Dismounted Motorist Safety Regulation,

*In the rural pedestrian study (Knoblauch, 1977) only 35 percent of the disabled vehicles displayed flashers while at night 44 percent of the vehicles flashers were used.

therefore, was structured to determine if there is evidence that some or all of the conspicuity enhancing elements of the model regulation have a positive safety benefit in terms of their ability to affect the behavior of passing motorists.

B. Relevant Research

Soliday (1975) in a study of driver maintenance of vehicle position on a 55 mph zoned two-lane highway and a 65 mph zoned four lane limited-access highway, found that under normal daytime driving conditions test subjects positioned their vehicles, on the average, almost exactly in the center of the lane of travel, and that dispersions from the center position were relatively small in comparison to lane width.

In a study of vehicle positioning and speed control under nighttime conditions, Matanzo and Rockwell (1967) found that drivers instructed to drive normally tended to reduce their speeds and/or drive farther from the shoulder edge as illumination level was reduced. However, drivers instructed to attempt to maintain constant speed were able to do do in the reduced illumination conditions. In this latter group, drivers given the choice of lane position tended to drive farther from the shoulder as illumination declined; those instructed to maintain speed and lane position drove more closely to the shoulder but also tended to move away from it as illumination was reduced.

Taragin (1955) studied the effect on vehicle speeds and lateral placement of objects (a car, truck or barricade) placed on roadway shoulders at various distances from the roadway. Regarding the speed of passing vehicles, he noted an average three miles per hour speed reduction when an object was placed on the shoulder of two-lane roads 16 and 20 feet wide and an average of one mile per hour reduction on two-lane roads 22 and 26 feet wide. The distance of the object from the pavement edge (zero, three or six feet) had no consistent effect on speed. However, the barricade tended to produce greater reductions than did the car or truck.

The objects on the shoulder were found by Taragin to have a pronounced effect on the lateral placement of passing vehicles especially on the narrower roadways. The change in lateral placement was found to be greater when the object was closer to the roadway edge, and when the maneuver was unimpeded by on-coming traffic.

The studies of Soliday (1975), Matanzo and Rockwell (1967) and Taragin (1955) suggest that drivers typically position their vehicles to minimize potential hazards, i.e., in the center of the lane of travel under normal conditions, or away from the shoulder edge under conditions of reduced visibility. Drivers also respond to objects detected adjacent to the roadway by a tendency to increase their separation from these objects.

Taragin (1955) noted that speed changes in his and other studies were less marked than might be expected. Apparently drivers normally are concerned with maintaining or establishing sufficient lateral separation from objects they might strike. It is possible that speed adjustments take place only as they are necessary to accomplish positioning maneuvers in a timely manner.

Helander (1978), however, using measurements of steering wheel angle rather than more gross observations of vehicle position or speed has indicated that drivers tend to turn their steering wheels toward on-coming cars, and toward parked cars and pedestrians found on the right side of a rural roadway. The effect is reported to begin approximately two seconds prior to the meeting and is reversed shortly after the passage. Helander suggests that drivers' steering is affected when attention is focused on objects of perceptual significance. Unfortunately, steering wheel angle does not give an indication of vehicle position on the roadway. That is, the "turning toward" steering behavior may occur only after the driver is satisfied that he will clear the object being approached. Helander's data related to passing a parked car show a marked leftward steering angle in the period from about eight seconds to two seconds prior to the passage. In the "passing pedestrian/cyclist" data, a smaller leftward steering angle is also shown from ten seconds to about two seconds before passage.

Summalo et al. (1981) also have questioned Helander's conclusions and provide data which suggest that the apparent steering toward on-coming vehicles described by Helander is, in fact, a corrective maneuver following steering away from the on-coming car.

The use of warning devices to mark disabled-vehicle situations has been explored in a field setting by Allen et al. (1973). In one experiment these authors made radar speed readings and gross vehicle position estimates as a function of particular configurations of warning flares and triangles. A simulated disabled vehicle was parked three feet away from the edge of the pavement and a person, a jack and a spare tire were in view. This setting was employed at two sites (a righthand and lefthand curve) on a 65 mile per hours zoned highway under clear, dry, daytime and nighttime conditions.

Regarding the effect of deploying flares, Allen et al. (1973) found that at night various configurations reduced the mean speeds of passing vehicles at both test locations by eight miles per hour or more, with a two flare deployment tending to produce greater effects than did single flares located either just behind the test vehicle or at 48 paces from the vehicle. By comparison, the daytime deployment of flares generally did not affect vehicle speeds, with only the two flare configuration producing a statistically significant effect at the lefthand curve test location.

In this same study, Allen et al. (1973) deployed retroreflective/ fluorescent triangles singly at two or 48 paces behind the test vehicle and in sets of three triangles located at two, 48 and 100 paces behind the vehicle. The effects on passing vehicle speeds were inconclusive. Under nighttime conditions only the three triangle configurations produced significantly slower speeds and only so at the lefthand curve site. In the daytime, one triangle at 48 paces from the vehicle, and the three triangle layout significantly slowed passing vehicle speeds at the righthand curve location while no effects were noted at the other test site.

In this study the authors used a three-point scale to judge the lateral-position of passing vehicles. They reported that the method was crude and that little of significance was found.

In a second related study Allen et al. (1973) repeated many of the initial test conditions, this time employing sensors buried in a straight section of highway to measure vehicle speeds. Judgments of changes in vehicle positions were also made. Under daytime conditions the results supported those of the earlier study, regarding effects on vehicular speeds, i.e., the configurations did not produce consistent speed reductions. In terms of lateral placement, the following data were presented for the daytime condition:

CONDITION	Percent of Vehicles Altering Course: Left	None	Right
Car Only	28.6	65.7	5.7
Car and one flare at 2 paces	37.2	61.4	1.4
Car and one flare at 48 paces	34.0	64.1	1.9
Car and two flares, 48 and 100 paces	37.5	62.5	0.0
Car and one triangle at 48 paces	31.5	67.1	1.4
Car and three triangles at 2, 48 and 100 paces	35.3	62.3	2.4

These data show that most of the warning device deployments in daylight increased the percentage of motorists who moved to the left when passing the site, compared with the car only condition.

The nighttime setting produced the following in terms of mean speed and vehicle course alterations:

CONDITION	Mean Speed (mph)	Percent of Vehicles Altering Course: Left	None	Right
Car Only	52.1	41.0	53.9	5.1
Car and one flare at 2 paces	45.2	77.1	22.9	0.0
Car and one flare at 48 paces	44.6	71.4	28.6	0.0
Car and two flares at 48 and 100 paces	44.7	84.2	15.8	0.0
Car and one triangle at 48 paces	54.4	16.9	78.0	5.1
Car and three triangles at 2, 48 and 100 paces	53.9	59.1	40.9	0.0

These data indicate that at night motorists were more likely to drive to the left when the flares were deployed than when the various triangle configurations were in place. In this study the flares also consistently produced changes in mean speeds while the triangles did not. Finally, in a third element of their report, Allen et al. (1973) reported that detection times of the triangles and flares were approximately the same under daylight conditions while at night the flares were detected sooner than the triangles.

Miller (1975) expanded on the study of Allen et al. (1973). He noted that the original work employed a test vehicle that, "was of a make, model and color strongly resembling patrol vehicles used by the local police department." In addition, Miller noted that several observers were used to obtain the vehicle position data who may not have employed standard criteria, and that the observations made on each test condition were done on different samples of traffic passing at differing times of day. He suggested that, "differences in movement patterns thought to be caused by difference in driver reaction to warning signals may, in fact, reflect differences in driver reaction to a police vehicle, or differences due to non-standardized measurement or differences based on driving habits at the test-site that normally vary at different times during the day or evening."

Miller's follow-on study to overcome these difficulties employed various arrangements of fluorescent and reflective triangles, fusees and the four-way flasher system of the test vehicle. The basic experimental setting involved speed and position change measurements in a before-treatment-after-paradigm where the before and after conditions involved the vehicle alone. That is, speed and position measurements were obtained on a group of vehicles passing the disabled vehicle by itself. A particular experimental condition was then deployed (e.g., three triangles) and measurements taken. This was followed by another period of measurements with the bare test vehicle alone. The particular before and after speed and position data were then used to determine whether the particular experimental condition had produced significant effects. All tests were conducted on a rural, two-lane highway at a straight and level location, with the maximum speed zoned at 65 miles per hour. Only two observers participated in the study, with one making the position change judgment. Vehicle speeds were obtained using buried loop sensors.

Miller found that under daylight conditions deploying one or two fusees variously at two, 48 and 100 paces behind the disabled vehicle reduced the speeds of passing vehicles, on average, by about three miles per hour. On the other hand, the use of the vehicle's emergency flashers or various deployments of fluorescent triangles generally did not affect passing vehicle speeds. Also during the daytime, Miller found that 32 percent of the passing motorists veered to the left in response to the test vehicle alone. Only the two fusee deployment significantly increased this response (to about 40 percent of the passing vehicles).

Under nighttime conditions it was found that the activation of the test vehicle's emergency flashers slowed passing traffic by an average of approximately five miles per hour while the fusees produced reductions in mean speeds of up to ten miles per hour. On the other hand, the retroreflective triangles deployed at night generally had no effect on the speeds of passing vehicles.

Miller reported that at night approximately 27 percent of passing motorists veered to the left in response to the disabled vehicle by itself. The deployment of the various conditions yielded equivocal findings. That is, some conditions as much as doubled the percentage of vehicles described as veering left while others produced no effect, with there being no logical pattern to this outcome. For example, a significant effect was noted for one fusee deployed at 48 paces behind the test vehicle while two fusees located at 48 and 100 paces from the vehicle had no effect. Similarly, one triangle at two paces from the vehicle had a significant effect while three triangles (at two, 48 and 100 paces) did not.

Examining his own and Allen et al.'s data, Miller concluded that during daylight hours a disabled vehicle stopped off the roadway has little effect by itself on the speeds of passing vehicles. This finding is in general agreement with that reported by Taragin (1955). Taragin, Allen et al., and Miller, however, all provide data which show that there is a pronounced effect of the disabled vehicle during daylight on the lateral placement of passing vehicles.

Regarding the effects of warning devices during daylight hours, Miller found that various fusee configurations produced approximately three mile per hour drops in the mean speed of passing vehicles. Allen et al., by comparison, reported significant effects of fusees on daytime vehicle speeds only for one particular deployment in their first experiment and in one different deployment in their second experiment. Most of the warning triangle deployments of Allen et al. and Miller failed to produce significant speed reductions under daylight conditions. Also, Miller reported no significant effect on speed of the test vehicle's emergency flashers in his daytime study.

Allen et al. reported that various daytime configurations of fusees and triangles increased the proportion of drivers who altered their course to the left when coming upon the disabled-vehicle site. However, Miller found such an effect only with a two fusee deployment.

Under nighttime conditions, both Allen et al. and Miller report that various deployments of fusees significantly slowed approaching traffic and increased the percentage of drivers who veered to the left. Results for the various triangle deployments at night were less clear cut. In their first experiment, Allen et al. found that only the three triangle layout at the left curve site produced significantly slower speeds; in the second experiment none of the triangle configurations slowed passing traffic and only a three triangle deployment increased the percentage of vehicles that altered course to the left. Similarly, Miller reports only one triangle deployment that slowed traffic and two which increased the percentage of leftward course changes. Finally, Miller noted that the test vehicle's emergency flashers, at night, slowed passing traffic but did not affect the course of these vehicles.

As a part of a broader study of the general effectiveness of vehicle four-way flashers, Knoblauch and Tobey (1980) examined their use in the disabled-vehicle situation in conjunction with other warning devices. Working on two and four lane road segments described as having speed limits of 50 miles per hour or more and having slight or steep upgrades, these authors recorded the speeds and lateral-position of vehicles passing the site of a simulated disabled vehicle during the daytime and at night. Table 2 summarizes their findings regarding mean speed differences (recorded at the test vehicle) between the various conditions and when just the disabled vehicle was present. It may be seen in the table that the flares generally reduced vehicle speeds at night and during the daytime, while the triangles generally were effective during the daytime only.*

Regarding just the four-way flashers, the authors report that these produced significant speed reductions in only two of eight testing situations (on the steep segments of the two and four lane roadway during the daytime) and that the flashers generally did not produce additive effects with the other test conditions. It may also be seen in Table 2 that the presence of a pedestrian standing by the disabled vehicle significantly slowed passing traffic during daytime testing. The pedestrian conditions were not tested at night, however.

*On the four lane road the flares and triangles were deployed at the rear of the test vehicle and 100 and 200 feet from the vehicle. On the two-lane road the Bureau of Motor Carrier Safety recommended deployment was followed, i.e., one device at the front of the vehicle, a second centered behind the vehicle and a third 100 feet from the vehicle.

Table 2. Mean Speed Differences for Various Warning Devices*

Light	Day								Night							
Road	Two-Lane				Four-Lane				Two-Lane				Four-Lane			
Grade	Steep		Slight		Steep		Slight		Steep		Slight		Steep		Slight	
Flashers	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off
Conditions																
Hood up	N	N	X	X	-1.9	N	N	N	X	X	X	X	X	X	X	X
Trunk up	-1.8	+1.8	X	X	N	N	N	N	X	X	X	X	X	X	X	X
Parking lights on	X	X	X	X	X	X	X	X	N	N	-2.5	+4.6	N	N	-2.0	-3.3
Triangles	-1.5	-2.2	N	-1.3	-1.6	N	-0.7	-0.6	N	N	N	X	N	X	-2.3	N
Flares	-2.4	-4.1	-3.3	-2.1	-2.9	-4.1	-1.8	-1.8	N	-7.3	-6.3	-7.3	-3.2	-6.6	-5.0	-3.2
Female pedestrian	-2.5	-4.7	-2.0	-1.4	-1.2	N	-0.9	-0.6	X	X	X	X	X	X	X	X
Male pedestrian	-2.4	-3.1	-1.0	-1.1	-2.2	-2.8	-0.6	N	X	X	X	X	X	X	X	X

*Data from Knoblauch and Tobey (1980). Values shown (miles per hour) are where mean differences were statistically significant; N = no significant difference; x = condition not studied.

Knoblauch and Tobey (1980) also present the outcomes of statistical testing of the lateral-position data recorded at the test vehicles. The results show that the flares and triangles significantly increased lateral separation from the test vehicle during the daytime on the four lane roadway. The magnitude of these changes are not shown, however. Similar differences were not detected on two-lane roadway during the daytime nor on either roadway at night. Additionally, no systematic effect on lateral-position was found for the four-way flashers or when the pedestrians were present.

C. Field Test of the Model Regulation

As noted earlier, the operational elements of the model regulation would entail some expense to the motoring public for the acquisition of fluorescent and retroreflective materials and for fusees or warning triangles. In addition, there are some possible hazards involved in utilizing fusees. For these reasons, as well as on general logical grounds, it was concluded that the critical information required regarding the model regulation was whether conspicuous materials used singly and in combination with hazard warning devices would influence the driving behavior of motorists encountering a disabled-vehicle situation. That is, it was believed to be fundamentally important to determine which, if any, of the operational elements of the model regulation produced measurable behavioral effects, where these behavioral effects could be considered to be related to an accident reduction potential.

The goal of each of the model pedestrian safety regulations is, via statute, to modify pedestrian and driver behavior in particular circumstances and thereby reduce the frequency of pedestrian accidents. Each of the regulations contains elements which are logically derived countermeasures intended to break the sequences of predisposing and precipitating factors shown by research to be associated with particular pedestrian accident types. In assessing the safety benefit of each of the model regulations, there are two main questions which ultimately should be examined. These are: 1) do the countermeasure elements of the model regulation, in fact, produce the intended driver and/or pedestrian behavioral changes, and 2) when these behavioral changes are produced, is the frequency of the relevant accident type reduced? In some instances the first of these questions may be settled based on existing information, with testing of the regulation then focusing on its accident reduction potential. With other regulations, including the one under consideration here, the ability of the elements of the regulation to produce the intended behavioral changes has not been clearly demonstrated. In such cases it is believed to be essential to determine such relationships first, before moving to the question of actual accident reduction following adoption of the regulation.

While the existing literature provides some relevant data concerning the effects of fusees and warning triangles, there are major gaps in the information provided by prior studies, in particular, regarding the effects of pedestrians being present at the scene. The Knoblauch and Tobey study (1980) has shown that during the daylight hours the presence of a pedestrian caused a greater reaction from passing motorists than did a simulated disabled vehicle by itself. Nothing is known, however, about whether enhancing pedestrian conspicuity during the daytime can amplify this effect, about the possible interactive effects of warning devices and the presence of a pedestrian, and about the presence of a pedestrian during the nighttime. Accordingly, a field test was designed and carried out which systematically deployed hazard warning devices and materials intended to enhance pedestrian conspicuity.

Analysis of dismounted motorist accidents has indicated that in the majority of these crashes the pedestrian was on the road shoulder or at the edge of the traveled way when struck. In most of these instances the pedestrian was described as either working on the vehicle or standing near it when the accident occurred. In other cases, the pedestrian was described as suddenly entering the lane of travel, such as stepping out from in front of the disabled vehicle. In his rural and suburban pedestrian accident study Knoblauch (1976) reports that the primary pedestrian causal factors in the disabled-vehicle accident type were:

- Unusual or unexpected place--41 percent of the cases
- Risk taking--31 percent of the cases
- Distraction from traffic--27 percent of the cases

The primary driver causal factors were:

- Inadequate search and detection--30 percent of the cases
- Vehicle speed--20 percent of the cases
- Ran off traveled way--20 percent of the cases

Given these accident characteristics and causal factors, the main operational elements of the model regulation can be viewed as intended to improve driver detection of the disabled-vehicle scene and to bring about vehicle courses which would increase the separation between passing motorists and the site. In the field test, therefore, both the lateral-positions and the speeds of vehicles passing a disabled-vehicle site were chosen as dependent measures, with lateral-position being considered a direct measure of course change and speed being a measure of a driver's anticipatory response regarding the need for a possible evasive maneuver.

The perspective of the study is that a safety benefit can be claimed for the elements of the model regulation if it can be shown that behavior of passing motorists can be influenced in terms of the amount of separation they provide and/or the speed reduction they exhibit as they pass the disabled-vehicle site. This perspective is adopted because the predisposing and precipitating factors of the accident type are such that the rational motorist cannot fully evaluate the accident potential of the situation. That is, the motorist, as he approaches the scene, cannot necessarily determine whether a pedestrian may appear, or if one is in view, what his movements may be.

This line of reasoning is introduced here to mitigate arguments that passing motorists may, in fact, have reacted to the warning devices, assessed the situation and proceeded past the test site without adjusting speed or separation because they judged that no hazard was involved (or that the motorists reacted well prior to the site and then resumed normal course and speed). The view adopted herein is that the potential pedestrian safety hazard exists at the disabled-vehicle site and that the model regulation is intended to enhance the safety of this situation at the location of the disablement.

1. Procedure

The field test of the Model Dismounted Motorist Pedestrian Safety Regulation was structured to determine in a realistic setting which, if any, of the operational elements of the regulation would affect the behavior of motorists passing the site of an apparently disabled-vehicle. Based on the findings of Knoblauch (1976) and Knoblauch et al. (1976) regarding the prevalence of the accident type on freeways and on high-speed rural and suburban roadways two road segments were employed in the study. One of these was a four lane limited-access highway with a 55 mile per hour speed limit and the other was a rural two-lane roadway with a 45 mile per hour speed limit.

From the content of the model regulation, and with the findings of previous research four specific disabled-vehicle conditions were examined. These were:

- A bare vehicle (no conspicuity enhancing devices or materials were used)
- A vehicle with its four-way flashers activated
- A vehicle with its four-way flashers activated and three reflective triangles deployed
- A vehicle with its four-way flashers activated and three fusees deployed.

To test the elements of the model regulation related to pedestrian conspicuity five pedestrian conditions were adopted. These were:

- No pedestrian present
- A pedestrian wearing gray coveralls
- A pedestrian wearing gray coveralls and a commercial available sash made of red-orange fluorescent and retroreflective material.
- A pedestrian wearing gray coveralls and a commercially available vest made of red-orange fluorescent plus retroreflective striping material.
- A pedestrian wearing a locally fabricated three-quarter length coat striped with yellow fluorescent and retroreflective material.

The vehicle and pedestrian conditions were examined in a factorial design. That is, testing was conducted for each cell of the following matrix:

Vehicle Condition / Pedestrian Condition	Bare Vehicle	Four Way Flashers	Triangles and Flashers	Fusees and Flashers
No pedestrian				
Pedestrian in street clothing				
Pedestrian wearing sash				
Pedestrian wearing vest				
Pedestrian wearing coat				

Testing was carried out during the daytime and at night on both road segments. Thus, there were four applications of the design matrix (on two road segments by day and at night). The four vehicle conditions were chosen for study based on the following rationale:

- Bare vehicle--this is the minimum essential feature for the disabled-vehicle setting. Previous research has shown that motorists will respond to a vehicle by the roadside with speed reductions and/or increased lateral separation. One basic question addressed by the field test was whether there were vehicle and/or pedestrian conditions which could enhance these responses. The bare vehicle setting, therefore, established the baseline against which the effects of the other conditions would be determined.

- Vehicle with four-way flashers activated--the activation of the vehicle's four-way flasher system is one of the requirements of the model regulation. As virtually all vehicles on the U.S. roads are now equipped with flashers, their use is a "no-cost" activity for motorists who become disabled.

- Deployment of three warning triangles or fusees--the deployment of triangles or fusees is one of the actions required by the model regulation. Previous research suggests that using three devices has an effect on passing traffic while using fewer units tends to be ineffective.

The five conditions involving pedestrians were selected based on the following considerations:

- No pedestrian present--this condition permitted the examination of the basic effects of the vehicle conditions without the possible additive effects of a pedestrian at the scene.

- Pedestrian wearing gray coveralls--this is the typical condition involved in the dismounted motorist accident type and the situation which is modified by the elements of the model regulation requiring the use of fluorescent and retroreflective materials. The inclusion of the condition provided a baseline for examining the effects of the other pedestrian conditions and the extent to which the presence of a pedestrian modified the responses to the vehicle conditions.

- Pedestrian wearing a fluorescent and retroreflective sash--the model regulation requires the donning of fluorescent/ retroreflective materials by persons who exit from disabled vehicles. The sash represents a low cost, readily available item for complying with this requirement.

- Pedestrian wearing a fluorescent and retroreflective vest--the vest is another example of a readily available item which could be used to comply with the model regulation. While somewhat more expensive than the sash, the vest has more area to return a signal to on-coming motorists.

- Pedestrian wearing a fluorescent and retroreflective coat--this one-of-a-kind garment was locally produced to yield a large surface area of materials and to outline a human form with retroreflective materials at night. The condition was intended to create an extreme end point in enhancement of pedestrian conspicuity in the attempt to determine the maximum effects which could be produced.

In the basic design matrix shown above, the row labeled "No pedestrian" involved the testing of the four vehicle conditions in the absence of a pedestrian, while the column labeled "Bare Vehicle" involved the testing of the pedestrian conditions in the absence of any active vehicle conditions. The remaining cells of the matrix involved the systematic testing of each pedestrian condition coupled with each vehicle condition.

a) Test Specifications

Testing was conducted on Mondays thru Thursdays during the day and evening in December 1980 and January and February 1981. (Friday and weekend days were not included to avoid potential safety problems associated with the increased number of drinking drivers on the roads during these days of the week.) Weather conditions were clear and seasonable when testing was conducted; the roadways were dry and there was no snow or ice build-up along the shoulder area. Daytime testing commenced about 10:00 a.m. and concluded at about 3:30 p.m. Nighttime testing commenced after full darkness (about 6:00 p.m.) and concluded at approximately 10:00 p.m.

The two test sites were located in suburban Connecticut. The two-lane roadway had a speed limit of 45 miles per hour and was selected as being typical of the rural and suburban roadways on which many of the disabled-vehicle related accidents occur. The road segment had ten foot wide lanes of travel in each direction separated by a double yellow line. On the test side of the roadway there was a two foot wide paved shoulder and a grassy area which permitted the test vehicle to be parked completely off the lane of travel. The lane of travel was demarked from the shoulder area by a solid white line. The test location was a straight and level segment of the roadway. Drivers coming upon the site on the testing side of the roadway came out of a left hand bend in the roadway and then had about 300 feet of straight travel before passing the test vehicle. Maximum sight distance to the test vehicle (from the upstream bend in the roadway) was approximately 700 feet.

The abutting property was primarily wooded in nature with private residences set behind the woods and well off the roadway. At night, the site was generally dark but did receive some illumination from abutting property and a small street light located approximately 100 feet beyond the test site.

Traffic on the two-lane roadway was very light during the times of testing. Vehicles passing the test installation almost never had to contend with traffic coming in the opposite direction, therefore.

The limited-access highway site was a four lane divided roadway built to interstate standards with a broad median, 12 foot wide concrete lanes of travel and a blacktop paved shoulder approximately ten feet wide. the test site was on a level, straight section of road and was visible for about 2,000 feet to drivers coming around a gentle bend. The roadway was unlighted and there was virtually no illumination from abutting property.

The vehicle used in all test conditions was a dark green 1974 AMC Hornet hatchback. On the limited-access highway the vehicle was parked with its left side wheels 24 inches off the edge of the lane of travel. On the two-lane roadway a distance of 18 inches was used (to insure that one set of wheels remained on the paved portion of the shoulder).

The fusees and triangles were purchased commercially, with the triangles marked as conforming to Motor Vehicles Safety Standard 125. Other than MVSS 125 there are no set guidelines for the positioning of hazard warning devices and the particular configuration specified in the standard was found by Knoblauch and Tobey (1980) to be less effective than placing all three devices to the rear of the vehicle. On the limited-access roadway the fusees and triangles were placed at ten, 100 and 300 feet upstream of the test vehicle, with the unit closest to the vehicle located 18 inches from the roadway edge, the middle unit located 24 inches from the roadway edge and the furthest unit located 48 inches from the roadway edge. These lateral-positions were selected to suggest a taper effect away from the test vehicle. The ten, 100 and 300 foot distances from the vehicle were selected as being reasonable locations given that at the speed limit a vehicle would cover 300 feet in less than four seconds.

In terms of the geometry of the disabled-vehicle situation the most exposed location for the motorist is when changing a tire on the side of the vehicle past which traffic is flowing (assuming, of course, that the motorist is not merely standing in the roadway). As described in Appendix B, changing tires on automobiles involves adopting positions in which the person's profile extends two to three feet from the side of the vehicle. Because of safety considerations such positions were not used in the present study.

Instead, when the pedestrian was present he stood at the center rear of the vehicle facing up the roadway in the direction from which passing traffic was coming (i.e., his back was to the rear of the test vehicle). During daytime one of two male staff members served as the pedestrian. At night a life size mannequin was employed. Observations at night indicated that from moving vehicles it was not possible to detect that the mannequin was other than a live person.

In the "regular clothing" condition the pedestrian (or the mannequin) wore a medium gray coverall to present a uniform appearance. The sash or the vest was worn over the coverall when these conditions were employed. As noted, the sash and the vest were purchased commercially to represent the kinds of materials suggested by the model regulation. The sash was a one-and-a-half inch band of Reflexite brand red-orange fluorescent and retroreflective material. It was worn diagonally across the body, over one shoulder and under the opposite arm.

The sleeveless vest employed consisted of red-orange nylon fluorescent material and two vertical strips of 3M 8910 silver material on the front and back. Sashes of the type used, retail for between $5 and $10 while vests sell for about $8 to $20.

The coat employed in the study was produced locally to yield an extreme end point in terms of enhancing pedestrian conspicuity. A white laboratory coat was used. Two-inch wide strips of 3M 8910 material were run from the collar, across each shoulder and down the sleeves to the cuffs. Two one-inch wide strips of 8910 material were run down the front and back of each sleeve. A three-inch wide band of 8910 was run entirely around the bottom of the coat. Three-inch wide bands of Reflexite lime-yellow fluorescent and retroreflective material were run front and back from the outer shoulders to the center at about waist level and from there outward to the lower hips. The coat was, thus, intended to have a large area of retroreflective material and through the striping, to suggest a human form. Sketches of the pedestrian materials are contained in Appendix C.

2. Instrumentation

The instrumentation employed was the Leupold and Stevens, Inc., Traffic Data Recorder (TDR) with surface mounted sensor cables deployed, using a method developed at the Federal Highway Administration Maine Test Facility (Lanman, 1976).

The basic TDR was designed to be employed in traffic surveys (i.e., recording vehicle counts, speeds, etc.). To determine vehicle speed, two surface mounted sensor cables were laid six feet apart parallel to one another across the lane of interest. The device then records on a magnetic tape cassette, speed to the nearest mile per hour, the number of axles on the vehicle and the exact vehicle arrival time at the sensor. Each TDR can record data from four speed traps simultaneously.

Using the TDR to measure speed and lateral placement involved the deployment of the sensor cables to form two traps at each measurement location. The first trap was for standard speed measurement, while the second trap had its second sensor cable laid at a 45 degree angle. The speed reading obtained from the second trap was a function of the vehicle's actual speed and its lateral-position. By using the vehicle's known speed as measured by Trap 1, it was possible to compute lateral placement.

Field trials indicated that errors in speed and lateral placement measurement were uniformly distributed with zero mean and a standard deviation of less than two mph. Over a vehicle speed range of 40 to 70 mph, it has been found that the distribution of lateral placement error has a mean of zero and a standard deviation of 0.3 feet. Thus, the system used had a high inherent accuracy. The cassette data were subsequently transferred to a remote computer facility where they were processed and analyzed by specially written programs.

Two measurement positions were employed on each roadway. On the two-lane site one of these was at the test vehicle and the other was 300 feet upstream. On the limited-access highway one measurement position was at the test vehicle and the other was 500 feet upstream. The upstream recording positions were arbitrarily chosen based on cable length and site condition. The primary purpose of these installations was to measure driver behavior before passage of the test site and any of the test items (i.e., the upstream fusee or triangle). In addition, on the limited-access highway the upstream recorder provided a basis for determining the frequency with which vehicles moved from the right to the left hand lane. That is, vehicles counted at the upstream location but not at the test vehicle were considered to have changed lanes. A diagram of the test installation can be found in Appendix C.

3. Testing Sequence

The sensor cable installations were made the day prior to the commencement of testing and insofar as possible were left in place until all testing had been completed.* Testing was carried out in a sequence of bare vehicle-test condition-bare vehicle trials. In this way the effects of the test conditions could be compared with the effects of the bare vehicle immediately before and after the test condition. On the two-lane road, measurements were made on 25 vehicles passing the bare test vehicle, on 50 vehicles passing the test condition and then on 25 vehicles passing the bare test vehicle. Measurement gaps were employed between condition changes to permit setting up and removing the test conditions.

D. Results

1. Two Lane Site

a) Vehicle Speeds

On the two-lane roadway speed recording was done at the test vehicle and at a point 300 feet upstream (prior to) the test vehicle. Table 3 shows the mean speed in miles per hour recorded at the test vehicle during each experimental condition and during each condition's comparison periods,

*The sensor cables were removed when snow was predicted. One set was lost following an overnight snowfall and subsequent snow plowing. On two occasions the sensors were partially destroyed by vandals, with one of these following an attempt to steal the instrumentation.

Table 3. Speeds Passing Test Vehicle--Two-Lane Road

Pedestrian Condition \ Vehicle Condition	Bare Vehicle			Four-Way Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	43.6	45.3	-1.7	50.1	49.4	0.7	47.2	49.3	-2.1	43.7	46.1	-2.4	46.2	47.6	-1.4
Night	47.4	46.6	0.8	46.9	49.1	-2.2	43.8	48.1	-4.3	38.3	49.0	-10.7	44.1	48.2	-4.1
Gray Ped															
Day	46.5	46.1	0.4	42.4	48.1	-5.7	44.9	49.7	-4.8	42.7	50.2	-7.5	44.1	48.5	-4.4
Night	47.2	50.4	-3.2	43.1	44.9	-1.8	41.5	50.6	-9.1	36.0	46.9	-10.9	42.0	48.2	-6.2
Ped w/Sash															
Day	48.6	50.5	-1.9	45.5	47.6	-2.1	41.6	49.3	-7.7	42.6	48.0	-5.4	44.6	48.9	-4.3
Night	47.2	48.4	-1.2	40.3	45.1	-4.8	39.6	43.8	-4.2	38.9	44.9	-6.0	41.5	45.6	-4.1
Ped w/Vest															
Day	46.1	50.8	-4.7	43.3	46.4	-3.1	45.8	51.5	-5.7	43.2	47.7	-4.5	44.6	49.1	-4.5
Night	48.3	49.6	-1.3	43.6	50.5	-6.9	39.9	44.8	-4.9	36.8	45.6	-8.8	42.1	47.6	-5.5
Ped w/Coat															
Day	45.8	48.2	-2.4	46.1	50.8	-4.7	43.3	45.2	-1.9	43.0	49.6	-6.6	44.4	48.3	-3.9
Night	46.1	45.5	0.6	45.5	49.2	-3.7	41.2	51.3	-10.1	35.3	49.1	-13.8	42.0	48.7	-6.7
Average of the Ped Conditions															
Day	46.7	48.8	-2.1	45.5	48.5	-3.0	44.6	49.1	-4.5	43.1	48.3	-5.2	44.8	48.5	-3.7
Night	47.2	48.1	-0.9	43.9	47.8	-3.9	41.2	47.7	-6.5	37.1	47.2	-10.1	42.3	47.6	-5.3

Table entries are in miles per hour

along with the differences between means. It may be recalled that each condition was examined on the two-lane road by taking measurements on 25 vehicles passing the site with just the bare vehicle in place, deploying a test condition and taking measurements on 50 vehicles and then again taking measurements on another 25 vehicles with just the bare vehicle in place. In Table 3 the values in the columns labeled "Condition" are the means for the 50 vehicle observations when the particular condition was in place; the adjacent values in the columns headed "Bare Vehicle" are the means for the 25 observations before and the 25 observations after the condition taken with just the bare vehicle. (Note that in the upper left of the table the bare vehicle was treated as a condition. That is, a sequence of 25, 50 and 25 observations was run to standardize the taking of data across the design matrix.) Corresponding speed data obtained at the upstream recording position are contained in Table 4.

The experimental design employed in the study called for the systematic balancing of the pedestrian and vehicle conditions (i.e., each pedestrian condition was paired with each vehicle condition) and, insofar as possible, a balancing of the conditions by day of testing and by order of testing within a test day. Test day and test order were not totally orthogonal, however. The study data, therefore, were treated as a four-factor design (pedestrian conditions, vehicle conditions, test day, test sequence) and analyzed using a general linear model approach with the mean squares being computed based on each factor's entry as the last term in the model (SAS Industries, 1979).

The resulting analysis of variance of the difference scores (between treatment and comparison period means) for vehicle speeds measured at the test vehicle is shown in Table 5. The results for the daytime speed readings indicate that the pedestrian and vehicle conditions were statistically significant while at night just the vehicle conditions were significant. During the daytime both the day of testing and the order of testing were significant factors while at night, day of testing was significant. These latter results suggest that the basic driving pattern on the test roadway--in this case the speeds of passing vehicles--as well as the magnitude of motorists' responses to the test conditions, varied by time of day and day of week. Underlying this are likely differences in trip purpose that occur throughout the day and in the nature of particular individuals using the roadway on any given day. In any event the effects of test sequence and day of testing are accounted for by the general linear model analytic approach.

In order to determine which particular conditions brought about the significant changes, tests for comparisons among all treatment means were carried out. The outcomes for the daytime results are contained in Table 6. The comparisons among the daytime vehicle condition means show that all of the differences were statistically significant. That is, each of the active vehicle conditions yielded a greater speed reduction (at the test vehicle) than did the bare vehicle and the active conditions differed from one another, with the fusees/flashers combination producing the greatest effect followed by the triangles/flashers and then the flashers alone.

Table 4. Speeds at the Upstream Position--Two-Lane Road

Pedestrian Condition \ Vehicle Condition	Bare Vehicle			Four Way-Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	45.6	47.6	-2.0	45.2	46.4	-1.2	46.0	45.8	0.2	45.5	45.7	-0.2	45.6	46.4	-0.8
Night	46.1	44.9	1.2	42.8	45.1	-2.3	42.3	43.9	-1.6	35.4	46.4	-11.0	41.6	45.0	-3.4
Gray Ped															
Day	46.7	45.8	0.9	46.2	49.8	-3.6	43.7	46.3	-2.6	40.6	45.5	-4.9	44.3	46.9	-2.6
Night	45.1	48.7	-3.6	44.7	45.4	-0.7	41.1	45.7	-4.6	37.5	47.1	-9.6	42.1	46.7	-4.6
Ped w/Sash															
Day	44.1	45.6	-1.5	43.4	42.9	0.5	44.6	48.9	-4.3	43.0	44.8	-1.8	43.8	45.6	-1.8
Night	44.1	44.8	-0.7	46.3	47.0	-0.7	42.3	45.7	-3.4	37.3	43.1	-5.8	42.5	45.2	-2.7
Ped w/Vest															
Day	44.7	46.9	-2.2	44.6	46.5	-1.9	43.0	46.1	-3.1	43.0	47.9	-4.9	43.8	46.8	-3.0
Night	43.8	44.7	-0.9	42.4	49.0	-6.6	42.1	45.3	-3.2	38.4	46.7	-8.3	41.7	46.4	-4.7
Ped w/Coat															
Day	43.5	43.0	0.5	43.4	47.2	-3.8	45.3	45.8	-0.5	41.9	46.7	-4.8	43.5	45.7	-2.2
Night	47.0	47.2	-0.2	43.6	44.4	-0.8	41.7	47.8	-6.1	36.1	45.7	-9.6	42.1	46.3	-4.2
Average of the Ped Conditions															
Day	44.9	45.8	-0.9	44.6	46.6	-2.0	44.5	46.6	-2.1	42.8	46.1	-3.3	44.2	46.3	-2.1
Night	45.2	46.0	-0.8	44.0	46.2	-2.2	41.9	45.7	-3.8	36.9	45.8	-8.9	42.0	45.9	-3.9

Table entries are in miles per hour

Table 5. Analysis of Variance of Vehicle Speeds Measured at the Test Vehicle--Two-Lane Road

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	5.44	3.28**	4	3.82	1.34
Vehicle Conditions	3	7.73	4.66**	3	69.51	24.39**
Test Day	5	4.80	2.89*	4	10.73	3.77**
Test Order	3	5.68	3.42*	3	1.66	<1
Between Cells Residual	4	3.27	1.96	5	4.14	1.45
Error	3426	1.66		2086	2.85	

* $p < .05$
** $p < .01$

Table 6. Mean Comparisons of Daytime Vehicle Speeds Measured at the Test Vehicle on the Two-Lane Road

Vehicle Condition	$\bar{X}$	$\bar{X}$-2.1	$\bar{X}$-3.0	$\bar{X}$-4.5
Fusees and Flashers	5.2	3.1*	2.2*	0.7*
Triangles and Flashers	4.5	2.4*	1.5*	
Flashers	3.0	0.9*		
Bare Vehicle	2.1			

Ped Conditions	$\bar{X}$	$\bar{X}$-1.4	$\bar{X}$-3.9	$\bar{X}$-4.3	$\bar{X}$-4.4
Ped w/Vest	4.5	3.1*	0.6*	0.2	0.1
Gray Ped	4.4	3.0*	0.5	0.1	
Ped w/Sash	4.3	2.9*	0.4		
Ped w/Coat	3.9	2.5*			
No Ped	1.4				

*$p<.05$ with D + .526 for the vehicle conditions and D = .560 for the pedestrian conditions.

In this and subsequent tables presenting the results of tests of all comparisons among means, the first column shows the overall difference between the mean value obtained during the applications of the condition and the condition's control periods, i.e., the bare vehicle trials run immediately before and after each condition. The D statistic is the magnitude of the difference between pairs of means which is significantly different at $\alpha = .05$, where D is the product of the estimated population standard deviation and the Studentized Range Statistic for the number of treatments and degrees of freedom involved, i.e., the Tukey procedure described in Snedecor (1956), p. 251.

Regarding the pedestrian conditions, the figures above show that during the daytime it was generally the presence or absence of the pedestrian which produced differential vehicle speeds rather than the various garments worn by the pedestrian.

Tests for comparisons among the nighttime vehicle condition means yielded the results shown in Table 7. These figures show that, as with the conditions during the day, each condition differed from one another. As the overall pedestrian factor was not statistically significant, individual mean comparisons were not carried out.

The results of the analysis of variance of the difference scores of vehicle speeds measured at the upstream position are contained in Table 8. The results for the upstream speed measurements parallel those for the speeds measured at the test vehicle. That is, during the daytime both the pedestrian and vehicle conditions produced significant reductions while at night only the vehicle conditions did so.

Tests for comparisons among daytime means for the upstream measurements are shown in Table 9. The mean differences for the vehicle conditions generally correspond to those recorded at the test vehicle except that in this case there was no difference between the triangles/flashers combination and the use of flashers alone. The upstream speed differences for the pedestrian conditions varied somewhat from those measured at the test vehicle. It can be seen in Table 9 that as with the speeds measured at the vehicle, each pedestrian condition had a significant effect compared with the absence of the pedestrian. In addition, it can be seen that the pedestrian wearing a vest produced a greater effect that the pedestrian wearing the sash or the coat. However, the pedestrian wearing the sash and produced an effect similar to wearing the coat.

The comparisons among means for upstream vehicle speeds at the night for the vehicle conditions are shown in Table 10. Comparing these figures with those in Table 7 for speeds at the test vehicle shows the same pattern. That is, each active condition produced significant effects compared with the bare vehicle and the active conditions all differed significantly from one another.

In the analyses of variance results shown in Tables 5 and 8, the sources of variance attributed to the between cells residual represents the pooled variance which could have been parceled into individual interaction terms had the basic design been completely orthogonal with respect to test day and order. The fact that none of the between cell residuals tested in Tables 5 and 8 were statistically significant suggests that significant interactions are note present in these data. However, to more explicitly examine the possible interaction effects of the pedestrian and vehicle conditions, the difference scores in Tables 3 and 4 were transformed by subtracting out the grand mean and the appropriate test day and test order means. The transformed values for each vehicle condition were then subjected to orthogonal comparisons*

*cf. Snedecor (1956, p. 329). The comparisons followed the model: $C=\lambda_1P_1+\lambda_2P_2+\lambda_3P_3+\lambda_4P_4$, where P_1 was the transformed score for the gray pedestrian, P_2 the score for the pedestrian with the sash, P_3 for the pedestrian with the vest and P_4 the pedestrian with the coat and $\lambda_1=-3$, λ_2, λ_3, $\lambda_4= +1$.

Table 7. Mean Comparisons of Nighttime Vehicle Speeds Measured at the Test Vehicle on the Two-Lane Road

Vehicle Condition	$\bar{x}$	$\bar{x}$-0.9	$\bar{x}$-3.9	$\bar{x}$-6.5
Fusees and Flashers	10.1	9.2*	6.2*	3.6*
Triangles and Flashers	6.5	5.6*	2.6*	
Flashers	3.9	3.0*		
Bare Vehicle	0.9			

*p<.05 with D = .887

Table 8. Analysis of Variance of Vehicle Speeds Measured at the Upstream Site--Two-Lane Road

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	4.25	3.29*	4	1.68	<1
Vehicle Conditions	3	5.17	4.01**	3	58.93	26.67**
Test Day	5	4.76	3.69**	4	11.27	5.10**
Test Order	3	3.58	2.77*	3	0.76	<1
Between Cells Residual	4	1.98	1.53	5	0.85	<1
Error	3264	1.29		2025	2.21	

* p < .05
** p < .01

Table 9. Mean Comparisons of Daytime Vehicle Speeds Measured Upstream on the Two-Lane Road

Vehicle Condition	$\bar{x}$	$\bar{x}$-0.9	$\bar{x}$-2.0	$\bar{x}$-2.1
Fusees and Flashers	3.3	2.4*	1.3*	1.2*
Triangles and Flashers	2.1	1.2*	0.1	
Flashers	2.0	1.1*		
Bare Vehicle	0.9			

Ped Conditions	$\bar{x}$	$\bar{x}$-0.8	$\bar{x}$-1.8	$\bar{x}$-2.2	$\bar{x}$-2.6
Ped w/vest	3.0	2.2*	1.2*	0.8*	0.4
Gray Ped	2.6	1.8*	0.8*	0.4	
Ped w/Coat	2.2	1.4*	0.4		
Ped w/Sash	1.8	1.0*			
No Ped	0.8				

*$p<.05$ with D = .470 for the vehicle conditions and D = .500 for the pedestrian conditions.

Table 10. Mean Comparisons of Nighttime Vehicle Speeds Measured Upstream on the Two-Lane Road

Vehicle Condition	$\bar{x}$	$\bar{x}$-0.8	$\bar{x}$-2.2	$\bar{x}$-3.8
Fusees and Flashers	8.9	8.1*	6.7*	5.1*
Triangles and Flashers	3.8	3.0*	1.6*	
Flashers	2.2	1.4*		
Bare Vehicle	0.8			

* $p<.05$ with D = .791

which compared the gray pedestrian results with the results for the pedestrian wearing the sash, vest or coat. None of these comparisons were found to be statistically significant indicating that on the two-lane roadway there were no interactive effects of the vehicle and pedestrian conditions on the speeds of passing vehicles.

The percent changes in mean speeds between each test condition and its bare vehicle comparison during the daytime recorded at the test vehicle and the upstream position are presented in Table 11. In this table values marked with asterisks are those where the t-test between condition and control means of the underlying data yielded statistically significant results. The data in the table suggest that during the daytime on the two-lane roadway none of the vehicle conditions had a significant effect on the speeds of passing vehicles beyond that which may have been produced by just the bare vehicle. With the pedestrian present and the bare vehicle, the vest and coat configurations significantly slowed vehicle speeds at the test vehicle but not upstream, while the sash and the gray coveralls had no effect.

As already noted the significant pedestrian factor in the analysis of variance was due to the presence or absence of the pedestrian and that there were no significant interactions between the active pedestrian and vehicle conditions. This can be confirmed in Table 11 where it can be seen that the magnitude of the responses to the gray pedestrian in the active vehicle conditions was as large as found with conspicuity enhancing materials. Finally in Table 11 it can be seen that the magnitude of the speed reductions generally was greater at the test vehicle than at the upstream recorder.

Data comparable to that in Table 11, for the nighttime, two-lane roadway vehicle speed data, are shown in Table 12. Here it may be seen that with the bare vehicle the various pedestrian conditions generally had no effect on vehicle speeds. It can also be seen that the triangles/flashers and fusees/flashers conditions generally produced effects across all of the pedestrian conditions. These effects tended to be greater at the test vehicle than upstream and greater for the fusees/flashers than for the triangles/flashers. Regarding the four-way flashers alone the data in Table 12 suggest that these were effective in combination with the sash, vest and coat worn by the pedestrian but not with the gray coveralls. This possible effect was not confirmed by the specific test for such an interaction, however.

b) Lateral Placement

On the two-lane roadway the instrumentation was capable of measuring the lateral placement (distance of the rightside tires from the roadway edge) at the test vehicle and at the upstream position. Table 13 shows the mean lateral placement in inches measured at the test vehicle during each condition and during each condition's control periods, and the differences between the means. Similar data recorded at the upstream position are shown in Table 14.

The analysis of variance of the lateral placement data measured at the test vehicle are contained in Table 15. Results for the upstream measurements are in Table 16. In Table 15 it can be seen that the vehicle conditions produced effects at the test vehicle during the day and at night but

Table 11. Percent Change in Mean Speed on the Two-Lane Road During Daytime

Pedestrian Conditions \ Vehicle Condition	Bare Vehicle	Four-Way Flashers	Triangles and Flashers	Fusees and Flashers
No Ped				
At vehicle	-3.8%	1.4%	-4.3%	-5.2%
Upstream	-4.2	-2.6	0.4	-0.4
Gray Ped				
At vehicle	0.9	-11.8**	-9.7**	-14.9**
Upstream	-2.0	-7.2**	-5.6*	-10.8**
Ped w/Sash				
At vehicle	-3.8	-4.4	-15.6**	-11.2**
Upstream	-3.3	1.2	-8.8**	-4.0
Ped w/Vest				
At vehicle	-9.3**	-6.7**	-11.1**	-9.4**
Upstream	-4.7	-4.1*	-6.7**	10.2**
Ped w/Coat				
At vehicle	-5.0**	-9.3**	-4.2	-13.3**
Upstream	1.2	-8.1**	-1.1	-10.3**

* p <.05
** p <.01

Table entries are in percent. Negative values indicate that the mean speed during the condition was less than during its comparison period.

Table 12. Percent Change in Mean Speed on the Two-Lane Road at Night

Pedestrian Condition \ Vehicle Condition	Bare Vehicle	Four-Way Flashers	Triangles and Flashers	Fusees and Flashers
No Ped				
At vehicle	1.7%	-4.5%	-8.9%**	-21.8% *
Upstream	2.7	-5.1	-3.6	-23.7**
Gray Ped				
At vehicle	-6.3	-4.0	-18.0**	-23.2**
Upstream	-7.4*	-1.5	-10.1**	-20.4**
Ped w/Sash				
At vehicle	-2.5	-10.6**	-9.6**	-13.4*
Upstream	-1.6	-1.5	-7.4*	-13.5**
Ped w/Vest				
At vehicle	-2.6	-13.7**	-10.9**	-19.3**
Upstream	-2.0	-13.5**	-7.1**	-17.8**
Ped w/Coat				
At vehicle	-1.9	-7.5**	-19.7**	-28.1**
Upstream	-0.4	-1.8	-12.8**	-21.0**

* p <.05
** p <.01

Table entries are in percent. Negative values indicate that the mean speed during the condition was less than during its comparison period.

Table 13. Lateral Placement Passing Test Vehicle--Two-Lane Road

Vehicle Condition / Pedestrian Condition	Bare Vehicle			Four-Way Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	61.8	60.1	1.7	48.3	49.9	-1.6	49.5	45.7	3.8	48.7	40.0	8.7	52.1	49.0	3.1
Night	64.4	69.3	-4.9	52.2	49.1	3.1	49.3	40.6	8.7	58.2	50.0	8.2	56.0	52.2	3.8
Gray Ped															
Day	44.1	38.9	5.2	61.0	55.3	5.7	51.4	45.3	6.1	64.0	50.6	13.4	55.1	47.5	7.6
Night	49.6	47.3	2.3	60.8	56.4	4.4	58.1	55.0	3.1	51.3	38.6	12.7	55.0	49.4	5.6
Ped w/Sash															
Day	49.8	48.9	0.9	49.3	48.9	0.4	67.4	62.9	4.5	49.2	44.7	4.5	53.9	51.3	2.6
Night	50.1	43.0	7.1	45.0	42.5	2.5	72.6	57.9	14.7	51.5	41.2	10.3	54.8	46.2	8.6
Ped w/Vest															
Day	48.2	47.2	1.0	40.4	39.1	1.3	59.2	50.6	8.6	71.2	63.6	7.6	54.8	50.2	4.6
Night	49.1	41.0	8.1	55.5	50.7	4.8	47.8	36.5	11.3	80.5	67.0	13.5	58.3	48.9	9.4
Ped w/Coat															
Day	49.6	47.1	2.5	46.9	46.4	0.5	45.0	38.5	6.5	56.4	49.3	7.1	49.5	45.4	4.1
Night	43.2	41.9	1.3	42.4	40.4	2.0	63.3	50.6	12.7	63.6	53.8	9.8	53.1	46.6	6.5
Average of the Ped Conditions															
Day	50.7	48.4	2.3	49.2	47.9	1.3	54.5	48.6	5.9	57.9	49.6	8.3	53.1	48.7	4.4
Night	51.3	48.5	2.8	51.2	47.9	3.3	58.2	48.1	10.1	61.0	50.1	10.9	55.4	48.6	6.8

Table entries are in inches from right side edge of traveled lane

Table 14. Lateral Placement at the Upstream Position--Two-Lane Road

Pedestrian Condition \ Vehicle Condition	Bare Vehicle			Four-Way Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	50.5	53.5	-3.0	41.3	34.6	6.7	44.0	39.6	4.4	48.7	38.9	9.8	46.1	41.6	4.5
Night	63.0	55.3	7.7	33.0	34.5	-1.5	43.1	41.9	1.2	45.7	37.4	8.3	46.2	42.3	3.9
Gray Ped															
Day	44.4	45.2	-0.8	56.3	54.7	1.6	40.1	36.2	3.9	46.6	31.8	14.8	46.9	42.0	4.9
Night	39.3	38.8	0.5	52.3	53.4	-1.1	38.3	33.9	4.4	51.0	45.7	5.3	45.2	42.9	2.3
Ped w/Sash															
Day	36.1	36.6	-0.5	36.9	29.7	7.2	64.1	52.1	12.0	47.0	42.4	4.6	46.1	40.3	5.8
Night	33.6	30.8	2.8	47.6	45.9	1.7	64.0	54.8	9.2	63.2	41.2	22.0	52.1	43.2	8.9
Ped w/Vest															
Day	45.7	40.6	5.1	42.0	42.5	-0.5	43.2	33.5	9.7	56.0	51.7	4.3	46.7	42.1	4.6
Night	42.3	41.1	1.2	38.9	39.9	-1.0	48.4	47.5	0.9	67.8	61.9	5.9	49.3	47.5	1.8
Ped w/Coat															
Day	32.0	28.6	3.4	37.7	45.5	-7.8	45.9	41.3	4.6	44.4	34.3	10.1	40.0	37.4	2.6
Night	47.8	46.9	0.9	36.1	34.5	1.6	46.4	37.3	9.1	55.4	36.3	19.1	46.4	38.7	7.7
Average of the Ped Conditions															
Day	41.7	40.9	0.8	42.8	41.4	1.4	47.5	40.6	6.9	48.5	39.8	8.7	45.1	40.6	4.5
Night	45.2	42.6	2.6	41.6	41.7	-0.1	48.0	43.1	4.9	56.6	44.5	12.1	47.8	42.9	4.9

Table entries are in inches from right side edge of traveled lane

Table 15. Analysis of Variance of Vehicle Lateral Placement Measured at the Test Vehicle--Two-Lane Road

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	8.09	1.02	4	20.66	1.21
Vehicle Conditions	3	42.50	5.35**	3	78.21	4.59**
Test Day	5	3.94	<1	4	1.08	<1
Test Order	3	3.52	<1	3	30.03	1.76
Between Cells Residual	4	1.01	<1	5	6.80	<1
Error	2888	7.95		1752	17.04	

* $p < .05$
** $p < .01$

Table 16. Analysis of Variance of Vehicle Lateral Placement Measured at the Upstream Location--Two-Lane Road

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	16.61	1.35	4	41.42	2.15
Vehicle Conditions	3	50.59	4.12**	3	134.53	6.99**
Test Day	5	28.97	2.36*	4	12.23	<1
Test Order	3	47.62	3.87**	3	13.89	<1
Between Cells Residual	4	7.90	<1	5	19.93	1.04
Error	2375	12.29		1446	19.25	

* $p < .05$
** $p < .01$

that the pedestrian conditions had no effect. Table 16 shows this same outcome for the upstream measurements and that day of testing and test order were significant for the daytime testing.

Comparisons among the vehicle condition means measured at the test vehicle are shown in Table 17. The figures in the table indicate the fusees/flashers and triangles/flashers combinations produced significant effects on lateral placement at the test vehicle compared with the flashers only condition and the bare vehicle. Also, the fusees/flashers condition produced greater effects than the triangles/flashers condition during the daytime but not so at night.

Comparisons among means measured upstream are contained in Table 18. The daytime results follow those for measurement at the test vehicle in that fusees/flashers and triangles/flashers conditions produced significant effects compared to the flashers only and the bare vehicle, with the fusees/flashers being superior to the triangles/flashers. At night the effect produced by the fusees/flashers significantly exceeded the other conditions while (somewhat anomalously) the triangles/flashers condition produced significant effects compared with the flashers but not the bare vehicle.

Specific tests of interactions of the pedestrian conditions with the active vehicle conditions were carried out in the same manner as employed with the vehicle speed data. None of these test outcomes were statistically significant.

The percent change in lateral placement for each condition during the daytime is shown in Table 19 while the nighttime data are in Table 20. The daytime figures in Table 19 suggest that in the absence of the pedestrian, only the fusees/flashers condition had a statistically significant effect. With the bare vehicle, the pedestrian conditions generally did not have an effect at the test vehicle or the upstream location. The triangles/flashers and fusees/flashers were generally effective across the pedestrian condition. However, there was no clear pattern indicating a greater or lesser effect at the test vehicle or the upstream location.

The data in Table 20 indicate that at night the triangles/flashers and fusees/flashers generally increased lateral placement at the test vehicle across the pedestrian conditions. With the bare vehicle the pedestrian wearing the sash and vest produced significant changes. However, these conditions did not have effects when coupled with the four-way flashers thus indicating that the bare vehicle outcome may be anomolous. As with the daytime lateral placement data, there is no consistent pattern in Table 20 to suggest a greater or lesser effect at the test vehicle or the upstream recorder.

2. Limited Access Highway

a) Vehicle Speeds

On the limited-access highway, recording was done at the test vehicle and upstream 500 feet prior to the test vehicle. The mean speeds during the conditions and comparison periods, and the differences between

Table 17. Mean Comparisons of Lateral Placement Measured at the Test Vehicle on the Two-Lane Road

Vehicle Condition	$\bar{x}$	Daytime $\bar{x}$-1.3	$\bar{x}$-2.3	$\bar{x}$-5.9
Fusees and Flashers	8.3	7.0*	6.0*	2.4*
Triangles and Flashers	5.9	4.6*	3.6*	
Bare Vehicle	2.3	1.0		
Flashers	1.3			

Vehicle Condition	$\bar{x}$	Nighttime $\bar{x}$-2.8	$\bar{x}$-3.3	$\bar{x}$-10.1
Fusees and Flashers	10.9	8.1*	7.6*	0.8
Triangles and Flashers	10.1	7.3*	6.8*	
Flashers	3.3	0.5		
Bare Vehicle	2.8			

*$p<.05$ with D = 1.26 for daytime comparisons and D = 2.43 for nighttime comparisons.

Table 18. Mean Comparisons of Lateral Placement Measured Upstream on the Two-Lane Road

Vehicle Condition	$\bar{x}$	Daytime $\bar{x}$-0.8	$\bar{x}$-1.4	$\bar{x}$-6.9
Fusees and Flashers	8.7	7.9*	7.3*	1.8*
Triangles and Flashers	6.9	6.1*	5.5*	
Flashers	1.4	0.6		
Bare Vehicle	0.8			

Vehicle Condition	$\bar{x}$	Nighttime $\bar{x}$+0.1	$\bar{x}$-2.6	$\bar{x}$-4.9
Fusees and Flashers	12.1	12.2*	9.5*	7.2*
Triangles and Flashers	4.9	5.0*	2.3	
Bare Vehicle	2.6	2.7		
Flashers	-0.1			

*$p<.05$ with D = 1.70 for daytime comparisons and D = 2.72 for nighttime comparisons.

Table 19. Percent Change in Lateral Placement on the Two-Lane Road During Daytime

Pedestrian Conditions \ Vehicle Condition	Bare Vehicle	Four-Way Flashers	Triangles and Flashers	Fusees and Flashers
No Ped				
At vehicle	2.8%	-3.2%	8.3%	21.7%**
Upstream	-5.6	19.4	11.1	25.2 **
Gray Ped				
At vehicle	13.4*	10.3	13.5**	26.5**
Upstream	-1.8	2.9	10.8	46.5**
Ped w/Sash				
At vehicle	1.8	0.8	7.2	10.1*
Upstream	1.4	24.2**	23.0**	10.8
Ped w/Vest				
At vehicle	2.1	3.3	17.0**	11.9
Upstream	12.6	-1.2	29.0**	8.3
Ped w/Coat				
At vehicle	5.3	1.1	16.9**	14.4*
Upstream	11.9*	-17.1**	11.1	29.4**

* $p < .05$
** $p < .01$
Table entries are in percent. Positive values indicate that lateral placement was further from the roadway edge during the condition than during its comparison period.

Table 20. Percent Change in Lateral Placement on the Two-Lane Road at Night

Pedestrian Conditions \ Vehicle Condition	Bare Vehicle	Four-Way Flashers	Triangles and Flashers	Fusees and Flashers
No Ped				
At vehicle	-7.1%	6.3%	21.4%**	16.4%*
Upstream	13.9	-4.3	2.9	22.2**
Gray Ped				
At vehicle	4.9	7.8	5.6	32.9**
Upstream	1.3	-2.1	13.0	11.6
Ped w/Sash				
At vehicle	16.5*	5.9	25.4*	25.0*
Upstream	9.1	3.7	16.8	53.4**
Ped w/Vest				
At vehicle	19.8*	9.5	31.0**	20.1*
Upstream	2.9	-2.5	1.9	9.5
Ped w/Coat				
At vehicle	3.1	5.0	25.1**	18.2*
Upstream	1.9	4.6	24.4*	52.6**

* $p < .05$
** $p < .01$
Table entries are in percent. Positive values indicate that lateral placement was further from the roadway edge during the condition than during its comparison period.

means are contained in Tables 21 and 22. Analysis of variance results for the difference scores measured at the vehicle are shown in Table 23 while the results for speed data measured upstream are shown in Table 24.

The results in Table 23 indicate that at the test vehicle during the daytime both the pedestrian and vehicle conditions were statistically significant while at night the vehicle conditions were significant as was the between cells residual (pooled interaction). The results for the upstream measurements (Table 24) show no significant effects during the daytime while at night the vehicle conditions, order of testing, and the between cells residual were significant.

Tests for comparisons among the means for the daytime results obtained at the test vehicle are shown in Table 25. Regarding the vehicle conditions, it can be seen that each of the active conditions produced significant effects compared with the bare vehicle and that the fusees/flashers condition produced greater effects than the other conditions. Among the pedestrian conditions, all produced significant effects compared with the no pedestrian condition. Also, the pedestrian wearing the gray coveralls had a greater effect than each of the pedestrian conspicuity enhancing conditions.

Comparisons among the vehicle condition means for the nighttime results at the test vehicle are shown in Table 26. The figures in the table indicate that at night the fusees/flashers and triangles/flashers each produced statistically significant speed reductions at the test vehicle compared with the flashers only and with the bare vehicle. Also, the fusees/flashers produced a significantly greater effect than the triangles/flashers.

Mean comparisons among the nighttime vehicle condition results measured upstream are contained in Table 27. These figures show the same pattern as the nighttime results measured at the test vehicle. That is, both the fusees/flashers and triangles/flashers conditions produced significant effects compared with the flashers only and with the bare vehicle, and the fusees/flashers producing a significantly greater effect than the triangles/ flashers.

The percent change in mean speeds between each condition and its comparison group during the daytime is shown in Table 28. It can be seen in the table that with the bare vehicle, none of the pedestrian conditions produced a significant effect and that in the absence of the pedestrian, none of the vehicle conditions had a significant effect. Specific tests for interactions of the pedestrian conspicuity enhancing conditions with the active vehicle conditions (carried out in the same manner as described for the two-lane roadway data) failed to yield any statistically significant results.

In general, the results regarding the speeds of vehicles on the limited-access highway suring the daytime parallel those obtained during the daytime at the two-lane site. That is, in the absence of the pedestrian none of the active vehicle conditions significantly slowed passing traffic at either test location and for the most part the pedestrian conditions were ineffective when coupled with the bare vehicle. In both instances the significant pedestrian effect noted in the analysis of variance were due to the presence or absence of the pedestrian rather than one or more of the conspicuity-enhancing garments. Also, no interactions were found between the pedestrian

Table 21. Speeds Passing Test Vehicle--Limited-Access Highway

Pedestrian Condition \ Vehicle Condition	Bare Vehicle			Four-Way Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	58.0	56.8	1.2	59.1	57.3	1.8	50.4	50.5	-0.1	55.9	55.5	0.4	55.9	55.1	0.8
Night	51.4	52.2	-0.8	50.3	52.3	-2.0	50.8	52.7	-1.9	55.8	59.0	-3.2	49.6	50.6	-1.0
Gray Ped															
Day	51.6	51.5	0.1	51.5	55.3	-3.8	51.0	52.7	-1.7	53.0	59.0	-6.0	51.8	54.7	-2.9
Night	48.6	51.7	-3.1	54.5	54.1	0.4	50.1	48.1	1.0	48.0	50.2	-2.2	50.3	51.0	-0.7
Ped w/Sash															
Day	50.6	51.2	-0.6	50.5	53.0	-2.5	53.9	56.7	-2.8	53.0	53.6	-0.6	52.0	53.6	-1.6
Night	53.9	53.4	0.5	51.4	51.8	-0.4	48.0	49.4	-1.4	42.1	50.5	-8.4	48.8	51.2	-2.4
Ped w/Vest															
Day	55.5	55.2	0.3	55.0	59.1	-4.1	55.2	55.4	-0.2	50.5	52.6	-2.1	54.1	55.6	-1.5
Night	49.2	50.3	-1.1	50.9	51.3	-0.4	48.4	53.2	-4.8	47.5	54.1	-6.6	49.1	52.3	-3.2
Ped w/Coat															
Day	56.8	56.7	0.1	54.9	54.8	0.1	50.4	52.9	-2.5	49.3	52.9	-3.6	52.8	54.3	-1.5
Night	51.4	49.1	2.3	49.5	51.1	-1.6	50.4	54.1	-3.7	44.3	47.9	-3.6	48.9	50.6	-1.7
Average of the Ped Condition															
Day	54.5	54.3	0.2	54.2	55.9	-1.7	52.2	53.7	-1.5	52.3	54.7	-2.4	53.3	54.7	-1.4
Night	50.9	51.3	-0.4	51.3	52.1	-0.8	49.6	51.6	-2.0	45.5	50.3	-4.8	49.3	51.3	-2.0

Table entries are in miles per hour

Table 22. Speeds at the Upstream Position—Limited-Access Highway

Pedestrian Condition \ Vehicle Condition	Bare Vehicle			Four-Way Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	57.3	56.8	0.5	58.9	57.1	1.8	53.8	53.9	-0.1	55.6	55.3	0.3	56.4	55.8	0.6
Night	56.0	57.1	-1.1	55.1	56.4	-1.3	52.8	55.1	-2.3	52.7	55.3	-2.6	54.2	56.0	-1.8
Gray Ped															
Day	55.0	56.0	-1.0	54.9	54.9	0.0	54.5	55.3	-0.8	56.1	57.7	-1.6	55.1	56.2	-1.1
Night	54.4	56.6	-2.2	55.1	56.3	-1.2	55.9	55.4	0.5	53.5	55.2	-1.7	54.7	55.9	-1.2
Ped w/Sash															
Day	53.3	54.1	-0.8	53.6	55.0	-1.4	54.8	56.0	-1.2	53.4	55.8	-2.4	53.8	55.3	-1.5
Night	55.8	55.9	-0.1	55.8	56.8	-1.0	52.3	56.1	-3.8	48.5	55.3	-6.8	53.1	56.0	-2.9
Ped w/Vest															
Day	55.5	55.4	0.1	56.2	58.8	-2.6	55.9	56.3	-0.4	53.9	55.1	-1.2	55.4	56.4	-1.0
Night	55.1	55.2	-0.1	56.7	56.0	0.7	53.5	56.8	-3.3	51.2	56.6	-5.4	54.1	56.1	-2.0
Ped w/Coat															
Day	56.7	57.1	-0.4	55.6	55.9	-0.3	54.2	55.0	-0.8	53.2	55.6	-2.4	54.9	55.9	-1.0
Night	56.0	55.3	0.7	54.3	55.2	-0.9	52.4	55.7	-3.3	52.4	55.5	-3.1	53.8	55.5	-1.7
Average of the Ped Conditions															
Day	55.6	55.9	-0.3	55.8	56.4	-0.6	54.6	55.3	-0.7	54.4	55.9	-1.5	55.1	55.9	-0.8
Night	55.5	56.1	-0.6	55.4	56.1	-0.7	53.4	55.8	-2.4	51.7	55.6	-3.9	54.0	55.9	-1.9

Table entries are in miles per hour

Table 23. Analysis of Variance of Vehicle Speeds Measured at the Test Vehicle--Limited-Access Highway

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	5.17	2.84**	4	3.04	1.59
Vehicle Conditions	3	9.13	5.02**	3	18.52	9.70**
Test Day	2	2.26	1.24	3	3.44	1.80
Test Order	6	2.91	1.60	4	3.12	1.63
Between Cells Residual	4	2.61	1.43	5	7.82	4.09**
Error	4004	1.82		4279	1.91	

* $p < .05$
** $p < .01$

Table 24. Analysis of Variance of Vehicle Speeds Measured at the Upstream Site--Limited-Access Highway

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	1.79	1.80	4	1.16	1.63
Vehicle Conditions	3	1.66	1.67	3	12.30	17.32**
Test Day	2	0.95	<1	3	1.61	2.27
Test Order	6	0.89	<1	4	2.14	3.01*
Between Cells Residual	4	0.36	<1	5	3.47	4.89**
Error	5607	0.996		6298	0.710	

* $p < .05$
** $p < .01$

Table 25. Mean Comparisons of Daytime Speeds Measured at the Test Vehicle on the Limited-Access Highway

Vehicle Conditions	$\bar{X}$	$\bar{X}$-0.2	$\bar{X}$+1.5	$\bar{X}$+1.7
Fusees and Flashers	-2.4	-2.6*	-0.9*	-0.7*
Flashers	-1.7	-1.9*	-0.2	
Triangles and Flashers	-1.5	-1.7*		
Bare Vehicle	0.2			

Ped Conditions	$\bar{X}$	$\bar{X}$-0.8	$\bar{X}$+1.5	$\bar{X}$+1.6
Gray Ped	-2.9	-3.7*	-1.4*	-1.3*
Ped w/Sash	-1.6	-2.4*	-0.1	
Ped w/Vest	-1.5	-2.3*	—	
Ped w/Coat	-1.5	-2.3*		
No Ped	0.8			

*$p<.05$ with D = .428 for the vehicle conditions and D = .455 for the pedestrian conditions.

Table 26. Mean Comparisons of Nighttime Speeds Measured at the Test Vehicle on the Limited-Access Highway

Vehicle Conditions	$\overline{X}$	$\overline{X}$+0.4	$\overline{X}$+0.8	$\overline{X}$+2.0
Fusees and Flashers	-4.8	-4.4*	-4.0*	-2.8*
Triangles and Flashers	-2.0	-1.6*	1.2*	
Flashers	-0.8	-0.4		
Bare Vehicle	-0.4			

*$p<.05$ with D = .531

Table 27. Mean Comparisons of Nighttime Speeds Measured at the Upstream Location on the Limited-Access Highway

Vehicle Conditions	$\overline{X}$	$\overline{X}$+0.6	$\overline{X}$+0.7	$\overline{X}$+2.4
Fusees and Flashers	-3.9	-3.3*	-3.2*	-1.5*
Triangles and Flashers	-2.4	-1.8*	-1.7*	
Flashers	-0.7	-0.1		
Bare Vehicle	-0.6			

*$p<.05$ with D = .259

Table 28. Percent Change in Mean Speed on the Limited-Access Highway During Daytime

Pedestrian Conditions \ Vehicle Condition	Bare Vehicle	Four-Way Flashers	Triangles and Flashers	Fusees and Flashers
No Ped				
At vehicle	2.1%	3.1%	-0.2%	0.7%
Upstream	0.9	3.2	-0.2	0.5
Gray Ped				
At vehicle	0.2	-6.9*	-3.2	-10.2**
Upstream	-1.8	0.0	-1.4	-2.8
Ped w/Sash				
At vehicle	-1.2	-4.7*	-4.9**	-1.1
Upstream	-1.5	-2.5	-2.1	-4.3*
Ped w/Vest				
At vehicle	0.5	-6.9*	-0.4	-4.0
Upstream	0.2	-4.4*	-0.7	-2.2
Ped w/Coat				
At vehicle	0.2	0.2	-4.7	-6.8**
Upstream	-0.7	-0.5	-1.5	-4.3*

* p <.05
** p <.01

Table entries are in percent. Negative values indicate that the mean speed during the condition was less than during its comparison period.

conditions and the active vehicle conditions. Regarding the vehicle conditions, the results from the two-lane roadway clearly showed that during the daytime the fusees/flashers, triangles/flashers and flasher alone significantly slowed passing traffic with the fusees/flashers having a greater effect than the triangles/flashers which, in turn, had a greater effect than the flashers alone. The comparable results from the limited-access highway are similar expect that the effects produced by the triangles/flashers did not differ from those produced by the flashers alone.

The percent change in mean speeds between each condition and its comparison group during the nighttime is shown in Table 29. It can be seen in the table that neither the bare vehicle nor the four-way flashers produced significant effects across the pedestrian conditions and that in the absence of the pedestrian, none of the vehicle conditions had an effect as measured at the test vehicle, nor when the gray pedestrian condition was employed. Specific tests for interactions showed a significant effect for the pedestrian conspicuity enhancing conditions coupled with the triangles/ flashers, $F_{(1,4279)} = 9.05$, $p < .01$, but not when coupled with the fusees/ flashers. The former outcome is the only instance in the study where a significant interaction of the pedestrian and vehicle conditions was statistically detected.

Overall comparisons of the nighttime vehicle speed data from the two test locations suggest that the vehicle conditions were less effective on the limited-access highway than on the two-lane site. For instance, the triangles/ flashers and fusees/flashers significantly slowed passing traffic on the two-lane road during the no pedestrian and gray pedestrian conditions, but not so on the limited-access highway. Also, the four-way flashers tended to produce effects at night on the two-lane road but did not do so on the limited-access highway. At both locations none of the pedestrian conditions coupled with the bare vehicle significantly slowed nighttime traffic and the pedestrian factors in the basic analyses were not statistically significant. This outcome when contrasted with the significant pedestrian effect on vehicle speeds found during the daytime suggests that at night the pedestrian was not recognizable as such (at least in time to have elicited a measurable speed change).

b) Lateral Placement

Table 30 indicates the mean lateral placement values measured at the test vehicle during each condition and control period along with the difference between means.* The results of the analysis of variance of the difference scores are contained in Table 31. It may be seen here that none of the conditions yielded statistically significant results during the day or at night. In addition, none of the specific tests for interactions yielded statistically significant results.

*Because of technical difficulties related to the long cable lengths involved, it was not possible to reliably record lateral placement at the upstream location.

Table 29. Percent Change in Mean Speed on the Limited-Access Highway at Night

Pedestrian Conditions \ Vehicle Condition	Bare Vehicle	Four-Way Flashers	Triangles and Flashers	Fusees and Flashers
No Ped				
At vehicle	-1.5%	-3.8%	-3.6%	-5.4%
Upstream	-1.9	-2.3	-4.2**	-4.7*
Gray Ped				
At vehicle	-6.0	0.7	4.2	-4.4
Upstream	-3.9	-2.1	0.9	-3.1
Ped w/Sash				
At vehicle	0.9	-0.8	-2.8	-16.6**
Upstream	-0.2	-1.8	-6.8**	-12.3**
Ped w/Vest				
At vehicle	-2.2	-0.8	-9.0**	-12.2**
Upstream	-0.2	1.2	-5.8**	-9.5**
Ped w/Coat				
At vehicle	4.7	-3.1	-6.8**	-7.5
Upstream	1.3	-1.6	-5.9**	-5.6*

* $p < .05$
** $p < .01$

Table entries are in percent. Negative values indicate that the mean speed during the condition was less than during its comparison period.

Table 30. Lateral Placement Passing Test Vehicle--Limited-Access Highway

Vehicle Condition / Pedestrian Condition	Bare Vehicle			Four-Way Flashers			Triangles and Flashers			Fusees and Flashers			Average of the Vehicle Conditions		
	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference	Condition	Bare Vehicle	Difference
No Ped															
Day	79.5	79.3	0.2	75.1	72.8	2.3	64.7	65.0	-0.3	77.9	72.6	5.3	74.3	72.4	1.9
Night	62.5	57.6	4.9	49.8	47.9	1.9	80.0	75.9	4.1	71.7	70.4	1.3	66.0	62.9	3.1
Gray Ped															
Day	72.6	74.0	-1.4	76.2	72.8	3.4	82.4	70.2	12.2	75.8	68.7	7.1	76.8	71.5	5.3
Night	60.8	66.4	-5.6	80.0	74.4	5.6	77.1	67.2	9.9	58.7	56.0	2.7	69.2	66.0	3.2
Ped w/Sash															
Day	68.4	69.4	-1.0	76.4	69.5	6.9	78.3	79.7	-1.4	71.1	68.4	2.7	73.6	71.8	1.8
Night	79.4	79.5	-0.1	63.0	51.9	11.1	69.4	63.0	6.4	82.3	69.9	12.4	73.5	66.0	7.5
Ped w/Vest															
Day	67.6	72.4	-4.8	75.4	70.4	5.0	74.8	70.8	4.0	72.0	68.8	3.2	72.5	70.6	1.9
Night	76.1	73.0	3.1	56.8	55.3	1.5	70.4	67.2	3.2	82.7	80.4	2.3	71.5	69.0	2.5
Ped w/Coat															
Day	79.2	69.3	9.9	73.5	70.3	3.2	69.2	73.9	-4.7	73.1	73.7	-0.6	73.8	71.8	2.0
Night	56.9	64.4	-7.5	76.3	72.2	4.1	84.4	74.4	10.0	73.6	58.2	15.4	72.8	67.3	5.5
Average of the Ped Conditions															
Day	73.5	72.9	0.6	75.3	71.1	4.2	73.9	71.9	2.0	74.0	70.5	3.5	74.2	71.6	2.6
Night	67.1	68.1	-1.0	65.2	60.4	4.8	76.3	69.6	6.7	73.8	67.0	6.8	70.6	66.3	4.3

Table entries are in inches from right side edge of traveled lane

Table 31. Analysis of Variance of Vehicle Lateral Placement Measured at the Test Vehicle—Limited-Access Highway

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Ped Conditions	4	7.56	<1	4	26.88	1.09
Vehicle Conditions	3	7.47	<1	3	48.31	1.96
Test Day	2	29.96	1.42	3	36.18	1.47
Test Order	6	39.11	1.85	4	38.67	1.57
Between Cells Residual	4	3.97	<1	5	11.11	<1
Error	3367	21.16		2984	24.65	

* $p < .05$
** $p < .01$

c) Changing Lanes

On the limited-access highway it was possible for motorists coming upon the test site to change position from the right to the left lane and, therefore, not be measured as they passed the test vehicle. To examine this possible behavior, the proportion of vehicles which provided a speed reading at the upstream location but not at the test vehicle was computed. The results for the various conditions are shown in Table 32.

Analysis of variance of the (arc sine transformed) data yielded the results shown in Table 33. It may be seen here that during the daytime neither the pedestrian nor vehicle conditions produced significantly different lane changing behavior while at night the vehicle conditions did so. Referring to Table 32 it appears that the effect is due primarily to the fusees/ flashers condition, which produced a far greater proportion of lane changing than did the other conditions.

The results from the two-lane site have shown that the fusees/ flashers and triangles/flashers significantly increased the lateral-position of passing vehicles during the day and at night. A similar effect was not found on the limited-access highway, nor did the vehicle conditions influence lane changing behavior at this site during the daytime. However, at night the fusees/flashers did bring about a large increase in the proportion of motorists who moved from the right to the left hand lane of travel before passing the test vehicle.

The basic findings of the field test are recapitulated in Table 34. As indicated, the pedestrian conditions produced effects only during the daytime and only on passing vehicle speeds. Also, the focus of the effect was generally the presence versus the absence of the pedestrian rather than the employment of fluorescent/retroreflective materials.

The vehicle conditions brought about speed and lateral-position changes on the two-lane road during the day and at night and speed changes, day and night, on the limited-access highway. In addition, the vehicle conditions produced increased lane changing behavior at night on the limited-access roadway. Within the vehicle conditions, the significant effects were as shown in Table 35.

Table 32. Percentage of Vehicles Changing Lanes

Vehicle Cond. / Ped Cond.	Bare Vehicle	Four-Way Flashers	Triangles & Flashers	Fusees & Flashers	Total All Vehicle Conditions
No Ped					
Day	3.03%	5.84%	3.33%	4.20%	4.12%
Night	4.05	12.66	7.58	24.32	10.24
Gray Ped					
Day	1.04	12.50	10.53	19.64	9.24
Night	18.48	7.25	4.23	32.32	13.80
Ped w/Sash					
Day	7.55	2.99	7.66	10.71	7.30
Night	0	1.85	17.44	51.02	12.61
Ped w/Vest					
Day	4.42	9.94	10.91	8.40	8.33
Night	9.50	8.66	14.84	56.52	16.79
Ped w/Coat					
Day	6.13	2.16	15.25	6.34	7.12
Night	5.74	3.50	9.95	32.69	9.45
Total All Ped Conditions					
Day	4.09	6.34	9.37	9.65	7.21
Night	6.81	6.52	10.16	39.80	12.60

Table 33. Analysis of Variance of the Proportions of Vehicles Changing Lanes

Source	Daytime			Nighttime		
	d.f.	MS	F	d.f.	MS	F
Pedestrian Conditions	4	22.73	< 1	4	48.14	< 1
Vehicle Conditions	3	42.18	1.75	3	687.42	13.08**
Error	12	24.11		12	52.56	
**p < .01						

Table 34. Findings of Field Test

	Two-Lane Road		Limited-Access Highway	
	Daytime	Nighttime	Daytime	Nighttime
Pedestrian Conditions	8.8% Speed Reduction No Lateral Position Effects	No Effects	3.4% Speed Reduction No Lateral Position or Lane Changing Effects	No Effects
Vehicle Conditions	8.7% Speed Reduction 10.6% Greater Lateral Separation	14.4% Speed Reduction 16.6% Greater Lateral Separation	3.4% Speed Reduction No Lateral Position or Lane Changing Effects	4.9% Speed Reduction 12.0% More Vehicles Changing Lanes No Lateral Position Effects

Percentage entries are averages over the four conditions where the pedestrian was present and the three active vehicle conditions. Noted changes are from the baseline of the bare vehicle.

Table 35. Significant Effects Within Vehicle Conditions

	Two-Lane Road		Limited-Access Highway	
	Daytime	Nighttime	Daytime	Nighttime
Fusees and Flashers	10.8% Speed Reduction 16.7% Greater Lateral Separation	21.4% Speed Reduction 21.8% Greater Lateral Separation	4.4% Speed Reduction No Lateral Position or Lane Changing Effects	9.5% Speed Reduction 33.0% More Vehicles Changing Lanes No Lateral Position Effects
Triangles and Flashers	9.2% Speed Reduction 12.1% Greater Lateral Separation	13.6% Speed Reduction 21.0% Greater Lateral Separation	2.8% Speed Reduction No Lateral Position or Lane Changing Effects	3.9% Speed Reduction No Lateral Position or Lane Changing Effects
Flashers	6.2% Speed Reduction No Lateral Position Effects	8.2% Speed Reduction No Lateral Position Effects	3.0% Speed Reduction No Lateral Position or Lane Changing Effects	No Speed, Lateral Position or Lane Changing Effects

E. Discussion

The major operational elements of the Dismounted Motorist Model Pedestrian Safety Regulation call on disabled motorists to activate their vehicle's four-way flashers, to deploy fusees or warning triangles behind their vehicles and to don fluorescent/retroreflective materials. The purpose of these steps is to alert passing motorists to the scene in a timely manner so that they will adopt courses which will insure safe passage by the site.

The field test of the model regulation set about to systematically study the effectiveness of the elements of the regulation singly and in combination, with a bare (without enhancement) vehicle serving as the baseline against which comparisons were made. Testing was carried out during the day and at night on two road segments which were typical of those on which the dismounted motorist accident type frequently occurs.

The results of the field test clearly show that the deployment of hazard warning devices affects the driving behavior of passing motorists. On the two-lane roadway, the "vehicle conditions" significantly affected both the speed and lateral placement of passing vehicles during the daytime and at night. On the limited-access highway, the speeds of passing vehicles were affected during the day and nighttimes. While no effects were noted on lateral placement, there was evidence that the proportion of vehicles that moved to the far lane just before passing the stopped vehicle (a maneuver unavailable on the two-lane road) was influenced, at least at night.

In terms of the effectiveness of the specific warning devices, the results of the study generally parallel those of other research. That is, the magnitude of the effects of the fusees in conjunction with the four-way flashers tended to be greater than with the triangles and flashers. However, the triangles together with four-way flashers produced effects nearly as large.

The four-way flashers by themselves produced effects on the speeds of passing vehicles during the daytime and nighttime on the two-lane road and during the daytime on the limited-access highway. They showed no improvement over the bare vehicle, however, on lateral placement or on lane changing behavior.

As noted earlier, Knoblauch and Tobey (1980) found that the presence of pedestrians had a significant effect on the speeds of vehicles passing a disabled vehicle during the daytime. The present study confirmed this finding on both the two-lane and limited-access highways. There was little or no evidence, however, that the fluorescent materials used to enhance daytime pedestrian conspicuity had any additional effect. For nighttime conditions, there was no evidence that the pedestrian conditions produced effects even when relatively elaborate retroreflective materials were employed.

During pilot testing for the study, it was found that at night the speeds and lateral placement of vehicles passing the bare vehicle on the two-lane road did not differ significantly from the speeds and lateral placement of drivers passing the bare site (i.e., without the test vehicle in place). On the other hand, placing the test vehicle on the limited-access highway location at night significantly slowed passing traffic and increased its lateral placement.

The two-lane roadway employed in the study was of the type where it would not be unexpected to find vehicles parked off the road surface. It is possible that the bare test vehicle was "categorized" as a safely parked car by passing motorists, with this accounting for the failure of the bare vehicle alone to elicit responses. On limited-access highways, by comparison, a stopped vehicle should elicit some cognitive response other than "safely parked" and, indeed, it was found that motorists adjusted their speeds and position in response to the bare vehicle.

This line of reasoning suggests that motorists extract and interpret information from the roadway environment and respond differentially, according to whether or not a real or potential hazard is identified. An apparently normally parked vehicle that is off the traveled way would not be considered hazardous and would cause no overt driving response (although it might, of course, prompt changes in visual search behavior or in readiness to respond, changes not detectable by remote measurement). Seemingly abnormal situations, on the other hand, would elicit responses because drivers attending to the situations either believed real hazards existed or believed that the situation might change quickly and present real danger.

The fact that the pedestrians during the daytime elicited responses, suggests that their presence significantly changes the information being received by passing drivers. That is, drivers may perceive a potential hazard of a sudden movement by the pedestrian or by other possible but undetected pedestrians at the scene. It is also possible that the responses caused by the warning devices (fusees, etc.) are due in part to their conveying information that people are likely to be in the vicinity.

The failure of the pedestrian conditions to elicit responses at night suggests that the retroreflective materials conveyed no additional information than that produced by reflections from the test vehicle or by the warning devices. That is, the materials returned a visible signal but this signal may not have been interpretable as indicating the presence of pedestrians. The sash and the retroreflective stripes on the vest do not return signals which denote a human form. The design of the coat was intended to convey this information, but it is possible that the design was inadequate for this purpose. Certainly, at the extreme ranges at which the coat was likely detectable, its shape would not have been discernible. Thus, it and the other retroreflective treatments may have appeared similar to the other bright spot sources (e.g., rear vehicle reflectors) in the environment. Also, vehicle rear reflectors, warning triangles and fusees are all brighter light sources than any of the pedestrian garments. Thus, the pedestrian conditions at night may not have prompted recognition of a pedestrian's presence and either been lost in the visual clutter or misinterpreted as part of the already detected and recognized stopped vehicle.

In terms of the elements of the model regulation, it is believed that the present study provides evidence for the safety benefit of the fusees and warning triangles. As already indicated, the fusees tended to elicit greater responses than the triangles. However, the triangles produced significant differences under the same circumstances as the fusees. Fusees have several operational disadvantages. They are, of course, consumable and will burn for only a limited duration (15-30 minutes). There is also a risk of being burned if fusees are not handled properly and the spike or wire bases of some fusees can be a hazard to vehicle tires if not removed. Because they are somewhat dangerous, many drivers may be reluctant to deploy them. Warning triangles are more expensive to acquire initially but will last indefinitely. They are safe and, therefore, are considered more likely to be used than fusees.

The portions of the model regulation dealing with the wearing of fluorescent and retroreflective materials are logically attractive. There is, unfortunately, no strong evidence in the present study that they produce a motorist response in terms of speed or lateral-position. Hence, no evidence of a safety benefit was accumulated. It is possible, nevertheless, that there are some situations in which the use of these materials would be of value. One of these is the case where the pedestrian has left the disabled vehicle and is walking along the roadway in search of aid. The other is where the pedestrian is in a highly vulnerable position working on the disabled vehicle. As described earlier, changing a tire on the left side of a disabled vehicle is the most potentially dangerous position, with a person's body extending three feet or more outward from the side of the vehicle. Depending on the particular type of vehicle involved, shoulder widths of eight to ten feet would be required to just accommodate the vehicle and person changing a left side tire. While some roads will provide this amount of shoulder width, many will not. There are, therefore, frequent likely circumstances when a motorist could not comply with the portion of the model regulation which would prohibit a motorist from having any part of his/her body over the roadway while repairing a disabled vehicle. In such situations, the ideal would be to have the motorist seek assistance rather than attempting the repair. In many cases, it is likely that this would not take place, however. It is possible that the wearing of conspicuous materials would provide a safety margin in this particular situation by generating a signal that there was an object alongside the disabled vehicle. The particular garment would have to be carefully designed, however, as the typical body positions assumed tended to obscure retroreflective materials on sashes and vests from oncoming traffic. This view is speculative, however. As noted, for safety reasons positioning the pedestrian alongside the vehicle could not be carried out in this study.

For most drivers, the experience of passing stopped vehicles on the shoulder of limited-access highways and on the side of other roadways is a fairly common one. During the daytime, stopped vehicles are detectable at considerable distances and at night required rear retroreflectors and shiny metal or glass surfaces appear to return signals that are detectable well in advance of the passage. In these situations, previous research suggests that drivers will adopt paths which will insure safe passage, i.e., will avoid a collision, and will change speed to make the necessary path changes or when there is uncertainty about the amount of course adjustment needed for safety. The fact that the dismounted motorist accident type occurs suggests that there are breakdowns in this normal response situation. The nature of this breakdown may involve several factors. For instance, the level of drivers' attentiveness may vary among individuals and within individuals over time. Also, the demands being placed on motorists by the traffic environment will vary such that the disabled-vehicle situation may be easily dealt with in some instances and not well handled in others. In addition, drivers may be operating under the influence of alcohol or at speeds which reduce the ability to respond to the situation in a timely manner. It is also possible that drivers have adopted paths which will insure clearance by a disabled vehicle but not past pedestrians who are undetectable.

In the field test, the speeds and lateral-positions of passing vehicles were the dependent measures of driver behavior. It should be noted that changes in these measures and possible safety benefits are inferentially rather than directly related. That is, the magnitude of the lateral-position changes elicited were not necessarily great enough to insure safe passage had a pedestrian been placed between the disabled vehicle and the roadway, nor were the speed reductions great enough to insure a safe motorist response had a pedestrian suddenly stepped from in front of the disabled vehicles. By inference, however, it is believed that changes in the dependent measures forecast an accident reduction potential in that they indicate heightened driver attentiveness to the setting and a better speed and position profile from which to respond had the simulated disabled-vehicle situation degraded into a more dangerous one regarding pedestrian location.

The results of the present study suggest that the elements of the regulation concerning the activation of four-way flashers and deployment of fusees or triangles appear sound and, therefore, that the portions of the regulation dealing with these items can be shared with locales and organizations seeking countermeasures for this accident type, and could be promoted in public education materials. Given the findings of the present study, it is recommended that the portions of the regulation dealing with pedestrian conspicuity <u>not</u> be retained as mandatory requirements as there is no basis for justifying these items in cost/benefit terms. These provisions could be included in informational materials as recommended practice on the grounds that their use might enhance general safety awareness by pedestrians at a disabled-vehicle setting or that there are certain pedestrian positions where the materials might produce an effect. It is also possible that future research on pedestrian conspicuity will uncover designs and techniques that would be effective in the disabled-vehicle situation. Should this occur, modification of the regulation to include such practices would, of course, be in order.

In terms of the method of disseminating information on the model regulation, it is recommended that consideration be given to the development and distribution of a brochure containing material on the accident type, the language of the revised regulation and related annotations. The brochure could also contain informational materials on the potential desirability of wearing fluorescent and retroreflective materials in the disabled-vehicle and other pedestrian situations in which enhanced conspicuity appears logically appropriate.

Regarding the hazard warning devices, there are at least two topics which could be usefully examined by future research. The first of these is whether there are alternative designs to the passive warning devices (i.e., the triangles) which would enhance their effectiveness. For example, an arrow shape might be more meaningful than the triangle form. The second area is whether different placements would yield different response levels and whether placements should be varied as a function of roadway geometry (around bends, for example).

The issue of the extent of the accident reductions that would be achieved if the regulation, or portions thereof, were to be adopted should also ultimately be considered. It is believed that the pursuit of this topic must await the adoption and enforcement of the regulation by one or more locales which had accurate "pre-regulation" accident data and the capability to collect data on compliance with the regulation when the accident type occurred.

III. THE ROAD WORKER MODEL REGULATION

A. Background

The Road Worker Model Pedestrian Safety Regulation is one of a set of nine model regulations developed and acceptance tested by Blomberg et al. (1974). Each of these regulations was targeted at specific pedestrian accident types defined in earlier research and for which corrective actions appeared logical based on examination of the predisposing and precipitating factors identified in available accident data.

Accidents to road-workers were described in detail by Snyder and Knoblauch (1971) who indicated that they accounted for approximately two percent of the 2,159 cases they studied. In developing the model regulation, Blomberg et al. (1974) concluded from the available data that the accident situation appeared to be related to the fact that individuals engaged in construction and maintenance activities on or near active roadways encounter special traffic hazards. First, passing motorists do not usually expect to find them on or near the roadway and, second, passing motorists may be distracted by temporary signs, lane drops, construction vehicles, etc. In addition, workers tend to be preoccupied with their tasks to the extent that they may not perceive a potential encounter with a passing vehicle.

The main provisions of the Road Worker Model Regulation are as follows:

- Permits required for all road work sites.
- Drivers to yield to workers and workers to exercise care to avoid sudden movements into the path of a car.
- Workers to wear approved retroreflective and fluorescent materials to be provided by their employers.
- Traffic control devices at road work sites to comply with standards contained in the Manual on Uniform Traffic Control Devices and every work site to have at least one such device or an approved flashing yellow light.

As described in the annotations to the model regulation (See Appendix A), the requirement for permits for all road work sites was included to make traffic authorities aware of these sites so that compliance with the regulation could be enforced. The requirement for employing traffic control devices in compliance with the Manual on Uniform Traffic Control Devices was noted to be a restatement of provisions appearing in the Uniform Vehicle Code and one which is followed by many jurisdictions. The new provisions of the regulation, therefore, were the requirements that motorists specifically yield the right of way to road-workers and that all workers be supplied and wear fluorescent/retroreflective garments. These provisions were adopted to attempt to break the causal chain of events that was assumed to take place in this accident type at the time the model regulation was developed.

The present study had the objective of collecting evidence on the effectiveness of the model regulation. The initially intended approach was to carry out a test of the behavioral and/or accident reduction changes, if any, brought about by the features of the regulation, or by the adoption of the regulation in a cooperating locale.

The first step in the effort was to examine in detail newer pedestrian accident data bases (specifically the rural pedestrian data base of Knoblauch [1976] and the freeway data base of Knoblauch et al. [1976]) to determine how the elements of the regulation might be expected to mitigate the factors involved in Road Worker accidents. This initial analysis suggested that the model regulation, and especially the element of the regulation dealing with enhancing worker conspicuity, was not addressing the correctable factors involved in the majority of accidents.

Because of the small number of relevant accident cases in the rural and freeway data bases, two efforts--one with the State of Florida and one with New York State--were undertaken to retrieve and analyze additional Road Worker accident reports. The purpose of this section is to present the results of these analyses and to discuss their implications for the viability of the model regulation.

B. Accident Analysis

1. Rural and Freeway Data Bases

The initial analysis of Road Worker accidents was done from the rural and freeway pedestrian data bases (Knoblauch [1976], Knoblauch et al. [1976]). The results of this analysis indicated that the Road Worker accident type was, in fact, composed of several different sub-types which differed in terms of predisposing and precipitating factors. The major sub-types identified from the rural and freeway data bases were:

- Vehicle ran off road or through barrier. The pedestrian (worker) is struck when a vehicle left the traveled way or the vehicle ran through construction barriers, traffic cones, etc., and hit the worker.
- Flagman struck. A worker flagging traffic to direct it approaching a construction/maintenance zone is struck.
- Worker Dart Out. A worker suddenly steps into the traveled way, often from behind construction equipment.
- Secondary Impact. A vehicle hits an item related to the construction/maintenance which, in turn, strikes a worker.
- Auto-Auto. There is a multiple vehicle crash with a vehicle involved then hitting a worker.
- Poor driver path prediction. Driver has worker in view but predicts path of vehicle travel poorly in relation to safe passage past worker. A common example is a worker being hit by right hand mirror on a truck or a van.

- Poor worker conspicuity--worker in traveled way not detected by driver. Worker position (e.g., kneeling), background, driver search load due to construction contribute to poor conspicuity.

The 33 relevant accidents in the rural and freeway data bases were classified into these sub-types as follows:

o Vehicle ran off road or through barrier, vehicle backing, unusual	33 percent
o Flagman struck	21 percent
o Worker dart-out	18 percent
o Secondary impact and auto-auto crash	12 percent
o Poor driver path prediction	9 percent
o Poor worker conspicuity	6 percent

The results suggest that worker conspicuity was an obvious issue in only a small percentage of these accidents. It can be seen, for example, that two categories in which the accidents began with various aberrant actions by the motorist and his vehicle (running off the road or through a barrier and the secondary impact and auto-auto crashes) accounted for 45 percent of the cases. Also of interest is the frequency with which flagmen are the victims. This is so as an Occupational Safety and Health Administration Standard (Part 1926.201 of Title 29 of the Code of Federal Regulations) requires that flagmen be provided and wear red or orange warning garments during the day and reflectorized garments at night. Furthermore, by the nature of their task, flagmen are using devices presumed to aid conspicuity (a flag, baton, sign, etc.) to attract the attention of motorists. Thus, although the flagman is often more exposed to traffic than other workers, he is also presumably more likely to be conspicuous.

2. Florida and New York State Data

Because of the relatively small number of cases in the rural and freeway data bases, additional data collection and analysis efforts were carried out with the cooperation of the Motor Vehicle Departments in the States of Florida and New York. In each case the procedures followed were the same. These involved a computer search of accident records over multi-year periods to identify all reported pedestrian injury accidents were the pedestrians' actions were coded as "Working in Roadway." The hardcopy accident reports were then obtained and reviewed.

Regarding the Florida data, the period searched covered the four year period from January 1974 to December 1977. In the computer search, 204 accidents were identified as indicating the pedestrian was working in the roadway. Upon examination of the actual accident reports, however, 96 of these were eliminated because they did not involve construction/maintenance activities (most commonly police officers, sanitation workers, etc. were involved). Thus, 108 Florida reports were included in the analysis.

In New York the search covered the 30-month period from June 1975 to December 1977. In all 840 accidents were identified as indicating that the pedestrian was working in the roadway. However, on examination of the hardcopy accident reports, 464 were eliminated as involving other than Road Workers and 194 were eliminated because they did not contain enough information to determine if a Road Worker was involved. Thus, 182 New York cases were available for analysis. The results for Florida and New York are shown in Table 36.

It may be seen in the table that two additional sub-types were added to the classification framework. These were: 1) where a worker was hit by a construction vehicle, and 2) where persons engaged in surveying were struck. The figures in the table show that there was a high degree of correspondence between the Florida and New York distributions. The results indicate that worker conspicuity was a factor in only a small percentage of these accidents. The category "Secondary Impact and Auto-Auto" includes cases where vehicles hit objects (usually involved in the construction or maintenance) which, in turn, hit workers and where two vehicles were in a collision and, in turn, a worker was struck. This category, plus the cases where a vehicle ran off the road or through construction barriers and hit a worker accounted for approximately 30 percent of all cases.

The second major category--in which a flagman was struck--accounted for 17-18 percent of the cases. Examination of the details of these accidents showed they occasionally occurred because the flagman stepped in the way of on-coming traffic. In most instances, however, driver distraction and overload appear to have been the major factors involved.

Overall, the data suggest that even if the model regulation was fully effective it would be expected to impact only those accidents where workers darted out, those involving poor worker conspicuity and perhaps those where surveyors were struck, with this impact accounting for about 25 percent of worker accidents and about one quarter of one percent of all pedestrian accidents.

C. Discussion

Among the elements of the model regulation, only the item regarding all workers wearing conspicuous materials could be considered a new practice or requirement.* Given the findings of the accident analysis just described, it does not appear that this element can be justified as having a significant accident reduction potential.

Regarding the other elements of the model regulation, compliance with the features of the Manual on Uniform Traffic Control Devices is being pursued by the Federal Highway Administration. In addition, this agency through a project entitled, "Traffic Management in Construction and Maintenance Zones," has sponsored laboratory and field studies to seek effective methods for controlling and directing traffic in and through construction and maintenance zones. Analysis such as that by Graham et al. (1977) have shown that vehicular accident levels tended to increase at construction and maintenance

*This practice is already common among utilities and some highway departments. The requirement for motorists to yield to workers in a sense is also a new practice; however, yielding to pedestrians is a general legal requirement.

Table 36. Factors in Road Worker Accidents

Factor	Percent of Cases Florida (N=108)	New York (N=182)
Secondary impact and auto-auto	25%	24%
Vehicle ran off road or through barrier	6	6
Poor path prediction by driver	9	5
Worker hit by construction vehicle	8	5
Flagman struck	17	18
Surveyor struck	6	2
Worker dart-out	11	8
Poor worker conspicuity	8	15
Other	3	3
Not classifiable	7	13

sites. These authors studied work site motor vehicle accidents in seven states and reported their frequency increased overall by 6.8 percent compared to comparable time periods prior to the start of construction/maintenance. Interestingly, Graham et al. do not discuss any Road Worker accidents nor do their data from case studies of 122 accidents indicate that any occurred (Graham in a personal communication has indicated these would have been included if they had occurred).

Results such as these suggest that the Road Worker pedestrian accident is a rare event compared to the frequency of other motor vehicle accidents in construction and maintenance zones. Also, the data from Florida and New York indicate that steps to reduce vehicle accidents in construction/maintenance zones may also reduce worker accidents (i.e., those where workers were hit following auto-auto crashes, where vehicles hit objects which, in turn, hit workers, etc.).

The Road Worker accident type represents a small percentage of all pedestrian accidents and is itself composed of several sub-types with differing predisposing and precipitating factors. The nature of these sub-types is such that even if the model regulation was fully effective, the expectation is that it would impact only about one-quarter of road-worker accidents (or approximately one-half of one percent of all pedestrian accidents). It is believed that rather than pursuing the model regulatory approach with its limited potential payoff, on-going efforts to reduce the vehicle crash problem in construction and maintenance zones, such as fostering compliance with the Manual on Uniform Traffic Control Devices, should be encouraged. A reduction in the frequency of these vehicular crashes would be desirable in itself and also would be expected to reduce worker injuries stemming from these accidents. In addition, it is recommended that future attention be directed toward encouraging: 1) practices at construction and maintenance sites which minimize worker exposure to secondary impacts; and 2) use of adequate physical barriers to prevent vehicles from entering work areas and which would discourage worker dart-out behavior. Also, developing and encouraging training and other steps to enhance the safety of flagging activities, such as employing flags made of fluorescent material, appear desirable.

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APPENDIX A
Language and Annotation of the Model Regulations

MODEL FREEWAY STOP LAW

§ 1--Stopping prohibited

A driver shall not stop, stand, park or leave a vehicle on any controlled-access highway.

§ 2--Exceptions to stopping prohibition

Section 1 shall not apply in areas where stopping is permitted by official traffic control devices nor when any stop is necessary:

1) To avoid conflict with other traffic;
2) To comply with a law;
3) To comply with the directions of a police officer or official traffic control device;
4) To perform authorized duties or engage in the construction, maintenance or repair of the highway; or
5) Because the vehicle has become disabled in such manner and to such extent that it is impossible to avoid stopping and temporarily leaving the vehicle on the highway.

§ 3--Disabled vehicle to be placed off the roadway

The driver of a disabled vehicle shall, when practicable, place the vehicle as far off the roadway as possible.

§ 4--Driver of stopped vehicle to actuate four-way flashers

(a) The driver of every passenger car stopped on a controlled-access highway shall actuate four-way flashers meeting the requirements of (a state law comparable to section 12-220 of the Uniform Vehicle Code). Such flashers shall be continuously displayed until the vehicle resumes motion or is removed from the highway.

(b) Subsection (a) shall not apply if the vehicle is not equipped with such flashers, when the vehicle is stopped in an area where such stopping is allowed by official traffic control devices, nor when another vehicle stopped within 30 feet to the rear of the driver's vehicle is displaying its four-way flashers.

§ 5--Conspicuous materials required; use of

(a) After (January 1, 1976), every motor vehicle operated on a controlled-access highway shall have fluorescent and retroreflective materials approved by the (department of motor vehicles) for use by occupants who are over five years of age.

(b) After (January 1, 1976), every occupant of a motor vehicle who walks upon a controlled-access highway shall wear fluorescent and retroreflective materials approved by the (department of motor vehicles). This requirement shall not apply to persons under five years of age, persons occupying a vehicle not equipped with such materials, persons who physically cannot comply, nor in emergency situations when compliance would be unreasonable.

(c) From one-half hour after sunset to one-half hour before sunrise, a light visible to approaching drivers may be used instead of wearing the materials required by subsection (b).

§ 6--Disablement warning devices

(a) The driver of a passenger car disabled on a controlled-access roadway or shoulder shall place a flare, fusee, or emergency warning triangle meeting standards approved by the (United States Department of Transportation) (department of motor vehicles) approximately 100-200 feet to the rear of the vehicle and within its width.

(b) Any person complying with subsection (a) shall wear the materials described in section 5 and shall erect the triangle or activate the flare or fusee at the vehicle and carry it in front of him as he walks down the highway.

§ 7--Walking and standing on controlled-access highways

(a) A person shall not walk or stand upon a controlled-access highway except when necessary to comply with a law, perform authorized duties, engage in the construction, repair or maintenance of the highway, or to reach or remain in a place of safety.

(b) Occupants of a disabled vehicle may walk on the highway to comply with this law or to summon assistance.

(c) Persons allowed or required by this law to walk on controlled-access highways shall walk as far away from moving traffic as is possible, safe and reasonable.

(d) The occupant of a disabled vehicle shall not stand in the roadway nor shall any part of his body be over the roadway while repairing the disabled vehicle.

ANNOTATION

§ 1--Stopping prohibited

Freeways and other controlled-access highways are characteristized by high vehicle speeds with concomitent reductions in the time drivers have to react to unexpected hazards. A stopped vehicle, with or without visible pedestrians, is certainly unexpected on a freeway. Thus, the backbone of any model regulation dealing with the problem of the dismounted motorist must be a provision such as this one to prohibit the capricious or unnecessary leaving of vehicles on expressways.

§ 2--Exceptions to stopping prohibition

The prohibition of stopping on freeways as stated in section 1 is a good general rule of the road. However, there are obvious circumstances in which such a stop is either mandatory or unavoidable. This section of the model covers these exceptions specifically so that it is absolutely clear that these are the only circumstances under which stopping is legally permitted.

§ 3--Disabled vehicle to be placed off roadway

The lessening of risk is self-evident here. The need for mandating this behavior is borne out by Johnson's study cited earlier, in which he determined that drivers often do not attempt to get their disabled vehicle off the roadway. Even if power is lost abruptly, there is often enough momentum for a vehicle on a freeway to coast off the roadway onto a shoulder or median strip (if one or the other exists and traffic conditions and vehicle velocity permit the maneuver). UVC section 11-1001(a) states virtually the same safety principle by forbidding stopping on the roadway when it is practicable to stop, park or leave a vehicle off the roadway. Many states already have substantially the same provision in their laws and, therefore, need not enact this section unless desirable to do so for completeness of the regulatory package.

§ 4--Driver of stopped vehicle to actuate four-way flashers

(a) UVC section 12-220(a) articulates the purpose of the warning light systems which is for... "warning the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing." Activating this system will enhance the conspicuity of the disabled vehicle as well as transmitting an appropriate message to all drivers in the vicinity of a stopped vehicle. Federal Motor Vehicle Safety Standards (e.g., FMVSS 108) require the installation of four-way flashers on all new passenger cars, but few states require drivers of disabled passenger cars to use them. However, there may be a trend toward mandating their use. "Virginia amended its law to require drivers stopped so as to impede traffic or create a hazard because of an emergency or mechanical breakdown to use four-way flashers." (Traffic Laws Annotated, 1973 Supplement, page 38).

Section 4(a) has been made applicable only to drivers of passenger cars because UVC section 12-408(a) and regulations of the U.S. Bureau of Motor Carrier Safety would require actuation of four-way flashers by drivers of stopped trucks and buses.

(b) It would be unreasonable to hold a motorist in violation of subsection (a) if he is driving a vehicle which is not equipped with flashers. This should become a relatively rare event once the applicable FMVSS 108 is over ten years old. Also, when stopping at a designated "rest stop" or similar area or when the vehicle is "covered" by a police or tow truck or other vehicle displaying flashers, it is not necessary for the stopped driver to actuate his car's emergency flasher system.

§ 5--Conspicuous materials required; use of

Increasing the conspicuity of dismounted pedestrians is a major concern. Johnson (1965) states that two-thirds of all pedestrian accidents on freeways occur during the hours of darkness. The International Road Safety Congress (1966) adopted Resolution No. 3, "Driving in Darkness or Poor Visibility," which in part,

> Emphasizes the particular importance, in conditions of bad visibility, of separating selected types of traffic, such as motor vehicles, cycles and pedestrians; and

> Recommends the use by pedestrians walking at night on unlit or poorly lit roads of reflectorized material on their clothing.

Moreover, the *Fourth International Congress of Traffic Police* (1963) resolved:

> That when they use public highway, pedestrians should be regarded as road users in the same way as cyclists, motorcyclists and drivers and that, in conditions of bad visibility, they should, therefore, be obliged to carry a light or some reflectorized devices in order that they shall be visible to other road users.

Before dismounted pedestrians can wear bright materials, steps must be taken to insure that they are available when needed. Hence, subsection (a) has been included.

However, having the materials available is not enough. They must also be worn. Thus subsection (b) mandates use of these materials except by:

- Youngsters for whom they would be of little value
- Occupants of a vehicle which does not comply with subsection (a)
- Persons who cannot comply physically, e.g., the injured
- People under the pressure of emergencies

Finally, subsection (c) allows a light to replace the reflective materials at night. This permits the use of flashlights and similar lights normally carried by many vehicle operators.

§ 6—Disablement warning devices

Federal Motor Vehicle Safety Standard 125 contains the specifications for a warning triangle itself as well as the recommended procedures for its deployment. Subsection (a), in effect, now mandates the use of the triangle or pyrotechnic devices such as the liquid burning emergency flares covered by SAE Standard J597 (SAE, 1974), by all motorists, regardless of whether these derives are supplied as standard equipment for new vehicles. The requirement in subsection (b) for the individual to wear the conspicuous materials described in section 5 and to carry the assembled or activated warning device in front of him to the place of deployment affords the individual the "protection" of the warning device while in transit to the point of deployment. Once the device is deployed, it will serve as a screen to protect the individual on any return trip to his vehicle. This additional screening is particularly important because the recommended deployment distance in FMVSS 125 (100 feet) has been lengthened to "100-200 feet" in the Model in response to the survey results cited earlier.

§ 7—Walking and standing on controlled-access highway

Johnson (1965) indicates that "persons standing within the freeway right of way constituted 31.9 percent of all freeway pedestrian accidents. In 114 of 132 of these accidents, the pedestrians were on the freeway because their vehicles were disabled, they were involved in a prior accident, or they were working. These people were on the freeway for reasons over which they had no control. Most of them did have control over where they stood, but in 67 of 132 accidents, they stood on the main traveled lanes." Johnson (1965) also reports that "people walking along the freeway comprise only 8.2 percent of freeway pedestrian accidents. It is hard to believe that anyone would walk on the main traveled lanes (assuming a shoulder is available), yet it is done." Finally, Johnson (1965) states that over one-half of the disabled vehicle operators in his study were "working on a vehicle on or near the main traveled lanes..." He goes on to report that "in 17.2 percent of the pedestrian accidents, the victim was working on his vehicle. Apparently a large number of people will work on vehicles when it is obviously unsafe to do so."

Subsections (a) and (d) of this section specifically address these identified behavioral errors. Subsection (a) prohibits capricious walking along the highway. Subsection (d) prohibits repairing of a vehicle if the pedestrian must stand in the roadway (traveled lane). Subsection (b) acknowledges that walking is sometimes necessary (e.g., to deploy a warning device required in section 6 (a) and permits it in these circumstances. However, such walking is to be guided by the tenets of subsection (c) which requires pedestrians to walk as far from moving traffic as possible. This is a basic rule of the road and may be found, for example, in UVC section 11-506(b).

MODEL ROAD WORK SITE LAW

§ 1--Definitions

(a) Road worker site--any place on a highway where construction, maintenance or repair requires workers, vehicles or equipment to be in the roadway or on an adjacent shoulder.

(b) Worker--any pedestrian officially engaged in work or its supervision or inspection at a road work site.

§ 2--Permits for road work sites required

(a) No person, firm, association, corporation or governmental agency shall engage in construction, maintenance or repair work on any highway without securing written permission of the (State highway commission) (city traffic engineer) except in an emergency of such nature that securing a permit is not consistent with preservation of life or property.

(b) The (State highway commission) (city traffic engineer) is authorized to inspect any road work site and to order it closed if traffic-control devices do not comply with section 5 or workers do not wear materials complying with section 4.

§ 3--Driver must yield to road workers

(a) The driver of a vehicle shall yield the right of way to any worker in a road work site indicated by official traffic control devices.

(b) The driver of a vehicle shall yield the right of way to any authorized vehicle or worker obviously and actually engaged in work upon a highway whenever such vehicle or pedestrian displays at least one flashing, oscillating or rotating yellow light visible at 500 feet in normal sunlight approved by the (State highway commission).

(c) No worker shall suddenly leave a place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard.

§ 4--Workers to wear conspicuous materials

(a) Every worker shall at all times wear retroreflective and fluourescent materials complying with standards approved by the (State highway commission) (city traffic engineer).

(b) The (State highway commission) (city department shall adopt standards for materials to be worn by workers (and shall approve items for their use). (These standards shall, as a minimum, specify values for the following properties for materials, whether wet or dry:

(1) Fluourescent material area, color and luminance requirements.
(2) Retroreflective material color specification.
(3) Retroreflective material reflectivity specification in total candlepower per incident foot candle as a function of observation angle and entrance angle for all entrance angles, 0-360°.
(4) Flexibility, durability and longevity.

(c) A person employing a worker shall provide the worker with materials specified herein and shall require the worker to wear them at all times.

§ 5--Traffic control devices or flashing lights to warn motorists

(a) Every traffic control device used to indicate a road work site shall conform with the design, use and visibility requirements of the most recent edition of the Manual on Uniform Traffic Control Devices (or specifications issued or endorsed by the State highway commission).

(b) At least one such device or an approved flashing yellow light shall be used to warn motorists of any work on a highway.

§ 6--Regulations authorized

The (State highway commission) (city traffic engineer) is authorized to adopt regulations necessary to implement this law, including but not limited to, procedures for securing permits, standards for materials to be worn by workers, and regulations governing installation, condition and visibility of traffic control devices.

ANNOTATION

§ 1--Definitions

The definition of road work site utilizes the definitions of "highway" and "roadway" from the Uniform Vehicle Code (UVC) and includes any work taking place in, on or over the "roadway" or the "shoulder." The definition of worker is intended to encompass those pedestrians whose primary involvement is with road work site activities, as distinct from the general population of passerby pedestrians.

§ 2--Permits for road work sites required

Subsection (a) is felt to be essential in that it specifically obligates any road work site operator to come under the scrutiny of the traffic authority via the permit system before the work site may be opened. Implicit in this regulation is that any road work site operator would, in the application for this permit, state his plans for operation (e.g., nature of work to be performed, days and hours of work site operation, personnel and equipment to be employed, traffic control devices to be used to protect the site, etc.). Approval of these plans by the traffic engineering authority would be manifest in the granting of the permit to open the work site.

While law enforcement is traditionally a police function, compliance with the guidelines of the Manual on Uniform Traffic Control Devices or its jurisdictional equivalent is probably best supervised by the traffic authority which has specific experience and training in the use of traffic control devices. Thus, subsection (b) provides the traffic authority with the necessary power to assume responsibility for the enforcement of sections 4 and 5 of the regulation. This would not, however, preclude any shared enforcement roles by the traffic authority and police.

§ 3--Drivers must yield to road workers

Subsections (a) and (b) are patterned after UVC section 11-406. Since these requirements were added to the UVC in 1971, they have not been widely adopted by the states as yet. The requirement for drivers to yield to workers in subsection (a) puts drivers on notice to be particularly attentive to worker movements in work sites. It is traditional for rules of the road to reflect an order of precedence for all road users. This provision accomplishes this by giving the right of way to the worker. Subsection (b) accounts for the situation in which a worker is operating some piece of equipment or small vehicle and is not riding upon it or within it (e.g., pavement marking device, asphalt seaming devices, lawn mowers, etc.). In this case the workers are, in effect, a part of a "mobile work site" which may not be amenable to identification with the traffic control device appropriate to fixed work sites. The worker and/or the equipment should, therefore, display at least the yellow warning light required by section 5(b). The 500 feet minimum visibility of the warning device exceeds the dry pavement minimum stopping sight distance for 60 miles per hour on level highways (i.e., 434 feet, Table 2.7, page 30, Traffic Engineering Handbook, 1965).

Subsection (c) is patterned after UVC section 11-502(b) and obligates workers to exercise prudence on or about roadways. It is provided to distribute the burden for worker safety in an equitable manner between the principals—namely, the drivers and workers. Applying the rule against walking into the path of an oncoming motor vehicle to road workers would be a departure from existing rule because UVC section 11-105 and comparable laws in most states make it clear that UVC section 11-502 (b) does not apply to a person working on a highway.

§ 4—Workers to wear conspicuous materials

Subsection (a) is self-explanatory and sets the requirements for workers to wear retroreflective and fluorescent materials at all times. The obvious intent of this measure is to make the worker and his frequently unpredictable movements more apparent to approaching and passing motorists.

The stipulation for performance specifications to be developed for the conspicuous materials by the appropriate jurisdictional authority in subsection (b) is desirable to engender uniform and cost-effective application. The requirements for the materials to function uniformly in wet or dry conditions is stated because some existing retroreflective materials lose much or all of their reflectivity when wet. Since rainy weather with its attendant reduction in normal visibility is particularly hazardous to workers, the retroreflective and fluorescent materials must retain their properties when wet.

Although attempted in the test version of this regulation, no definitive and quantitative performance specifications are provided in this final regulation. Survey results and further thinking on the matter indicated that the structure and content of FMVSS 125 would not be an appropriate design standard for inclusion in this regulation. Categorical guidelines are, however, provided (optional to enact) to structure the development of performance parameters for the conspicuous materials. At this point, it would be fair to say that there are many fluorescent and retroreflective materials currently on the market that can and should be employed immediately (e.g., fluorescent net vests with reflective striping) in lieu of waiting for definitive performance specifications to be developed).

Subsection (c) clearly places the responsibility for the provision of the conspicuous materials on the employer of the worker—the most appropriate party. Moreover, the provision compells the employer to enforce the wearing of these materials by his workers.

§ 5—Traffic control devices or flashing lights to warn motorists

In subsection (a) the MUTCD or a jurisdictional equivalent is specifically given the power of law. The MUTCD, among other things, establishes state-of-the-art practices for traffic control devices to be employed at road work sites, and it is periodically updated to include new and more effective devices and practices. Therefore, adherence to its principles is logically supportable and is already suggested in many jurisdictions. In fact, this section is a restatement of provisions appearing in sections 15-104 to 15-106 of the UVC. States with comparable laws should, therefore, consider whether specific enactment of this section is necessary or a desirable.

Subsection (b) sets a minimum requirement for marking the location of work sites upon the highway. The alternatives specified are at least one conventional traffic control device or one flashing yellow light for work sites.

§ 6--Regulations authorized

This section clearly empowers the appropriate jurisdictional traffic engineering authority to take the necessary steps with regard to the development of permit application granting procedures and the implementation and enforcement of the other provisions of this regulation.

APPENDIX B
Pedestrian Exposure in the Disabled Vehicle Situation

As indicated in the body of this report the majority of the disabled-vehicle related accidents occur along the roadway shoulder or at the edge of the traveled way. Modern limited-access highways are typically designed with 12 foot wide lanes of travel; shoulder widths vary but commonly are eight feet or more. Lane and shoulder widths on other types of roadways tend to be less than on limited-access highways. Secondary roads such as employed in this study and rural highways frequently have only narrow, paved shoulder areas beyond which may or may not lie natural terrain which will permit drivers to stop completely off the traveled way.

Automobiles on American roadways vary in width from approximatley 59 to 80 inches. Thus, to stop a car completely off the traveled way, drivers of subcompact cars require shoulders of at least five feet in width, while the operator of full size vehicles require almost seven foot wide shoulders. As noted earlier, pedestrians struck in the disabled-vehicle related situation commonly were standing by or working on the vehicle. From the basic geometry of the setting the most vulnerable situation occurs when a pedestrian is changing a tire on the left side of a vehicle.

As noted in Appendix A, one of the provisions of the model regulation (§7d) would prohibit motorists from having any part of their body over the roadway while repairing a disabled vehicle. In order to determine how much space is required by individuals when changing tires, a measurement situation was created. Parallel lines one foot apart were laid down next to a parked vehicle. Two individuals--one just over six feet tall and the other approximately five feet seven inches tall--were asked to change a tire on the left side of the vehicle (a full size and a subcompact car were used). The scene was recorded on videotape for subsequent analysis.

When changing the tire, both subjects were most frequently in a squatting position (Figure B-1-A). The distance, number 1 in the figure, was just over 24 inches for the smaller subject and approximately 36 inches for the larger subject. When kneeling (Figure B-1-B) the distance, number 2 in the figure, was over 36 inches for the smaller subject and approximately 42 inches for the larger subject.

A special situation was noted with the subcompact vehicle which had a side jacking position common among many imported vehicles. Here, in order to place the jack in the bracket under the car body, the larger subject adopted a supine position (Figure B-1-C). His total exposure, distance 3 in the figure, exceeded four feet in this position.

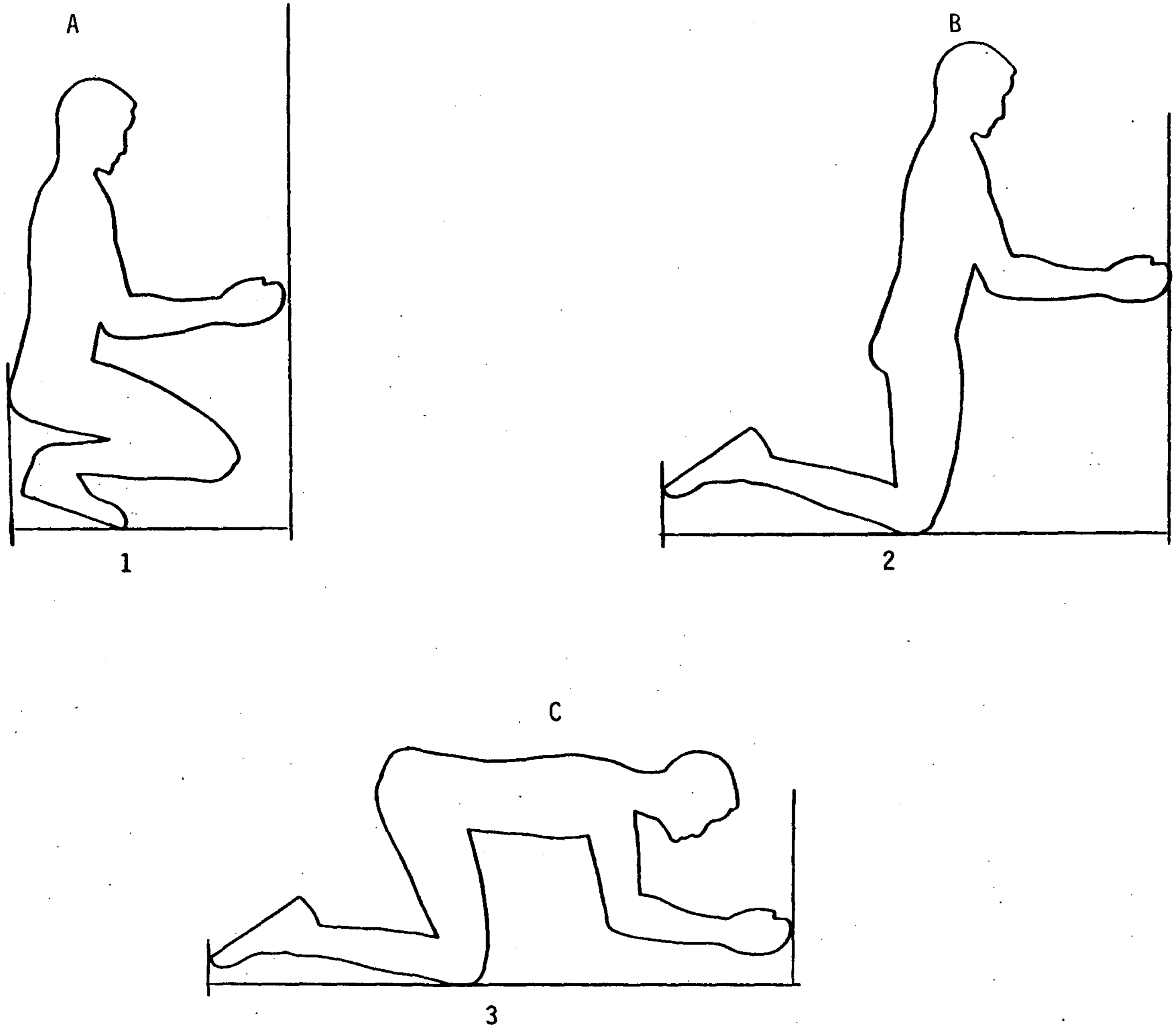
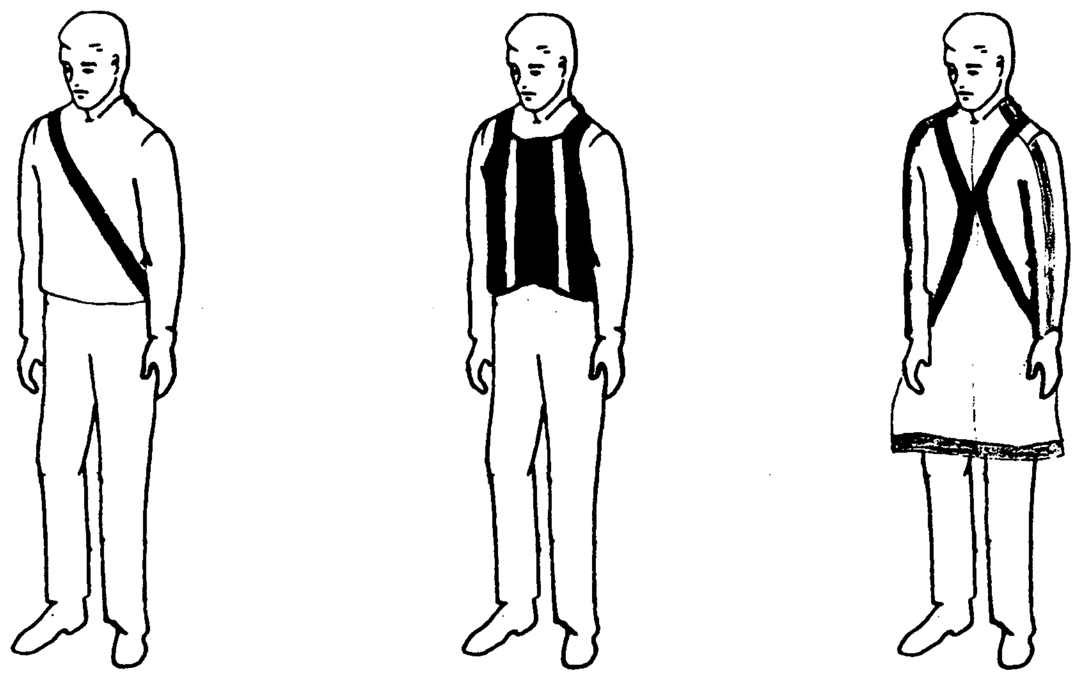


Figure B-1. Body Exposure While Changing a Tire

APPENDIX C.

ILLUSTRATIONS



a) Sash b) Vest c) Coat

Figure C-1. Fluorescent and Retroreflective Materials Used in the Study

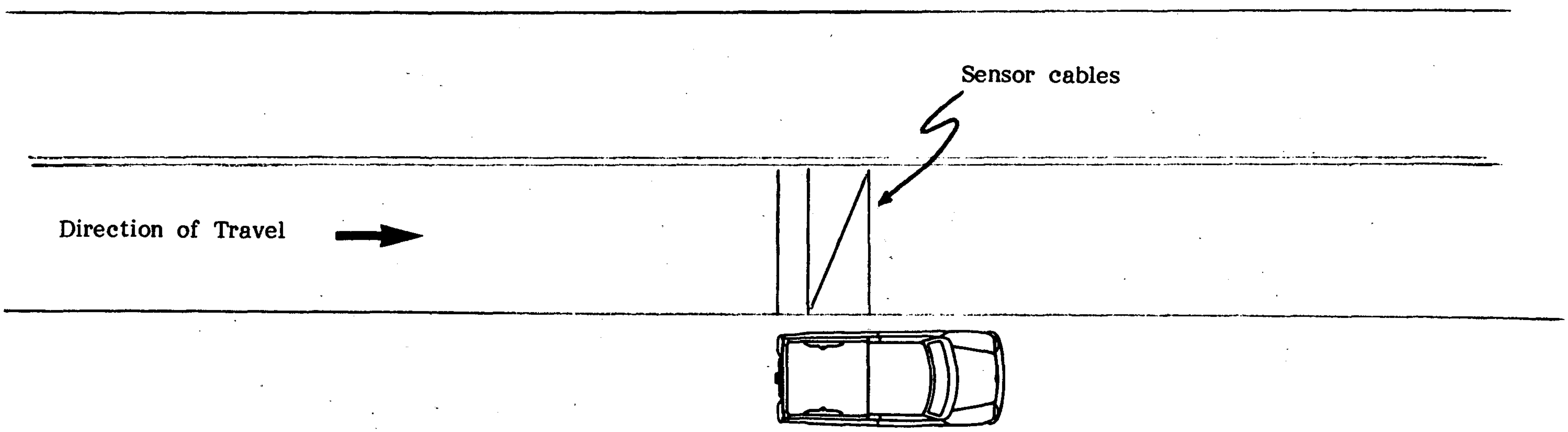


Figure C-2. Typical Test Installation

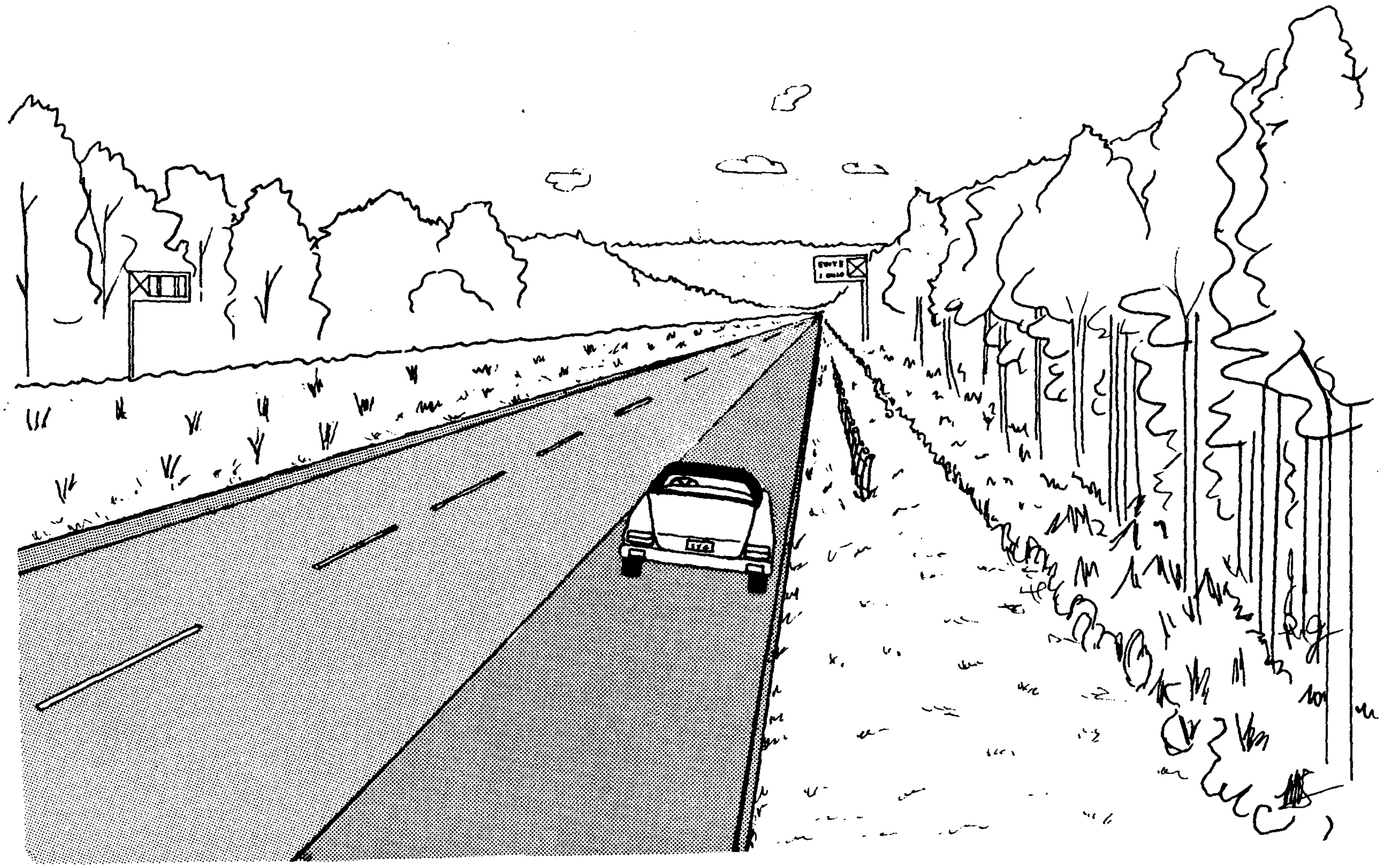


Figure C-3. Artist's Rendition of the Limited-Access Highway Site

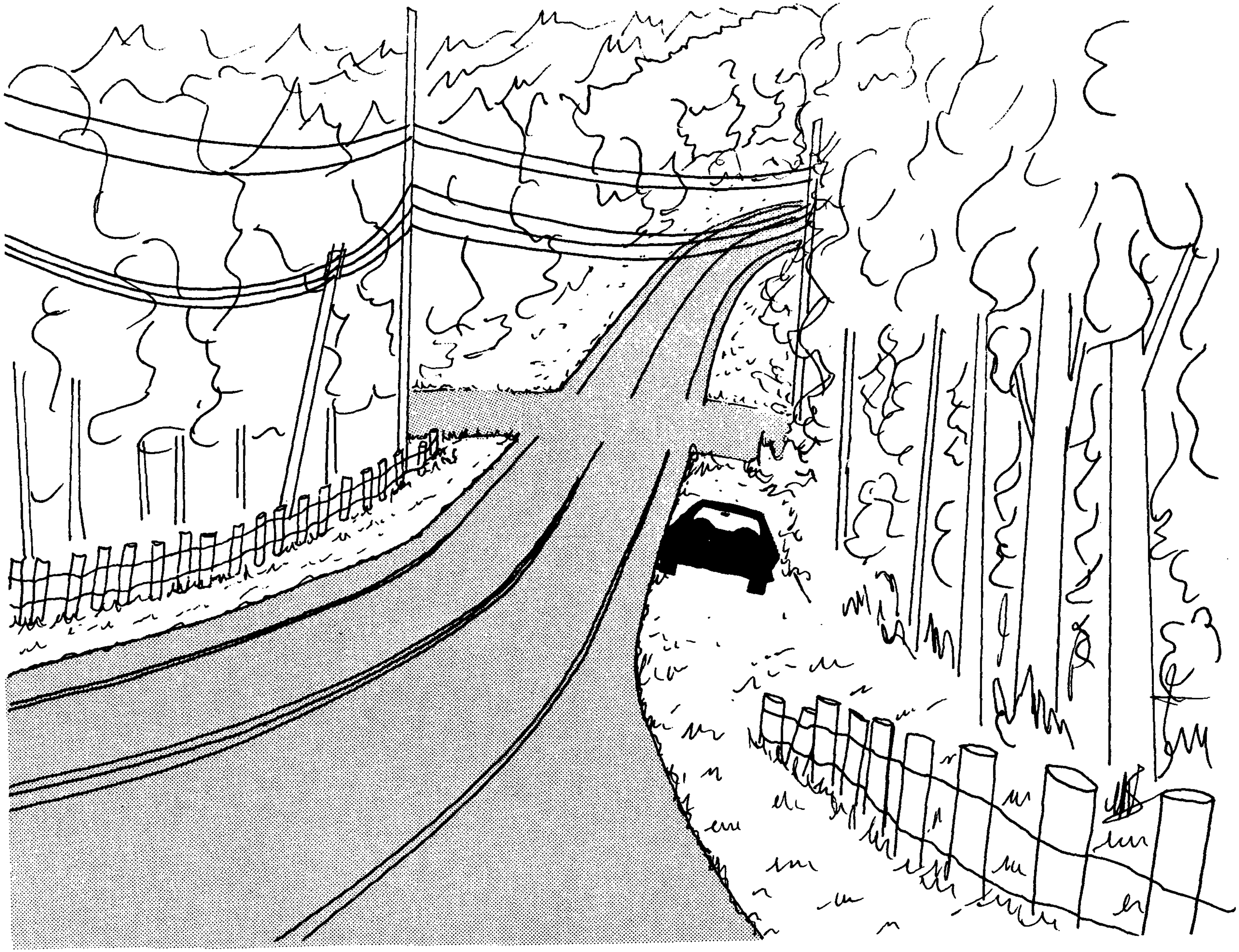


Figure C-4. Artist's Rendition of the Two-Lane Highway Site