DOT HS 803 263

MEASUREMENT OF PEDESTRIAN BEHAVIOR

A Handbook for Identifying the Behaviors to Measure and the Measurement Systems for Use in Countermeasure Evaluation

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16. Abstract

The most direct approach to countermeasure evaluation would involve implementing a countermeasure at selected sites and comparing pre- and post- countermeasure accident rates with those obtained at control sites. However, this approach is inefficient and costly since years of monitoring the relatively low-frequency accident event is likely to be required before sufficient information can be accumulated to permit meaningful conclusions to be reached. In light of this and in line with the goal of determining potential countermeasure effectiveness prior to full-scale or widespread implementation, a supplementary approach to evaluation has been developed. This approach emphasizes the capability of a countermeasure to modify critical pedestrian and driver behaviors presumed to relate to various types of accidents. It was assumed that an assessment of the capability of countermeasures to modify selected critical behaviors would permit conclusions to be drawn regarding the potential effectiveness of the countermeasures for accident reduction.

A categorization of behavioral items was developed which included only search and locomotion behaviors, since these are the only observable events in the crossing situation. There are five parameters of pedestrian searching behavior: object, direction, duration, sequence, and position. These terms refer to, respectively, the pedestrian's object(s) of attention while searching, what direction he looks in (with respect to his direction of movement), how long he looks in each direction,

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16. Abstract (continued)

the sequence of directional searches, and his position when searching (in terms of both distance between pedestrian and curb and between pedestrian and approaching vehicle). There are four parameters of pedestrian locomotion: velocity, acceleration, direction (with respect to the curb), and position (again in terms of both distance between pedestrian and curb and between pedestrian and approaching vehicle). Parameters concerned with driver behavior are essentially equivalent to pedestrian parameters. The five search parameters of object, duration, direction, sequence, and position are exactly parallel for the driver and the pedestrian. Locomotion parameters include vehicle movement characteristics (vehicle path and speed) and driver control characteristics (velocity and direction).

Judgments were made as to which of the behavioral parameters were likely to be significantly impacted upon given the implementation of each of 24 potential countermeasures. These judgments were formulated for each of 11 selected accident types. The result of this procedure was the determination of a set of behaviors which were presumed to be most important to measure for the purpose of evaluating the effectiveness of a countermeasure on a specific accident type.

Eleven measurement systems were evaluated in terms of their cost-effectiveness in measuring each of the behavioral parameters. These systems included direct observation, interview, road tubes, radar, three types of filming systems, and four types of television systems. Effectiveness was assessed along six dimensions. These were validity, reliability, accuracy, ease of implementation, efficiency, and environmental range. A total system effectiveness index was computed as the product of the ratings of a system on each dimension. Five cost components were identified which constituted the total cost of system use. These were purchase price, implementation, maintenance, operation, and data reduction costs. The ratio of system effectiveness to total cost was computed for each system as it applied to the measurement of each of the behavioral parameters. The result was a set of data which can be used to select the most cost-effective measurement system to employ in order to measure a particular behavioral parameter. Further, the methodology and procedures developed can be used to generate cost-effectiveness information for other measurement systems which were not evaluated in the present effort.

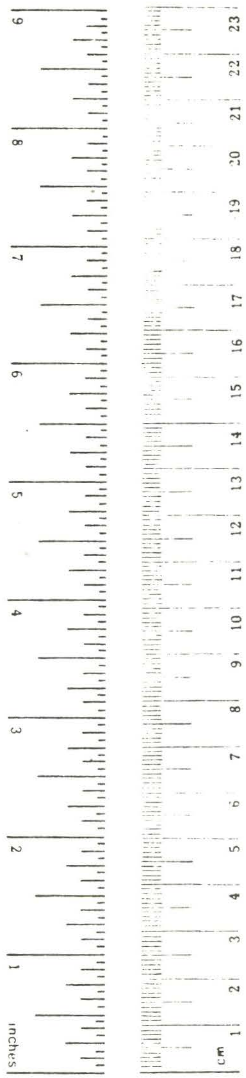
This handbook was prepared in order to guide the user through a series of steps enabling him to identify the critical behaviors to measure for the purpose of evaluating the impact of a particular countermeasure on a particular type of accident and to determine the most cost-effective system to be used for measuring those behaviors.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

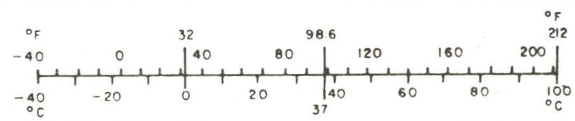
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



ADDENDUM

NHTSA Order 170-2 regarding technical reports (November 5, 1976) indicates that the responsible Associate Administrator or his designee is allowed two weeks for review of the final report and development of an addendum if one is necessary. Because of the current staff shortage, it has not been possible to review this report adequately within the permitted time. Therefore, this report is being published prior to a thorough internal review, and any staff comments will be documented separately.

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INTRODUCTION

As part of its long-range research program aimed at reducing pedestrian and motor vehicle accidents, the National Highway Traffic Safety Administration has been engaged in the development, evaluation, and implementation of countermeasures designed to reduce the incidence of specific pedestrian accident types. Countermeasures have been developed on the basis of a detailed analysis of the predisposing factors and precipitating events associated with various kinds of pedestrian accidents. With respect to countermeasure evaluation, the most direct approach would involve implementing a countermeasure at selected sites and comparing pre- and post-countermeasure accident frequencies with those obtained at control sites. This approach tends to be both time-consuming and costly since years of monitoring the relatively low-frequency accident event may be required before sufficient information can be accumulated to permit meaningful evaluation. In light of this and in line with the goal of determining potential countermeasure effectiveness prior to full-scale or widespread implementation, a supplementary approach to evaluation has been developed. This approach emphasizes the capability of a countermeasure to modify pedestrian or driver behaviors that have been identified as relating to various types of accidents. If countermeasures can be demonstrated to result in changes in these behaviors, it might then be possible to draw inferences regarding the countermeasure's effectiveness for pedestrian accident reduction.

This handbook presents, in concise fashion, recommendations as to specific pedestrian, driver, and vehicle behaviors to be studied and measured in order to assess the effectiveness of each of 24 proposed potential countermeasures as they relate to each of 11 common accident types. Further, the handbook provides information regarding the selection of cost-effective measurement systems to be used for the purpose of behavioral measurement. The handbook is designed for use by both researchers in highway safety and non-technically oriented local traffic safety officials. For the researchers, the handbook contains the methodological detail necessary to stipulate the behaviors which should be studied for any proposed countermeasure which is being considered for possible implementation, and the bases for choosing among alternative measurement systems to be employed in the assessment of those behaviors. For the traffic safety official, the handbook provides a simple means of determining the critical behaviors to be measured for a wide variety of accident by countermeasure situations and the best of several measuring instruments to be used.

The handbook is divided into three major sections. The first, "Specification of Behavioral Parameters," is directed towards the organization of all potentially relevant behavioral items relating to various accident types and countermeasures. The primary purpose is to specify, for all accident type by countermeasure combinations, those parameters of pedestrian, driver, and vehicle behavior which are potentially or actually impacted upon and which could or should be assessed during countermeasure evaluation. First, a conceptual scheme is developed and presented (the Behavioral Classification System) which specifies the universe of measurable behaviors. Next, a set of recommended countermeasures for 11 selected accident types is mapped onto the Behavioral Classification System, thereby specifying the universe of behaviors potentially impacted upon by the countermeasures. Third, the behavioral parameters implicated by the intersection of a particular countermeasure and accident type are further screened in order to determine priorities for measurement. Finally, levels of measurement for each behavioral parameter are discussed.

The second section of the handbook, "Cost-Effectiveness of Measurement Systems," presents a method and the results of the application of that method for the selection of cost-effective systems for the measurement of behavioral parameters. First, components of a cost-effectiveness model are defined. Next, for each of 11 selected measurement systems, figures of merit (FOM) for effectiveness in the measurement of each behavioral parameter are presented, along with the specification of the environmental limitations constraining the use of each system. Cost data are then presented for each system. Finally, cost-effectiveness ratios are provided for each system for each behavioral parameter.

This self-contained section also contains summary statements regarding the use of this handbook and its implications for countermeasure evaluation. Certain potential users of this handbook (e.g., those not particularly concerned about the methodology used to generate the desired information, nor about specific data components of the overall ratings) could go directly to this final section and use the handbook information in a "look-up" fashion. However, such a strategy, while minimizing the time spent in analysis of a particular countermeasure evaluation problem, would also minimize the user's understanding of the particular approach used in this research.

SPECIFICATION OF BEHAVIORAL PARAMETERS

In order to specify the universe of measurable pedestrian, driver, and vehicle behaviors, a hierarchical categorization of behavioral items was developed. Only search and locomotion behaviors are included since these are the only observable events in the crossing situation. Considering the pedestrian first, there are five parameters of searching behavior: object, direction, duration, sequence, and position. These terms refer to, respectively, the pedestrian's object(s) of attention while searching, what direction he looks in (with respect to his direction of movement), how long he looks in each direction, the sequence of directional searches, and his position when searching (in terms of both distance between pedestrian and curb and between pedestrian and approaching vehicle). Next, there are four parameters of pedestrian locomotion: velocity, acceleration, direction (with respect to the curb), and position (again in terms of both distance between pedestrian and curb and between pedestrian and approaching vehicle).

Parameters concerned with driver behavior are essentially equivalent to pedestrian parameters. The five search parameters of object, duration, direction, sequence, and position are exactly parallel for the driver and the pedestrian. Locomotion parameters have been extended to incorporate vehicle movement characteristics (vehicle path and speed) and driver control characteristics of speed and direction.

We believe that these parameters, if complemented by appropriate measures, would provide a complete description of the potentially accident-relevant, observable behaviors emitted during a crossing. Furthermore, these parameters (again if adequately measured) specify behaviors that potentially could be observed every time a pedestrian crossed a street. The hierarchical behavioral classification consists of the nine parameters, five relating to search and four to movement; the pedestrian search and movement behaviors are represented in each of five zones of activity. These five zones are represented for each accident type.

The Behavioral Classification System (BCS)

Table 1 presents behavioral items for 11 accident types according to the structure discussed above. Each accident type is described for both typical accident behavior sequences and for what was judged to be minimally safe behavioral sequences; that is, the "worst" values for each parameter which would still enable the pedestrian to cross the street without a collision. For example, it was judged that a minimally safe value for "Pedestrian search: Direction" at the Parking Lane would be to look left and right. Blank options indicate the judgment that any value for that particular parameter would still enable the pedestrian to cross the street without an accident. Specific entries for the typical accident behavior sequences were derived primarily from Snyder and Knoblauch (1971). In order to fill in particular values for each parameter, some conventional measurement levels have been adopted. Wherever possible, measurement categories used by Snyder and Knoblauch (1971) have been retained. Additional measurement designations will be discussed for each column heading in Table 1 in the following paragraphs. Note that entries under the major column headings labeled PRECURB through TRAFFIC LANE TWO all refer to pedestrian behaviors. Also note that the last column in each location (labeled "MISCELLANEOUS") specifies what the particular non-traffic object of search was.

Table 1. THE BEHAVIORAL CLASSIFICATION SYSTEM

CIRCUMSTANCES

Categories	11. FREEWAY CROSSING	10. WORKING IN ROAD	9. BACKING UP	8. ICE CREAM	7. BUS STOP	6. MULTIPLE THREAT	5. PED HITS VEHICLE	4. TURN/MERGE	3. INTER-SECTION DASH	2. DART OUT$_2$	1. DART OUT$_1$
Location	Midblock	Midblock, intersection	Midblock, intersection	Midblock	Intersection, midblock	Intersection	Intersection	Intersection	Intersection	Midblock	Midblock
Area	Mixed com/res, open	Commercial, residential	Commercial, residential	Residential	Commercial, residential	Commercial	Commercial	Commercial	Commercial, residential	Commercial, residential	Residential
Light Conditions	Day, street lights	Day, S.L., Night (NSL)	Day	Day	Day, street lights	Day	Day	Day, street lights	Day	Day	Day
Age	15–59, 10–14, 60–89	15–59, 5–9	15–59, 60–89	5–9, 0–4, 10–14	15–59, 60–89, 10–14	15–59, 10–14, 60–89	15-59	15-59, 60-89	5-9, 15-59, 10-14	5-9	5-9, 0-4
Time of Day	1–6 p.m., 7–12 p.m.	1–6 p.m., 7–12 a.m	1–6 p.m., 7–12 a.m	1–6 p.m.	1–6 p.m., 6–12 a.m	1–6 p.m., 7–12 a.m.	1-6 p.m.	1-6 p.m., 7-12 a.m.	1-6 p.m., 7-12 a.m.	1-6 p.m.	1-6 p.m.
Pre-Speed	30 +	All	0–9, 10–19	20–29, 30 +, 10–19	0–9, 20–29	20–29, 30 +	0-9	10-19, 0-9	20-29, 30+, 10-19	20-29, 30+, 10-19	20-29, 10-19
Traffic Flow	Normal, congested	Normal, light	All	Normal, light	Normal, congested	Normal, congested	Normal	Normal, congested	Normal, congested	Normal, light	Normal, light
Predisp. Factors											

PRECURB

	11 Safe	11 Typical	10 Safe	10 Typical	9 Safe	9 Typical	8 Safe	8 Typical	7 Safe	7 Typical	6 Safe	6 Typical	5 Safe	5 Typical	4 Safe	4 Typical	3 Safe	3 Typical	2 Safe	2 Typical	1 Safe	1 Typical
Search: DURATION	NO DATA	NO DATA	IRRELEVANT DATA	IRRELEVANT DATA		To Curb		To Curb		To Curb		To Curb	To Curb	To Curb		To Curb		To Curb		To curb		To Curb
Search: Loc (Distance bet. ped-curb / ped-veh)						P C		PC		P C		P C	P C	P C						P C		P C
SEQUENCE						Unknown		Unchanging		Unknown		Unknown	L–R–L	Unknown		Unchanging		Unknown		Unchanging		Unchanging
Locomotion: Pos (Distance bet. ped-curb / ped-veh)						P C		P C		P C		P C	P C	P C		P C		P C		P C		P C
MISCELLANEOUS								*Ice Cream truck		*Bus		*Standing Traffic				*Signal						

CURB

	11 Safe	11 Typical	10 Safe	10 Typical	9 Safe	9 Typical	8 Safe	8 Typical	7 Safe	7 Typical	6 Safe	6 Typical	5 Safe	5 Typical	4 Safe	4 Typical	3 Safe	3 Typical	2 Safe	2 Typical	1 Safe	1 Typical
Search: Dir.															Far							
DURATION	NO DATA	NO DATA	IRRELEVANT DATA	IRRELEVANT DATA	To PL	To PL		To PL	To PL	To PL	To PL	Inadequate	To PL	Inadequate	To PL	Inadequate	To PL	Inadequate		To PL		To PL
SEQUENCE					L–R–L	Unchanging		Unchanging	L-R-L	Unchanging	A–L–R–L	Unknown	L–R–L	Unknown	A-F-L-R-F-L	Unchanging	A-L-R-L	Unchanging		Unchanging		Unchanging
Locomotion: Vel.														Unknown								
MISCELLANEOUS								*Ice Cream Truck		*Bus	*Signal	*Standing traffic			*Signal	*Signal	*Signal					

PARKING LANE

	11 Safe	11 Typical	10 Safe	10 Typical	9 Safe	9 Typical	8 Safe	8 Typical	7 Safe	7 Typical	6 Safe	6 Typical	5 Safe	5 Typical	4 Safe	4 Typical	3 Safe	3 Typical	2 Safe	2 Typical	1 Safe	1 Typical
DURATION	To TL 1	To TL 1	IRRELEVANT DATA	IRRELEVANT DATA	To TL 1	To TL 1	To TL 1	To TL 1	To TL 1	To TL 1	SEE CURB DATA	SEE CURB DATA	SEE CURB DATA	SEE CURB DATA	SEE CURB DATA	SEE CURB DATA	SEE CURB DATA	SEE CURB DATA	To TL 1	Inadequate	To TL 1	Inadequate
Search: Loc	P L	P L			P L	P L	P L	P L	P L	P L									P L	P L	P L	P L
SEQUENCE	Left	Unchanging			L–R–L	Unchanging	L–R–L	Unchanging	L–R–L	Unchanging									L–R–L	Unchanging	L–R–L	Unchanging
Locomotion: Vel.					As appropriate																	
Locomotion: Acc.	Stop				As appropriate		Stop		Stop										Stop		Stop	
Pos	P L	P L			P L	P L	P L	P L	P L	P L									P L	P L	P L	P L
MISCELLANEOUS								*Ice Cream truck		*Bus												

TRAFFIC LANE ONE

	11 Safe	11 Typical	10 Safe	10 Typical	9 Safe	9 Typical	8 Safe	8 Typical	7 Safe	7 Typical	6 Safe	6 Typical	5 Safe	5 Typical	4 Safe	4 Typical	3 Safe	3 Typical	2 Safe	2 Typical	1 Safe	1 Typical
Search: Obj./Dir.				B											Far							
DURATION	To TL 2	To TL 2	As Necessary	Unknown	To TL 2	To TL 2	To TL 2	To TL2	To TL 2	To TL 2	To TL 2	To TL 2	To TL 2	Inadequate	To TL 2	Inadequate	To TL 2	Inadequate	To TL 2	Inadequate	To TL 2	Inadequate
Loc	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	F-L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1
SEQUENCE	Left	Unchanging	As Necessary	None	L–R	Unchanging	L–R	Unchanging	L–R–L	Unchanging	L–R	Unknown	L–R	Unknown	F-L-R-L	Unchanging	L–R	Unchanging	L–R	Unchanging	L–R	Unchanging
Locomotion: Vel.	As appropriate		As appropriate		As appropriate		As appropriate		As appropriate				As appropriate		As appropriate		As appropriate		As appropriate		As appropriate	
Direction			None	None																		
Acc.	As appropriate		As appropriate	None	As appropriate		As appropriate		As appropriate		Stop		As appropriate	In appropriate	As appropriate		As appropriate		As appropriate		As appropriate	
Pos	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1	T L 1
MISCELLANEOUS				* Behind				*Ice Cream truck				*Standing traffic			*Merging Traffic							

TRAFFIC LANE TWO

	11 Safe	11 Typical	10 Safe	10 Typical	9 Safe	9 Typical	8 Safe	8 Typical	7 Safe	7 Typical	6 Safe	6 Typical	5 Safe	5 Typical	4 Safe	4 Typical	3 Safe	3 Typical	2 Safe	2 Typical	1 Safe	1 Typical
DURATION	To Median	To Median	NO DATA	NO DATA	To Curb	To Curb	To Truck	To Truck	To Curb	To Curb	To Curb	To Curb	To Curb	Inadequate	IRRELEVANT DATA	IRRELEVANT DATA	To Curb	Inadequate	To Curb	Inadequate	IRRELEVANT DATA	IRRELEVANT DATA
Loc	T L 2	T L 2			T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2			T L 2	T L 2	T L 2	T L 2		
SEQUENCE	Left	Unchanging			R-L	Unchanging	Right	Unchanging	Right	Unchanging	L–R	Unknown	Right	Unknown			Right	Unchanging	Right	Unchanging		
Locomotion: Vel.					As appropriate		As appropriate		As appropriate		As appropriate		As appropriate				As appropriate		As appropriate			
Acc.	As appropriate				As appropriate		As appropriate		As appropriate		As appropriate		As appropriate	In appropriate			As appropriate		As appropriate			
Pos	T L 2	T L 2			T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2	T L 2			T L 2	T L 2	T L 2	T L 2		
MISCELLANEOUS								*Ice Cream truck				*Standing traffic										

VEHICLE

	11 Safe	11 Typical	10 Safe	10 Typical	9 Safe	9 Typical	8 Safe	8 Typical	7 Safe	7 Typical	6 Safe	6 Typical	5 Safe	5 Typical	4 Safe	4 Typical	3 Safe	3 Typical	2 Safe	2 Typical	1 Safe	1 Typical
Driver Search: Obj.			Pedestrian		Pedestrian		Pedestrian		Pedestrian	Bus / Signal	Pedestrian		Pedestrian				Pedestrian		Pedestrian		Pedestrian	
Driver Search: Dir.					Behind	Behind																
DURATION	Adequate	Inadquate	Adequate	Adequate	Adequate	Constant	Adequate	Inadequate	Adequate	Inadequate	Adequate	Constant	Adequate	Adequate	Adequate	Inadequate	Adequate	Inadequate	Adequate	Inadequate	Adequate	Adequate
Loc (Distance bet. ped-curb / ped-veh)	TL 2	TL 2	TL 1	TL 1	TL 2	TL 2	TL1	TL 1	TL 1	TL 1	TL 2	TL 2	TL 1	TL 1	Corner	Corner	TL 1	TL 1	TL 2	TL 2	TL 1	TL 1
SEQUENCE	As appro	Unknown	As appro	Unchanging	As appro	Unchanging	As appro	Unknown	As appro	Unknown	A-R	Ahead	A-L-R	A–L–R	L–R–L	Unchanging	A–L–R	Unchanging	As appro	Ahead	As appro	Ahead
Driver Control: DIRECTION	Straight	Straight	Straight	Straight	Backing Up	Backing Up	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Turn	Turn	Straight	Straight	Straight	Straight	Straight	Straight
Driver Control: VELOCITY	Constant	Constant	Decelerate	Constant	Constant	Constant	Decelerate	Constant	Constant or Decel	Accelerate	Decelerate	Constant or Accel	All	All	Acc or Dec	Acc or Dec	Constant	Constant	Decelerate	Constant	Constant	Constant
VEHICLE PATH	Straight	Straight	Straight	Straight	Backing Up	Backing Up	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Straight	Turn	Turn	Straight	Straight	Straight	Straight	Straight	Straight
VEHICLE SPEED	30 +	30 +	↓0	All	0–9	0–9	↓0	20–29	0–9	0–9	↓0	20–29	0–9	0–9	0–19	0–19	20 +	20 +	↓0	20 +	10–29	10–29

Pedestrian/Driver Search

1. Object. Three categories were employed: traffic irrelevant, traffic relevant, and non-traffic. These refer to, respectively, vehicles which do not pose a threat to the pedestrian or driver, threatening vehicles, and non-vehicular objects. For the most part, it was not deemed necessary to indicate particular non-traffic objects of search (such as parents or friends). Particular traffic-irrelevant objects have been indicated when they are assumed to be specific predisposing factors. A further designation has been used in the traffic-relevant column, namely a traffic-relevant minus label (-). This was used whenever the data indicated that the pedestrian was searching relevant traffic, but neglected to search for all potential threats.

2. Direction. The simple designations of left, right, and ahead were used for this parameter. These were sufficient to describe the pedestrian/driver behavior except for two circumstances: for the Working in Roadway and Backing Up accident types the category of rearward searches was necessary, and for the Vehicle Turn/Merge accident type, a far-left (i.e., more than 90° search) category was needed.

3. Duration. It is impossible to specify a priori what a desirable duration of search would be. Therefore, we used the following designations: If the data indicated that a pedestrian or driver clearly did not make a sufficient search, the behavior was labeled as inadequate. If there was no clear indication, it was assumed that the search lasted until the next traffic zone.

4. Location. In the absence of more detailed information (e.g., specific distance and/or time measurements), location of search was indicated by traffic zone for distance between pedestrian and curb, and as approaching zero for distance or time between pedestrian and vehicle.

5. Sequence. Conventionally, we have used the designation of "unchanging" whenever the data indicated that pedestrians were looking at a specific object. For several of the minimally safe sequence entries, the particular sequence depends upon which corner of an intersection the pedestrian is starting to cross. Likewise, sequences of search in the traffic lane required assumptions about the direction of oncoming traffic and whether the crossing takes place on a one-way or two-way street.

Pedestrian Locomotion

1. Velocity. While a standard measure of this parameter is feet per second, this datum was not supplied. Running, walking, or stopped as indicators of velocity were sufficient for purposes of

describing accidents in the BCS. A common entry in the minimally safe behavioral descriptions was "as appropriate." We felt that in most circumstances where crossings take place in the presence of traffic, the pedestrian's speed should vary (within limits) as a function of the gap in the oncoming traffic. Naturally, this assumes that the pedestrian can adequately judge the speed of oncoming traffic, the gap size, and the limits of his own speed.

2. Direction. In order to specify a pedestrian's direction of movement, reference must be made to a fixed point. The point of reference used here is the curb. Thus, "forward perpendicular" indicates that the pedestrian was moving forward directly toward or away from the curb. The other symbols (/, ||) are meant to indicate diagonal or parallel movement, respectively.

3. Acceleration. As was the case for velocity, a standard measure (feet/sec^2) was not available; hence, we used the simple classifications of accelerate, decelerate, and constant. Acceleration was never entered at the curb, since acceleration must be considered across a distance.

4. Position. The same conventions were used for these parameter entries as were used for the search-location entries (see 4 above).

Vehicle and Vehicle Control Parameters

1. Driver control of direction. This parameter refers to the driver's control of the steering wheel. The entries in the table reflect the movement of the vehicle; however, if further information was made available concerning more specific direction control malfunctions (e.g., due to vehicle malfunction or driver impairment due to alcohol), it would be entered for this parameter.

2. Driver control-velocity. The driver's control of velocity is determined by how he controls the accelerator and/or brake; hence, the entries are in terms of acceleration measures (acceleration, deceleration, or constant). Again, if further information concerning specific malfunctions were made available, it would be entered appropriately.

3. Vehicle path. This parameter parallels the pedestrian locomotion-direction parameter. The vehicle is moving forward, backward, or turning with reference to a fixed point--in this case, the pedestrian at the curb.

4. Vehicle speed. In this case, specific entries in terms of miles per hour were possible since the data were reported by Snyder and Knoblauch for each accident type.

Elaboration of the BCS

Given the parameter definitions above, Table 1 was completed by filling in behavioral items for each accident type. The net result was the description of an accident, both in terms of the typical behavior (as inferred from accident descriptions) and a judgment as to the minimally safe set of behaviors for that given situation.

In a previous report (Rose, Wheaton, & Levine, 1975) it was suggested that this dual description could serve as an operational definition of "unsafe" behaviors. An unsafe behavior could be defined as a mismatch between the typical accident sequence entry and the corresponding minimally safe entry. For example, consider a portion of Turn-Merge with Attention Conflict. Following the conventions described above, the entries indicate that (as determined by accident descriptions and the judgment of the research staff) in the precurb zone, pedestrians typically are walking forward at a constant speed, looking at the traffic signal and at the traffic directly in their line of sight. There are no "minimally safe" objects of search or direction of search, nor is there any minimally safe velocity or acceleration (our opinion is that the pedestrian could be looking at anything and traveling at any speed and still could avoid an accident). At the curb, the pedestrian typically is still looking at the traffic signal and traffic in front of him; he is running or walking (presumably depending upon the status of the traffic signal). The minimally safe pedestrian, however, should stop at the curb; in addition to a normal left-right-left search sequence, he should search for potential turning vehicles (far left). In terms of the "safe-unsafe" operationalization discussed above, there are "mismatches" for several parameters at the curb: search object, direction, duration, sequence, and locomotion velocity. The remainder of the crossing is described in a similar manner.

Having elaborated each of the 11 accident types, we now turn to the evaluation of a set of countermeasures, using the BCS framework and specific accident descriptions as inputs.

Impact of Countermeasures on Behavioral Parameters

In order to evaluate potential countermeasures prior to their broadscale implementation, the behaviors impacted upon by each countermeasure must be precisely specified. This specification would enable evaluators of countermeasure effectiveness to determine precisely what needs to be measured.

The formalization of the hierarchical behavioral classification system and the specification of typical circumstances involved in each of the 11 accident types shown in Table 1 provided the necessary information to carry out an analysis of the impact of specific countermeasures on each of the accident types. Two such analytic efforts were carried out and are summarized in Tables 2 and 3 below. These tables are multidimensional, the three principal dimensions being countermeasure (of which there are 24), accident type (of which there are 11), and behavioral parameters, which are further classified on the basis of whether or not

Table 2

Behavioral Parameters Impacted Upon by Countermeasures

COUNTERMEASURE	PRECURB									CURB								
	Search					Loco				Search					Loco			
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
STREET PARKING REDEPLOYMENT (Diagonal Parking)																		
1. DART OUT 1	*	*	*		*	*		*		*	*	*		*	*			
2. DART OUT 2	*	*	*		*	*		*		*	*	*		*	*			
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM	*	*	*		*					*	*	*		*	*			
9. BACKING UP										*	*	*		*				
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
PROHIBITION OF ON-STREET PARKING																		
1. DART OUT 1	*	*	*		*	*		*		*	*	*		*	*			
2. DART OUT 2	*	*	*		*	*		*		*	*	*		*	*			
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM	*	*	*		*	*		*		*	*	*		*	*			
9. BACKING UP	*	*	*		*	*		*		*	*	*		*	*			
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
METER POST BARRIER																		
1. DART OUT 1	*	*	*		*	*	*	*		*	*	*		*	*	*		
2. DART OUT 2	*	*	*		*	*	*	*		*	*	*		*	*	*		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM	*	*	*		*	*	*	*		*	*	*		*	*	*		
9. BACKING UP							*											*
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIGNAL RETIMING OR MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH	*	*	*		*	*		*		*	*	*		*	*			
4. TURN MERGE																		
5. PED HITS VEHICLE	*	*	*		*	*		*		*	*	*		*	*			
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2								
	Search					Loco				Search					Loco				Search					Loco			
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
STREET PARKING REDEPLOYMENT (Diagonal Parking)																											
1. DART OUT 1		*	*	*	*		*		*																		
2. DART OUT 2		*	*	*	*		*		*																		
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM		*	*	*	*		*		*																		
9. BACKING UP		*	*	*	*		*		*																		
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
PROHIBITION OF ON-STREET PARKING																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
METER POST BARRIER																											
1. DART OUT 1						*		*	■																		
2. DART OUT 2						*		*	■																		
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM						*		*	■																		
9. BACKING UP									■																		
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
SIGNAL RETIMING OR MODIFICATION																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											

COUNTERMEASURE	DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Obj	Dir	Dur	Loc	Seq				
STREET PARKING REDEPLOYMENT (Diagonal Parking)									
1. DART OUT 1	*	*	*		*	*	*	*	*
2. DART OUT 2	*	*	*		*	*	*	*	*
3. INTERSECTION DASH									
4. TURN MERGE									
5. PED HITS VEHICLE									
6. MULTIPLE THREAT									
7. BUS STOP									
8. ICE CREAM	*	*	*		*	*	*	*	*
9. BACKING UP		*	*		*	*	*	*	*
10. WORKING IN ROAD									
11. FREEWAY CROSSING									
PROHIBITION OF ON-STREET PARKING									
1. DART OUT 1	*		*			■	*	■	*
2. DART OUT 2	*		*			■	*	■	*
3. INTERSECTION DASH									
4. TURN MERGE									
5. PED HITS VEHICLE									
6. MULTIPLE THREAT									
7. BUS STOP									
8. ICE CREAM	*		*			■	*	■	*
9. BACKING UP	*	*	*			*	■	*	■
10. WORKING IN ROAD									
11. FREEWAY CROSSING									
METER POST BARRIER									
1. DART OUT 1									
2. DART OUT 2									
3. INTERSECTION DASH									
4. TURN MERGE									
5. PED HITS VEHICLE									
6. MULTIPLE THREAT									
7. BUS STOP									
8. ICE CREAM									
9. BACKING UP									
10. WORKING IN ROAD									
11. FREEWAY CROSSING									
SIGNAL RETIMING OR MODIFICATION									
1. DART OUT 1									
2. DART OUT 2									
3. INTERSECTION DASH							■		■
4. TURN MERGE							■		■
5. PED HITS VEHICLE							■		■
6. MULTIPLE THREAT							■		■
7. BUS STOP									
8. ICE CREAM									
9. BACKING UP									
10. WORKING IN ROAD									
11. FREEWAY CROSSING									

Table 2

Behavioral Parameters Impacted Upon by Countermeasures (Cont'd)

	PRECURB									CURB									PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco				Search					Loco				Search					Loco				Search					Loco				Obj	Dir	Dur	Loc	Seq				
COUNTERMEASURE	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos									
SPECIFIC DRIVER TRAINING																																																						
1 DART OUT 1																																														*	*	*	*	*		*		*
2 DART OUT 2																																														*	*	*	*	*		*		*
3 INTERSECTION DASH																																														*	*	*	*	*		*		*
4 TURN MERGE																																																						
5 PED HITS VEHICLE																																														*	*	*	*	*		*		*
6 MULTIPLE THREAT																																																						
7 BUS STOP																																																						
8 ICE CREAM																																														*	*	*	*	*		*		*
9 BACKING UP																																																						
10 WORKING IN ROAD																																																						
11 FREEWAY CROSSING																																																						
SIDEWALK PARKS																																																						
1 DART OUT 1	*	*	*		*	*	*	*		*	*	*		*	*	*								*		*	■																											
2 DART OUT 2	*	*	*		*	*	*	*		*	*	*		*	*	*								*		*	■																											
3 INTERSECTION DASH																																																						
4 TURN MERGE																																																							
5 PED HITS VEHICLE																																																						
6 MULTIPLE THREAT																																																						
7 BUS STOP																																																						
8 ICE CREAM	*	*	*		*	*	*	*		*	*	*		*	*	*								*		*	■																											
9 BACKING UP							*											*									■																											
10 WORKING IN ROAD																																																						
11 FREEWAY CROSSING																																																						
SPECIFIC ADULT EDUCATION																																																						
1 DART OUT 1							*											*																																				
2 DART OUT 2							*											*																																				
3 INTERSECTION DASH	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
4 TURN MERGE																																																						
5 PED HITS VEHICLE																																																						
6 MULTIPLE THREAT																																																						
7 BUS STOP																																																						
8 ICE CREAM							*											*																																				
9 BACKING UP																																																						
10 WORKING IN ROAD																																																						
11 FREEWAY CROSSING																																																						
SPECIFIC PRESCHOOL AND PRIMARY GRADE EDUCATION																																																						
1 DART OUT 1							*											*																																				
2 DART OUT 2							*											*																																				
3 INTERSECTION DASH	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
4 TURN MERGE																																																						
5 PED HITS VEHICLE																																																						
6 MULTIPLE THREAT																																																						
7 BUS STOP																																																						
8 ICE CREAM							*											*																																				
9 BACKING UP																																																						
10 WORKING IN ROAD																																																						
11 FREEWAY CROSSING																																																						

Table 2

Behavioral Parameters Impacted Upon by Countermeasures (Cont'd)

COUNTERMEASURE	PRECURB									CURB									PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco				Search					Loco				Search					Loco				Search					Loco												
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
STOP LINE MODIFICATION																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																				■	■	
4. TURN MERGE																																																				■	■	
5. PED HITS VEHICLE																																																				■	■	
6. MULTIPLE THREAT												■	■		✱	✱		■			■	■		✱	✱	✱	■			■	■		■	✱	✱	✱			■	■		✱	✱	✱	✱							■	■	
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
DRIVER PROCEDURES AND TRAFFIC ORDINANCE																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																												■	■	■		■	■		■		■	■	■		■	■		■		✱	✱	✱			✱	✱	✱	✱
7. BUS STOP																																														✱	✱	✱			✱	✱	✱	✱
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
INTERSECTION LIGHTING AND REMOVAL OF VISUAL OBSTRUCTIONS																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
RIGHT TURN ATTENTION CONFLICT REDUCTION																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE										✱	■	✱		✱	✱				✱	■	✱		✱	✱		✱																				✱	✱	✱		✱	✱	✱	✱	■
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						

Table 2

Behavioral Parameters Impacted upon by Countermeasures (Cont'd)

COUNTERMEASURE	PRECURB									CURB									PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco				Search					Loco				Search					Loco				Search					Loco												
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
PREVENTIVE MARKINGS ("Caution")																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH	*	*	*		*	*		*				*		*	*						*		*	*		*				*		*							*		*													
4. TURN MERGE	*	*	*		*	*		*				*		*	*						*		*	*		*				*		*							*		*													
5. PED HITS VEHICLE	*	*	*		*	*		*				*		*	*						*		*	*		*				*		*							*		*													
6. MULTIPLE THREAT	*	*	*		*	*		*				*		*	*						*		*	*		*				*		*							*		*													
7. BUS STOP												*		*	*						*		*	*		*				*		*							*		*													
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
MEDIAN BARRIERS																																																						
1. DART OUT 1	*	*	*			*	*	*		*	*	*			*	*			*	*	*			*	*	*	*						*		*	■											*	*				■		■
2. DART OUT 2	*	*	*			*	*	*		*	*	*			*	*			*	*	*			*	*	*	*						*		*	■						*		*	■		*	*				■		■
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM	*	*	*			*	*	*		*	*	*			*	*			*	*	*			*	*	*	*						*		*	■											*	*				■		■
9. BACKING UP	*	*	*			*	*	*		*	*	*			*	*		*									■									■																		
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
CROSSWALK SETBACKS																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																		■																																				
4. TURN MERGE																		■												*																		*				■		■
5. PED HITS VEHICLE																		■																																				
6. MULTIPLE THREAT																		■																																				
7. BUS STOP																		■																																				
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
MIDBLOCK CROSSWALK																																																						
1. DART OUT 1							*											*	*	*	*		*	*		*	*																					*				*		*
2. DART OUT 2							*											*	*	*	*		*	*		*	*																					*				*		*
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM							*											*	*	*	*		*	*		*	*																					*				*		*
9. BACKING UP							*											*	*	*	*		*	*		*	*																					*				*		*
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																							

Table 2

Behavioral Parameters Impacted Upon by Countermeasures (Cont'd)

COUNTERMEASURE	PRECURB									CURB									PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco				Search					Loco				Search					Loco				Search					Loco												
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
BUS STOP RELOCATION																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP										*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*																				■	■				■		■
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
BACKUP WARNING DEVICES																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP	*	*	*		*	*	*	*		*	*	*		*	*				*	*	*		*	*	*	*		*	*	*		*	*	*	*		*	*	*		*	*	*	*										
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
FREEWAY COUNTERMEASURES																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																									■									■																				
ROADWAY WORKER PROTECTION REQUIREMENTS																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																														*	*	*		*	*	*	*	*
11. FREEWAY CROSSING																																																						

Table 2

Behavioral Parameters Impacted Upon by Countermeasures (Cont'd)

COUNTERMEASURE	PRECURB									CURB									PARK LANE								
	Search					Loco				Search					Loco				Search					Loco			
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
LEFT TURN ATTENTION CONFLICT REDUCTION																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE										*	■	*		*	*				*	■	*		*	*		*	
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
PEDESTRIAN AND DRIVER EDUCATION—LEGAL INTERSECTION CONFLICTS																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE	*	*	*		*					*	*	*		*	*				*	*	*		*	*		*	
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
VEHICLE DESIGN SUN ACCESSORY																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
ICE CREAM TRUCK REGULATION AND WARNING DEVICE																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											

COUNTERMEASURE	TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco												
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
LEFT TURN ATTENTION CONFLICT REDUCTION																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																			*	*	*		*	*	*	*	*
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
PEDESTRIAN AND DRIVER EDUCATION—LEGAL INTERSECTION CONFLICTS																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE	*	*	*		*	*		*		*	*	*		*	*		*		*	*	*		*	*	*	*	*
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
VEHICLE DESIGN SUN ACCESSORY																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																											
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											
ICE CREAM TRUCK REGULATION AND WARNING DEVICE																											
1. DART OUT 1																											
2. DART OUT 2																											
3. INTERSECTION DASH																											
4. TURN MERGE																											
5. PED HITS VEHICLE																											
6. MULTIPLE THREAT																											
7. BUS STOP																											
8. ICE CREAM																			*	*	*		*		*	*	*
9. BACKING UP																											
10. WORKING IN ROAD																											
11. FREEWAY CROSSING																											

the behavior relates to the pedestrian or the driver. For the pedestrian, the nine behavioral parameters are further categorized with respect to search or locomotion and the traffic zone in which the behaviors occur. The parameters of driver behavior are classified into search, vehicle control, and "vehicle behavior" categories.

The first analysis, depicted in Table 2, addressed the following two questions: First, which accident type is each of the countermeasures designed to or likely to have an impact upon? Second, for each of these accident types, which of the behavioral parameters could reasonably be expected to be influenced? Table 2 represents a delineation of all behavioral parameters which, for a given countermeasure and accident type, might be expected to be impacted upon if the countermeasure has any influence. For the purpose of this analysis the specific descriptions given by Snyder and Knoblauch (1971) and the information contained in Table 1 jointly provided operational definitions for the accident types. In addition, the descriptions of the 24 countermeasures considered were taken directly from Snyder and Knoblauch (1971) and Berger (1975). Brief descriptions of each accident type and countermeasure that was evaluated are given in Appendices B and C, respectively.

The analysis proceeded in the following manner. Each countermeasure was considered individually and a detailed understanding of its deployment was obtained from the literature. Both the typical and the safe patterns of behavior (as depicted in Table 1) involved in each of the accidents were then reviewed. Next, judgments were made as to which of the behavioral parameters were likely to be impacted upon by virtue of the selected countermeasure. This procedure was carried out with respect to the pedestrian in each of the five zones of interest and the driver. The analysis' was carried out only for that subset of the 11 accident types which were considered to possibly be impacted upon by the countermeasure. For example, <u>street parking redeployment</u> has a potential impact only on those accident types which take place in mid-block and therefore only dart out first- and second-half, ice cream vendor-related accidents, and accidents involving a vehicle backing up were considered in our behavioral analysis.

Another major consideration in this analysis was the location or zones in which it could be reasonably assumed that the countermeasure would have an impact on behavior. Consider the example of <u>street parking redeployment</u>. We concluded that, if implemented, this countermeasure would be likely to impact on pedestrian behavior in the pre-curb, curb, and park lane zones exclusively. Once a pedestrian was past the traffic boundary, no further behaviors would vary as a function of whether or not parking had been diagonal or parallel. Thus, there are no entries in the first and second traffic lanes for any of the accident types upon which this particular countermeasure was judged to have an impact. In general, we assumed that behaviors in zones beyond those in which the countermeasure was designed to have an impact would be identical whether or not the countermeasure was implemented. Therefore, behaviors taking place in these zones would not be useful as measures of countermeasure effectiveness and thus were not included in our analysis.

The entries in Table 2 are of two general types. Cells containing a star represent those behavioral parameters which we have concluded would be impacted upon by a particular countermeasure for a specific accident type in a positive fashion. These behavioral changes could be expected to lead to a lowered probability of an accident occurring. Other cells contain squares which represent behaviors impacted upon which could have a negative effect. If the countermeasure results in a change of behavior, the new behavior would increase the probability of an accident rather than reduce it. As an example, consider the countermeasure signal retiming or modification. We have indicated that this could influence vehicle speed for four of the accident types. This influence might be to cause the driver to speed up as he approaches an intersection in order to avoid a long red-light delay. If this were the case, there would be a clear negative impact of the countermeasure. The point here is that it is extremely important to consider possible direct negative impacts of behavioral changes and to include them in any assessment of countermeasure effectiveness.

The analytical scheme is broad-based and highly comprehensive, and, as such, could be used to assess the impact upon behaviors of countermeasures in addition to those 24 considered here. New or existing countermeasures could be considered within the analytical framework as long as they were described in sufficient detail.

Relative Importance of Behaviors Influenced by Countermeasures

One obvious conclusion that can be drawn from Table 2 is that there are, for many of the countermeasures, a large number of behavioral parameters that are impacted upon for each of the relevant accident types. In view of this, a second analysis was carried out which is structurally and conceptually identical to that depicted in Table 2. The second analysis addressed the question of which behavioral parameters it would be most important to measure, given the task of evaluating the effectiveness of a particular countermeasure. Specifically, for each countermeasure and each accident type, of the behavioral parameters that are likely to be influenced, which are the most important to concentrate upon as the best indicators of countermeasure effectiveness? Table 3 shows the results of this analysis. Cell entries of concentric circles depict those behavioral parameters which in our judgment are most critical to measure for the purpose of evaluating the effectiveness of the countermeasure on a specific accident type. Circle entries suggest a set of behavioral parameters judged as being of secondary importance. Finally, those behaviors which are likely to be impacted upon by the countermeasure, as shown in Table 2, and for which there is no designation in Table 3, are the subset of behaviors which are relatively unimportant to measure in order to assess the effectiveness of the countermeasure.

In order to stipulate the behaviors to be measured when evaluating a particular countermeasure, Tables 2 and 3 are entered first, by specifying the countermeasure being considered for deployment, and second, by stipulating which of the 11 accident types the countermeasure is intended to impact upon. For the particular countermeasure by accident type combination, the behaviors which could or should be measured are then simply read across the row of the tables.

Table 3

Behavioral Parameters of Greatest Importance for Evaluating Countermeasure Effectiveness

	PRECURB									CURB								
	Search					Loco				Search					Loco			
COUNTERMEASURE	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
STREET PARKING REDEPLOYMENT (Diagonal Parking)																		
1. DART OUT 1						●					●	●			◉			
2. DART OUT 2						●					●	●			◉			
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM						●					●	●			◉			
9. BACKING UP											●	●						
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
PROHIBITION OF ON-STREET PARKING																		
1. DART OUT 1		◉	◉		◉						◉	◉		◉	●			
2. DART OUT 2		◉	◉		◉						◉	◉		◉	●			
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM		◉	◉		◉						◉	◉		◉	●			
9. BACKING UP											◉	◉		◉	●			
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
METER POST BARRIER																		
1. DART OUT 1															●			
2. DART OUT 2															●			
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM															●			
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIGNAL RETIMING OR MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH															◉			
4. TURN MERGE																		
5. PED HITS VEHICLE															◉			
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

	PARK LANE									TRAFFIC LANE 1								
	Search					Loco				Search					Loco			
COUNTERMEASURE	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
STREET PARKING REDEPLOYMENT (Diagonal Parking)																		
1. DART OUT 1		●	●			◉		◉										
2. DART OUT 2		●	●			◉		◉										
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM		●	●			◉		◉										
9. BACKING UP		●	●															
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
PROHIBITION OF ON-STREET PARKING																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
METER POST BARRIER																		
1. DART OUT 1						◉			◉									
2. DART OUT 2						◉			◉									
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM						◉			◉									
9. BACKING UP									◉									
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIGNAL RETIMING OR MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

	TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco												
COUNTERMEASURE	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
STREET PARKING REDEPLOYMENT (Diagonal Parking)																		
1. DART OUT 1																		●
2. DART OUT 2																		●
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		●
9. BACKING UP																		●
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
PROHIBITION OF ON-STREET PARKING																		
1. DART OUT 1												●					◉	◉
2. DART OUT 2												●					◉	◉
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM												●					◉	◉
9. BACKING UP											●							◉
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
METER POST BARRIER																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIGNAL RETIMING OR MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		◉
4. TURN MERGE																		◉
5. PED HITS VEHICLE																		◉
6. MULTIPLE THREAT																		◉
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

Table 3

Behavioral Parameters of Greatest Importance for Evaluating Countermeasure Effectiveness (Cont'd)

COUNTERMEASURE	PRECURB Search Obj	PRECURB Search Dir	PRECURB Search Dur	PRECURB Search Loc	PRECURB Search Seq	PRECURB Loco Vel	PRECURB Loco Dir	PRECURB Loco Acc	PRECURB Loco Pos	CURB Search Obj	CURB Search Dir	CURB Search Dur	CURB Search Loc	CURB Search Seq	CURB Loco Vel	CURB Loco Dir	CURB Loco Acc	CURB Loco Pos
SPECIFIC DRIVER TRAINING																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIDEWALK PARKS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SPECIFIC ADULT EDUCATION																		
1. DART OUT 1							●											◉
2. DART OUT 2							●											◉
3. INTERSECTION DASH											◉			◉	◉			
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM							●											◉
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SPECIFIC PRESCHOOL AND PRIMARY GRADE EDUCATION																		
1. DART OUT 1							●											◉
2. DART OUT 2							●											◉
3. INTERSECTION DASH											◉			◉	◉			
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM							●											◉
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	PARK LANE Search Obj	PARK LANE Search Dir	PARK LANE Search Dur	PARK LANE Search Loc	PARK LANE Search Seq	PARK LANE Loco Vel	PARK LANE Loco Dir	PARK LANE Loco Acc	PARK LANE Loco Pos	TRAFFIC LANE 1 Search Obj	TRAFFIC LANE 1 Search Dir	TRAFFIC LANE 1 Search Dur	TRAFFIC LANE 1 Search Loc	TRAFFIC LANE 1 Search Seq	TRAFFIC LANE 1 Loco Vel	TRAFFIC LANE 1 Loco Dir	TRAFFIC LANE 1 Loco Acc	TRAFFIC LANE 1 Loco Pos
SPECIFIC DRIVER TRAINING																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIDEWALK PARKS																		
1. DART OUT 1						●			◉									
2. DART OUT 2						●			◉									
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM						●			◉									
9. BACKING UP									◉									
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SPECIFIC ADULT EDUCATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH		◉			◉													
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SPECIFIC PRESCHOOL AND PRIMARY GRADE EDUCATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH		◉			◉													
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	TRAFFIC LANE 2 Search Obj	TRAFFIC LANE 2 Search Dir	TRAFFIC LANE 2 Search Dur	TRAFFIC LANE 2 Search Loc	TRAFFIC LANE 2 Search Seq	TRAFFIC LANE 2 Loco Vel	TRAFFIC LANE 2 Loco Dir	TRAFFIC LANE 2 Loco Acc	TRAFFIC LANE 2 Loco Pos	DRIVER SEARCH Obj	DRIVER SEARCH Dir	DRIVER SEARCH Dur	DRIVER SEARCH Loc	DRIVER SEARCH Seq	DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
SPECIFIC DRIVER TRAINING																		
1. DART OUT 1											●	●		●				◉
2. DART OUT 2											●	●		●				◉
3. INTERSECTION DASH											●	●		●				◉
4. TURN MERGE																		
5. PED HITS VEHICLE											●	●		●				◉
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM											●	●		●				◉
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SIDEWALK PARKS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SPECIFIC ADULT EDUCATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
SPECIFIC PRESCHOOL AND PRIMARY GRADE EDUCATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

Table 3

Behavioral Parameters of Greatest Importance for Evaluating Countermeasure Effectiveness (Cont'd)

COUNTERMEASURE	PRECURB									CURB								
	Search					Loco				Search					Loco			
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
STOP LINE MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		◉
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
DRIVER PROCEDURES AND TRAFFIC ORDINANCE																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
INTERSECTION LIGHTING AND REMOVAL OF VISUAL OBSTRUCTIONS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
RIGHT TURN ATTENTION CONFLICT REDUCTION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE											●			●				
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	PARK LANE									TRAFFIC LANE 1								
	Search					Loco				Search					Loco			
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos
STOP LINE MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT			◉						◉									
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
DRIVER PROCEDURES AND TRAFFIC ORDINANCE																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT											●	●			◉		◉	
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
INTERSECTION LIGHTING AND REMOVAL OF VISUAL OBSTRUCTIONS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
RIGHT TURN ATTENTION CONFLICT REDUCTION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE		●			●													
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco												
	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
STOP LINE MODIFICATION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		◉
4. TURN MERGE																		◉
5. PED HITS VEHICLE																		◉
6. MULTIPLE THREAT																		◉
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
DRIVER PROCEDURES AND TRAFFIC ORDINANCE																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT		●	●			◉		◉									◉	◉
7. BUS STOP																	◉	◉
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
INTERSECTION LIGHTING AND REMOVAL OF VISUAL OBSTRUCTIONS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
RIGHT TURN ATTENTION CONFLICT REDUCTION																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE										◉	◉	◉		◉			◉	◉
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

Table 3

Behavioral Parameters of Greatest Importance for Evaluating Countermeasure Effectiveness (Cont'd)

COUNTERMEASURE	PRECURB Search Obj	PRECURB Search Dir	PRECURB Search Dur	PRECURB Search Loc	PRECURB Search Seq	PRECURB Loco Vel	PRECURB Loco Dir	PRECURB Loco Acc	PRECURB Loco Pos	CURB Search Obj	CURB Search Dir	CURB Search Dur	CURB Search Loc	CURB Search Seq	CURB Loco Vel	CURB Loco Dir	CURB Loco Acc	CURB Loco Pos
PREVENTIVE MARKINGS ("Caution")																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH												◉		◉	◉			
4. TURN MERGE												◉		◉	◉			
5. PED HITS VEHICLE												◉		◉	◉			
6. MULTIPLE THREAT												◉		◉	◉			
7. BUS STOP												◉		◉	◉			
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
MEDIAN BARRIERS																		
1. DART OUT 1															●			
2. DART OUT 2															●			
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM															●			
9. BACKING UP															●			
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
CROSSWALK SETBACKS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		◉
4. TURN MERGE																		◉
5. PED HITS VEHICLE																		◉
6. MULTIPLE THREAT																		◉
7. BUS STOP																		◉
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
MIDBLOCK CROSSWALK																		
1. DART OUT 1																		●
2. DART OUT 2																		●
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		●
9. BACKING UP																		●
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	PARK LANE Search Obj	PARK LANE Search Dir	PARK LANE Search Dur	PARK LANE Search Loc	PARK LANE Search Seq	PARK LANE Loco Vel	PARK LANE Loco Dir	PARK LANE Loco Acc	PARK LANE Loco Pos	TRAFFIC LANE 1 Search Obj	TRAFFIC LANE 1 Search Dir	TRAFFIC LANE 1 Search Dur	TRAFFIC LANE 1 Search Loc	TRAFFIC LANE 1 Search Seq	TRAFFIC LANE 1 Loco Vel	TRAFFIC LANE 1 Loco Dir	TRAFFIC LANE 1 Loco Acc	TRAFFIC LANE 1 Loco Pos
PREVENTIVE MARKINGS ("Caution")																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH			◉		◉	◉		◉										
4. TURN MERGE			◉		◉	◉		◉										
5. PED HITS VEHICLE			◉		◉	◉		◉										
6. MULTIPLE THREAT			◉		◉	◉		◉										
7. BUS STOP			◉		◉	◉		◉										
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
MEDIAN BARRIERS																		
1. DART OUT 1						●		●	◉									
2. DART OUT 2						●		●	◉									
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM						●		●	◉									
9. BACKING UP									◉									
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
CROSSWALK SETBACKS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE												●						
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
MIDBLOCK CROSSWALK																		
1. DART OUT 1		●			●													
2. DART OUT 2		●			●													
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM		●			●													
9. BACKING UP		●			●													
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

COUNTERMEASURE	TRAFFIC LANE 2 Search Obj	TRAFFIC LANE 2 Search Dir	TRAFFIC LANE 2 Search Dur	TRAFFIC LANE 2 Search Loc	TRAFFIC LANE 2 Search Seq	TRAFFIC LANE 2 Loco Vel	TRAFFIC LANE 2 Loco Dir	TRAFFIC LANE 2 Loco Acc	TRAFFIC LANE 2 Loco Pos	DRIVER SEARCH Obj	DRIVER SEARCH Dir	DRIVER SEARCH Dur	DRIVER SEARCH Loc	DRIVER SEARCH Seq	DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
PREVENTIVE MARKINGS ("Caution")																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
MEDIAN BARRIERS																		
1. DART OUT 1																		
2. DART OUT 2									◉									
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
CROSSWALK SETBACKS																		
1. DART OUT 1																		
2. DART OUT 2																		
3. INTERSECTION DASH																		
4. TURN MERGE																		◉
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		
9. BACKING UP																		
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		
MIDBLOCK CROSSWALK																		
1. DART OUT 1																		●
2. DART OUT 2																		●
3. INTERSECTION DASH																		
4. TURN MERGE																		
5. PED HITS VEHICLE																		
6. MULTIPLE THREAT																		
7. BUS STOP																		
8. ICE CREAM																		●
9. BACKING UP																		●
10. WORKING IN ROAD																		
11. FREEWAY CROSSING																		

Table 3

Behavioral Parameters of Greatest Importance for Evaluating Countermeasure Effectiveness (Cont'd)

	PRECURB									CURB									PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco				Search					Loco				Search					Loco				Search					Loco												
COUNTERMEASURE	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
BUS STOP RELOCATION																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																		◉			●			●			◉																											●
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
BACKUP WARNING DEVICES																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP											●	●			●					◉	◉			●		●			◉	◉			●		●																			
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
FREEWAY COUNTERMEASURES																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
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6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																											◉									◉																		
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2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
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6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																													●	●	●					◉	◉
11. FREEWAY CROSSING																																																						

Table 3

Behavioral Parameters of Greatest Importance for Evaluating Countermeasure Effectiveness (Cont'd)

	PRECURB									CURB									PARK LANE									TRAFFIC LANE 1									TRAFFIC LANE 2									DRIVER SEARCH					DIR CONT	SPEED CONT	VEH PATH	VEH SPEED
	Search					Loco				Search					Loco				Search					Loco				Search					Loco				Search					Loco												
COUNTERMEASURE	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq	Vel	Dir	Acc	Pos	Obj	Dir	Dur	Loc	Seq				
LEFT TURN ATTENTION CONFLICT REDUCTION																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE											●			●						●			●																							◉	◉	◉		◉			◉	◉
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
PEDESTRIAN AND DRIVER EDUCATION—LEGAL INTERSECTION CONFLICTS																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE		●	●		●						◉	●		◉						◉	●		◉																								◉	◉		◉				◉
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
VEHICLE DESIGN SUN ACCESSORY																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																																						
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						
ICE CREAM TRUCK REGULATION AND WARNING DEVICE																																																						
1. DART OUT 1																																																						
2. DART OUT 2																																																						
3. INTERSECTION DASH																																																						
4. TURN MERGE																																																						
5. PED HITS VEHICLE																																																						
6. MULTIPLE THREAT																																																						
7. BUS STOP																																																						
8. ICE CREAM																																															●	●	●						◉
9. BACKING UP																																																						
10. WORKING IN ROAD																																																						
11. FREEWAY CROSSING																																																						

Measures of Behavioral Parameters

The entries in Table 3 do not reflect the nature of the behavioral measures to be taken but only the behavioral parameters to be measured. In order to translate behavioral parameters to behavioral measures one would need to refer back to Table 1. In doing this, we would, for example, ask what aspect of the direction of search at the curb should be measured for a particular accident type. In Table 1 we would find that the measure should differentiate among searching left, right, and straight ahead. The measure to be employed, then, would be an index such as line of sight relative to the curb.

The behavioral measures which are descriptive of the parameters of behavior independent of any countermeasure or accident type are shown in Illustration 1 for each of the parameters of pedestrian and driver behavior. These measures represent the most detailed levels of precision necessary to detect a significant behavioral change. Less precise levels of measurement (e.g., "fast" vs. "slow" for Velocity of Locomotion) might be appropriate for particular countermeasure evaluations. In order to determine the level of precision necessary to record, one must carefully consider the expected impact of a countermeasure. For example, consider the "meter post barrier" countermeasure, which is designed to prevent pedestrians from making midblock crossings. Table 3 indicates that "pedestrian locomotion: position" is important to measure. However, it is clear that a simple "presence" or "absence" measure is sufficient for countermeasure evaluation, and the measurement of "distance between pedestrian and vehicle" would be superfluous.

Illustration 1

Candidate Behavioral Measures

Behavioral Parameter	Behavioral Measures
Pedestrian/Driver Search	
1. Object of Search	Type of object attended to
2. Duration of Search	Time in seconds
3. Direction of Search	Angle of line of sight relative to curb
4. Sequence of Search	Pattern of head movements (left, right, straight ahead)
5. Position of Searcher	Distance between edges of crossing zone Distance between pedestrian and vehicle Time in seconds to vehicle-pedestrian encounter
Pedestrian Locomotion	
1. Velocity of Locomotion	Feet/sec
2. Direction of Locomotion	Angle of pathway relative to curb
3. Acceleration	Feet/sec^2
4. Position of Locomotor	Distance between edges of crossing zone Distance between pedestrian and vehicle Time in seconds to pedestrian-vehicle encounter
Driver/Vehicle Motion	
1. Driver Directional Control	Duration of steering wheel displacement Angular displacement of steering wheel Number of steering wheel reversals Angular velocity of displacement
2. Driver Speed Control	Angular displacement of accelerator Angular displacement of brake
3. Vehicle Path	Angle of pathway relative to roadbed Distance between vehicle and curb
4. Vehicle Speed	Feet/sec

COST EFFECTIVENESS OF MEASUREMENT SYSTEMS

Once the user of this handbook has determined the specific behaviors to measure for the particular countermeasure to be evaluated (as it applies to a particular accident type), the next step is to choose a measurement system for use in studying the behaviors of interest. Eleven generally useful measurement systems have been evaluated and are described in detail in Appendix A. The specific configuration of each system and a brief scenario describing a general data collection situation are given in the following paragraphs. It was necessary to assume one particular scenario for the purpose of establishing comparative cost and effectiveness information and to reduce the potential variance in cost assessment due to unusual or idiosyncratic situations. That is to say that the cost and effectiveness of any particular system would vary widely depending upon the specific location, area, time, etc.; in order to compare systems, a "typical" scenario was generated to provide a common reference for cost and effectiveness judgments.

Subsequent sections of this handbook describe the method by which each measurement system was evaluated in terms of (1) its effectiveness, (2) its cost, and (3) its cost-effectiveness for measuring each behavioral parameter. Procedures for the establishment of cost-effectiveness ratings in situations not corresponding to the given scenario are presented in a later section of this handbook.

Data collection is projected to take place in a residential area (single unit or apartment houses) during a four-hour period (1:00 to 5:00 p.m.) on weekday afternoons for a total of 20 days. The location to be observed is midblock (approximately 200 feet of curb) on a relatively narrow street lined on both sides with parked cars, trees, and street lights. Expected incidence of pedestrian crossing is light (10-15 per hour); traffic volume is light to medium, traveling at approximately 20-30 mph (sustained).

For the given scenario, the measurement systems which were evaluated and their specific configurations were as follows:

Direct Observation: Team

Two independent observers are appropriately stationed for parameter of interest and visibility requirements--pedestrians and/or driver cannot see observers, while observers have a clear view of the midblock area. Furthermore, observers are mobile and can move relatively close to pedestrians. No visual aids (e.g., binoculars) are to be used. Behavior is recorded manually; observations are "structured" in that only one parameter at a time is to be observed and recorded and a formal scoring sheet is used. Data reduction and analysis are done manually.

Interview

A single interviewer is appropriately stationed, having a clear view of pedestrians and/or vehicles. "Acceptable" questions have been formulated which directly address the parameter of interest (e.g., how fast were you walking? In which direction did you look before crossing?). Data-gathering takes place for pedestrians immediately after crossing; for driver interviews, drivers are signalled to stop and are questioned immediately. Responses are recorded manually on a formal scoring sheet. Data reduction and analysis are performed manually.

Road Tube

Two pneumatic tubes are laid across the roadway five feet apart. Clamps are used to secure the tubes to the roadway along natural expansion lines in order to minimize noticeability. The tubes are lined to strip chart recorders via cable to a recording station (a parked car). Sensor output is in the form of relay contact closures caused by vehicle passing over each tube. Data is reduced and analyzed manually from a permanent strip chart recording.

Doppler Radar

System includes an observer manually recording vehicle speeds. Sensors are located in an appropriate location (i.e., a direct line of sight is available). Data is recorded manually in real time.

Real-time Filming: Ground

System includes a 16mm camera, equipped with an automatic exposure control, a zoom lens (16mm to 100mm telephoto), spring drive, and 400 ft. film magazine. Observer starts filming when pedestrian (or auto) approaches field of view; he films for duration of crossing (assume 30 secs/crossing for pedestrians, 10 secs/traverse for auto). Data reduction equipment includes a stop-action reversable projector with single frame capability and a screen. Scoring is done manually from motion picture playback. Assume that a 400 ft. magazine will be sufficient to last for four hours of filming for light pedestrian and traffic volume.

Real-time Filming: Aerial

System includes same equipment as above; the observer, however, is located 25 ft. above the roadway. Camera is mounted on a tripod. Assume that the camera is not directly above pedestrians or vehicles. Data collection and reduction procedures are the same as given above.

Time-Lapse Filming: Aerial

System includes the same camera, lens, and film magazine as described in above two systems. Additional equipment for time-lapse operation includes an intervalometer, solenoid, and a driver motor. The data collection and reduction procedures are the same as above. At three frames per second, 400 ft. of film will last approximately eight times as long as real-time filming.

Real-time CCTV: Ground

The basic system components are a video camera (monochrome) with control unit, zoom lens (12.5mm to 100mm, f2), video recorder, and video monitor/receiver (18" diagonal screen). This system is semi-portable; the camera can be hand-held and moved, but its control unit and the recorder are stationary. Observer starts recording when pedestrian (or auto) approaches field of view. Assume that a single tape reel is sufficient to last for four hours of recording. Data reduction and scoring is done manually from video tape playback (on TV monitor). Tape is reused each session.

Real-time CCTV: Aerial

System includes same equipment as above; the observer, however, is located 25 ft. above the roadway. Camera is mounted on a tripod. Assume that the camera is not directly above the pedestrians or vehicles. Data collection and reduction procedures are the same as the above system.

Time-lapse CCTV

System includes the same camera, control unit, lens, and video monitor as described in above two systems; however, a special time-lapse recorder is required. Data collection and reduction procedures are also described in the above systems.

Real-time CCTV: Memory

System consists of a remote-controlled CCTV camera mounted in a stationary position above the roadway and connected to a control room. An observer in the control room monitors a real-time display. Every 20 seconds the observer decides either to keep the tape (in which case it is then transferred to a second tape) or erase it for the next 20 seconds. Data reduction procedures are the same as above.

System Effectiveness

Effectiveness was assessed along six dimensions. These were validity, reliability, accuracy, ease of implementation, efficiency, and environmental range. We believe that these six components represent a necessary and sufficient set of characteristics of effectiveness.

Validity is defined as the probability that the measurement system can detect the behavioral parameter of interest. As an example, consider the use of a time-lapse moving-picture camera mounted above an intersection and being used to measure "sequence of pedestrian search." The validity of the system would be represented by the ability of the camera to detect very rapid head movements in proper sequence. At one end of the scale, the film speed of the camera may be too slow to detect rapid movements and would miss several pedestrian head turnings. In such a situation the validity of the system would be very low at best and perhaps even zero. Validity judgments were made for each measurement system on a parameter-by-parameter basis. The precision of measurement required was assumed to be the levels presented in Illustration 1 (p. 23).

Reliability is defined as the extent to which the behavioral record can be interpreted consistently. Consider the same example as above: a time-lapse moving-picture camera being used to measure sequences of pedestrian search. As distinct from its validity (e.g., the probability of missing a head-turning), the system's reliability refers to the degree of agreement among judges viewing the filmed behavior that a particular event was, for example, a left-right-left pattern of head movement. If several judges could not agree that a particular filmed behavioral record was, in fact, a left-right-left search, the measurement system would be considered unreliable. The definition of reliability is not the more typical "probability of system malfunction" definition; we believe that this latter definition is a cost rather than an effectiveness consideration. Furthermore, the present definition is not concerned with reliability in the sense of replication of measurement (e.g., the probability that, if several moving-picture cameras filmed the same sequence, all filmed records would be identical). Rather, the concern is the replication of the data extraction process: If several judges saw the same film, would there be an unambiguous translation of the filmed behaviors. Note again that this judgment was based on the assumption that the levels of precision of measurement were those given in Illustration 1 (p. 23).

Accuracy is defined as the precision of parameter measurement the system is capable of recording. For example, if the parameter under consideration is "pedestrian locomotion-velocity," a particular measurement system might be capable of measuring in feet per second; alternatively, another system could only record velocity as "fast," "slow," or "stopped." For each parameter, the levels of measurement given in Illustration 1 were considered the most precise levels. Notice, however, that the particular accuracy level of a measurement system is a factor that must be judged separately for each countermeasure. Depending upon the hypothesized or desired impact of a particular countermeasure, a given level of measurement specificity might be adequate, inadequate, or unnecessarily precise. For example, the goal of a particular countermeasure might be to reduce vehicle speed by 15 miles per hour. A measurement system capable of measuring vehicle velocity as "fast" or "slow" would be inadequate. On the other hand, if the desired impact of another countermeasure is to get pedestrians to stop at the curb, a measurement system capable of measuring velocity in feet per second would be unnecessarily precise from a cost-effective point of view. The judgments presented in this handbook should be considered as "absolute" accuracy judgments, assuming the countermeasure would require the highest level of precision.

Ease of implementation is defined as the overall simplicity or difficulty of installing and operating the measurement system in the field. While there are direct and indirect costs associated with implementation, this dimension refers to the expected incidence of problems associated with data acquisition. For example, a closed-circuit television system used to measure "pedestrian locomotion-acceleration" would require at least a stationary camera, field depth markers, tape units, etc.; furthermore, the entire system would not be portable and probably could not be used unobtrusively. It would, in short, be quite difficult to implement.

Efficiency is defined as the ease of data extraction. Given a behavioral record (e.g., films, tape recordings, etc.) it is the relative degree of difficulty of reducing the raw data (e.g., films of vehicles) into a usable form (e.g., vehicle speed in M.P.H.). For example, the record of activities produced by an observation team measuring "pedestrian search-sequence" might be a straightforward enumeration of head-turning directions. It would be simple to convert that list into usable data. On the other hand, a moving-picture camera employed for the same purpose might require real-time or slow-motion projection. In terms of time and effort, the camera system might be less efficient for data reduction (although it may be more reliable or valid than an observation team).

Environmental range is defined as the range of environmental circumstances in which the measurement system is capable of being used. In previous work on this project, we have identified circumstances in which accidents are most likely to occur. In order for a measurement system to be effective, it must be capable of deployment in a wide range of conditions (different physical locations, light conditions, etc.).

Of the six components of system effectiveness, four bear upon the quality of the data generated by the system, and two do not. Validity, reliability, accuracy, and environmental range are indices of data quality. Efficiency and ease of implementation are not data quality components.

For five of the six components of system effectiveness, categorical scales were generated which allow for judgments to be made as to the degree to which each measurement system possesses the particular component for each of the 18 behavioral parameters. On the basis of the information derived from the literature, each measurement system was rated in terms of validity, reliability, efficiency, and ease of implementation on a scale from zero to three. A zero rating indicated that the system had none of the particular component of effectiveness being scaled. The values of one, two, and three were used to reflect judgments of low, medium, and high degrees of effectiveness.

The scale for environmental range was slightly different. This scale represented a continuum from narrow to broad use. A scale value was derived by considering the number of environmental situations (out of 24 possible ones) in which the measurement system could be used when measuring a particular behavioral parameter. This frequency was then divided by 8 in order to force the range of values to be zero to three, thereby consistent with all other scale ranges.

Illustration 2 shows the composition of the six scales used to rate system effectiveness. In order to aid in the judgments, anchor points defining positions on each scale were developed and are shown in Illustration 3.

Certain of the measurement systems cannot be used to measure specific behaviors due to environmental constraints. Table 4 depicts the limitations of each system for each behavioral parameter to be measured.

Illustration 2

RATING FORM FOR EFFECTIVENESS

System: ______________________ Parameter: ______________________

VALIDITY (A)

0	1	2	3
None	Low	Med	High

RELIABILITY (B)

0	1	2	3
None	Low	Med	High

ACCURACY (C)

0	1	2	3
Inadequate Precision	Minimal Precision	Moderately Precise	Very Precise

EASE OF IMPLEMENTATION (D)

0	1	2	3
Very Difficult	Difficult	Easy	Very Easy

EFFICIENCY (E)

0	1	2	3
Very Inefficient	Inefficient	Efficient	Very Efficient

ENVIRONMENTAL RANGE (F)

Narrow ( ) Broad

0 ____ 3

Location: midblock intersection freeway

Crossing zone: pre-curb traffic boundary traffic lane

Area: residential commercial industrial

Lighting: day twilight night

Traffic: light medium heavy

Pedestrian volume: light medium heavy

Vehicle speed: slow medium fast

Predisposing factors: parked cars trees visibility (weather)

Data = ΣU_i / 8

Illustration 3

ANCHORS FOR RATING SCALES

VALIDITY

0	1	2	3
None	Low	Medium	High
$\leq .10$	.11-.40	.41-.79	$\geq .80$

RELIABILITY

0	1	2	3
None	Low	Medium	High
$\leq .20$	.21-.50	.51-.79	$\geq .80$

ACCURACY

0	1	2	3
Inadequate Precision	Minimal Precision	Moderately Precise	Very Precise
The unit of measurement is not sensitive enough for measuring behavior of interest.			The unit of measurement is sufficiently sensitive for measuring the behavior of interest.
	e.g., An instrument which can measure speed only in terms of fast vs. slow is of minimal precision.		e.g., An instrument which can measure speed in ft/sec would be very precise.

EASE OF IMPLEMENTATION

0	1	2	3
Very Difficult	Difficult	Easy	Very Easy
Installation and operation of the system is time consuming and requires specially trained technicians. Maintenance is extensive. Problems and breakdowns are to be expected due to complexity of system.			The system is quickly installed and maintained by naive operators. Its use requires no special training. No problems or breakdowns are anticipated due to simplicity of system. May be portable or self-contained.

Illustration 3 (Cont'd)

EFFICIENCY OF DATA EXTRACTION

0 Very Inefficient	1 Inefficient	2 Efficient	3 Very Efficient
Extraction of data requires extensive manual operation by several operators. Raw data from record must be looked at, scored and the desired information generated manually.	←———	———→	Extraction of data is automatic and requires no manual effort. The data is taken directly from a record and the information desired is generated automatically.
e.g., Accomplishing statistical analyses from raw data of pen recordings.			e.g., Analyzing amplitude of EEG waves directly recorded on analog-digital computer.

ENVIRONMENTAL RANGE

0	1	2	3
Narrow			Broad
Can be used in only a highly restrictive fashion in a single location and area, under particular visibility limits and for certain traffic situations.			Can be used in a very wide variety of conditions of traffic, location, area, and visibility.

Table 4.

ENVIRONMENTAL LIMITATIONS OF MEASUREMENT SYSTEMS AS A FUNCTION OF BEHAVIORAL PARAMETERS

Measurement System: Direct Observation

ENVIRONMENTAL LIMITATION

BEHAVIORAL PARAMETER	Location			Crossing Zone			Area			Lighting			Traffic			Pedestrian Volume			Vehicle Speed			Predisposing Factors		
	midblock	intersection	freeway	precurb	traffic boundary	traffic lane	residential	commercial	industrial	day	twilight	night	light	medium	heavy	light	medium	heavy	slow	medium	fast	parked cars	trees	visibility (weather)
PEDESTRIAN SEARCH																								
1. OBJECT												●						●						●
2. DIRECTION												●												●
3. DURATION												●						●						●
4. LOCATION												●						●						●
5. SEQUENCE												●						●						●
PEDESTRIAN LOCOMOTION																								
6. VELOCITY												●						●						●
7. DIRECTION												●												●
8. ACCELERATION												●						●						●
9. POSITION												●						●						●
DRIVER SEARCH																								
10. OBJECT			●									●								●	●			●
11. DIRECTION			●									●									●			●
12. DURATION			●									●								●	●			●
13. LOCATION			●									●									●			●
14. SEQUENCE			●									●									●			●
15. DRIVER CONTROL DIRECTION			●									●								●	●			●
16. DRIVER CONTROL VELOCITY	←											N/A												→
17. VEHICLE PATH																								●
18. VEHICLE SPEED												●												●

Table 4.

ENVIRONMENTAL LIMITATIONS OF MEASUREMENT SYSTEMS AS A FUNCTION OF BEHAVIORAL PARAMETERS (Cont'd)

Measurement System: Road Tube

ENVIRONMENTAL LIMITATION

BEHAVIORAL PARAMETER	Location			Crossing Zone			Area			Lighting			Traffic			Pedestrian Volume			Vehicle Speed			Predisposing Factors		
	midblock	intersection	freeway	precurb	traffic boundary	traffic lane	residential	commercial	industrial	day	twilight	night	light	medium	heavy	light	medium	heavy	slow	medium	fast	parked cars	trees	visibility (weather)
PEDESTRIAN SEARCH																								
1. OBJECT																								
2. DIRECTION																								
3. DURATION																								
4. LOCATION																								
5. SEQUENCE																								
PEDESTRIAN LOCOMOTION																								
6. VELOCITY																								
7. DIRECTION																								
8. ACCELERATION																								
9. POSITION																								
DRIVER SEARCH																								
10. OBJECT																								
11. DIRECTION																								
12. DURATION																								
13. LOCATION																								
14. SEQUENCE																								
15. DRIVER CONTROL DIRECTION																								
16. DRIVER CONTROL VELOCITY																								
17. VEHICLE PATH																								
18. VEHICLE SPEED				●	●																			

Table 4.

ENVIRONMENTAL LIMITATIONS OF MEASUREMENT SYSTEMS
AS A FUNCTION OF BEHAVIORAL PARAMETERS (Cont'd)

Measurement System: Doppler Radar

ENVIRONMENTAL LIMITATION

BEHAVIORAL PARAMETER	Location			Crossing Zone			Area			Lighting			Traffic			Pedestrian Volume			Vehicle Speed			Predisposing Factors		
	midblock	intersection	freeway	precurb	traffic boundary	traffic lane	residential	commercial	industrial	day	twilight	night	light	medium	heavy	light	medium	heavy	slow	medium	fast	parked cars	trees	visibility (weather)
PEDESTRIAN SEARCH																								
1. OBJECT																								
2. DIRECTION																								
3. DURATION																								
4. LOCATION																								
5. SEQUENCE																								
PEDESTRIAN LOCOMOTION																								
6. VELOCITY																								
7. DIRECTION																								
8. ACCELERATION																								
9. POSITION																								
DRIVER SEARCH																								
10. OBJECT																								
11. DIRECTION																								
12. DURATION																								
13. LOCATION																								
14. SEQUENCE																								
15. DRIVER CONTROL DIRECTION																								
16. DRIVER CONTROL VELOCITY																								
17. VEHICLE PATH																								
18. VEHICLE SPEED				●	●																	●	●	

Table 4.

ENVIRONMENTAL LIMITATIONS OF MEASUREMENT SYSTEMS AS A FUNCTION OF BEHAVIORAL PARAMETERS (Cont'd)

Measurement System: 1. Real-Time Filming: Ground; 2. Real-Time Closed Circuit Television: Ground

ENVIRONMENTAL LIMITATION

BEHAVIORAL PARAMETER	Location			Crossing Zone			Area			Lighting			Traffic			Pedestrian Volume			Vehicle Speed			Predisposing Factors		
	midblock	intersection	freeway	precurb	traffic boundary	traffic lane	residential	commercial	industrial	day	twilight	night	light	medium	heavy	light	medium	heavy	slow	medium	fast	parked cars	trees	visibility (weather)
PEDESTRIAN SEARCH																								
1. OBJECT											●	●						●				●	●	●
2. DIRECTION											●	●						●				●	●	●
3. DURATION											●	●						●				●	●	●
4. LOCATION											●	●										●	●	●
5. SEQUENCE											●	●						●				●	●	●
PEDESTRIAN LOCOMOTION																								
6. VELOCITY											●	●						●				●	●	●
7. DIRECTION											●	●						●				●	●	●
8. ACCELERATION											●	●						●				●	●	●
9. POSITION											●	●										●	●	●
DRIVER SEARCH																								
10. OBJECT											●	●						●			●	●	●	●
11. DIRECTION											●	●						●			●	●	●	●
12. DURATION											●	●						●			●	●	●	●
13. LOCATION											●	●						●			●	●	●	●
14. SEQUENCE											●	●						●			●	●	●	●
15. DRIVER CONTROL DIRECTION											●	●									●	●	●	●
16. DRIVER CONTROL VELOCITY	← N/A →																							
17. VEHICLE PATH											●	●										●	●	●
18. VEHICLE SPEED											●	●										●	●	●

Table 4.

ENVIRONMENTAL LIMITATIONS OF MEASUREMENT SYSTEMS
AS A FUNCTION OF BEHAVIORAL PARAMETERS (Cont'd)

Measurement System: 1. Real-Time Filming: Aerial; 2. Real-Time Closed Circuit Television: Aerial; and 3. Real-Time Closed Circuit Television: Memory

ENVIRONMENTAL LIMITATION

	Location			Crossing Zone			Area			Lighting			Traffic			Pedestrian Volume			Vehicle Speed			Predisposing Factors		
BEHAVIORAL PARAMETER	midblock	intersection	freeway	precurb	traffic boundary	traffic lane	residential	commercial	industrial	day	twilight	night	light	medium	heavy	light	medium	heavy	slow	medium	fast	parked cars	trees	visibility (weather)
PEDESTRIAN SEARCH																										
1. OBJECT											●	●												●
2. DIRECTION											●	●												●
3. DURATION											●	●												●
4. LOCATION											●	●												●
5. SEQUENCE											●	●												●
PEDESTRIAN LOCOMOTION																										
6. VELOCITY											●	●												●
7. DIRECTION											●	●												●
8. ACCELERATION											●	●												●
9. POSITION											●	●												●
DRIVER SEARCH																										
10. OBJECT											●	●									●			●
11. DIRECTION											●	●									●			●
12. DURATION											●	●									●			●
13. LOCATION											●	●									●			●
14. SEQUENCE											●	●									●			●
15. DRIVER CONTROL DIRECTION											●	●									●			●
16. DRIVER CONTROL VELOCITY	◄												N/A											►
17. VEHICLE PATH											●	●												●
18. VEHICLE SPEED											●	●												●

Table 4.

ENVIRONMENTAL LIMITATIONS OF MEASUREMENT SYSTEMS
AS A FUNCTION OF BEHAVIORAL PARAMETERS (Cont'd)

Measurement System: 1. Time Lapse Filming: Aerial; 2. Time Lapse Closed Circuit Television

ENVIRONMENTAL LIMITATION

BEHAVIORAL PARAMETER	Location			Crossing Zone			Area			Lighting			Traffic			Pedestrian Volume			Vehicle Speed			Predisposing Factors		
	midblock	intersection	freeway	precurb	traffic boundary	traffic lane	residential	commercial	industrial	day	twilight	night	light	medium	heavy	light	medium	heavy	slow	medium	fast	parked cars	trees	visibility (weather)
PEDESTRIAN SEARCH																								
1. OBJECT											●	●												●
2. DIRECTION											●	●												●
3. DURATION											●	●												●
4. LOCATION											●	●												●
5. SEQUENCE											●	●												●
PEDESTRIAN LOCOMOTION																								
6. VELOCITY											●	●												●
7. DIRECTION											●	●												●
8. ACCELERATION											●	●												●
9. POSITION											●	●												●
DRIVER SEARCH																								
10. OBJECT											●	●									●			●
11. DIRECTION											●	●									●			●
12. DURATION											●	●									●			●
13. LOCATION											●	●									●			●
14. SEQUENCE											●	●									●			●
15. DRIVER CONTROL DIRECTION											●	●									●			●
16. DRIVER CONTROL VELOCITY	◄—— N/A ——►																							
17. VEHICLE PATH											●	●												●
18. VEHICLE SPEED											●	●												●

Table 5

Average Ratings on Each Dimension of Effectiveness for Each Measurement System Used to Measure Each Behavioral Parameter

Measurement System: Direct Observation

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	3	2.5	2.5	2	2	2.63	196.87	53.22
Direction	3	2	1	2	2	2.63	63.00	19.75
Duration	2	1.5	1.5	2	2	2.63	47.25	15.81
Location	2.5	2	2	2	2	2.63	105.00	30.25
Sequence	2	1.5	2.5	2	2	2.63	78.75	23.69
Pedestrian Locomotion								
Velocity	3	3	1.5	2	2	2.63	141.75	39.44
Direction	3	3	2.5	2	2	2.63	236.25	63.00
Acceleration	1.5	1.5	1	2	2	2.63	23.63	9.91
Position	3	2.5	2.5	2	2	2.63	196.87	53.22
Driver Search								
Object	1.5	1.5	1.5	2	2	2.63	35.44	12.86
Direction	1.5	1.5	2.5	2	2	2.63	47.25	15.81
Duration	1	1	1	2	2	2.63	10.50	6.63
Location	1.5	1.5	1.5	2	2	2.63	35.44	12.86
Sequence	1	1	1	2	2	2.63	10.50	6.63
Driver Control--Direction	2	1	1	2	2	2.63	21.00	9.25
Driver Control--Velocity	0	0	0	2	2	0	0.00	4.00
Vehicle Path	3	2.5	2	2	2	2.63	157.50	43.37
Vehicle Speed	2.5	2	2	2	2	2.63	105.00	30.25

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Interview

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	2.5	2.5	2.5	2	2	3	187.50	50.87
Direction	3	3	2.5	2	2	3	270.00	71.50
Duration	1	1	2	2	2	3	24.00	10.00
Location	2	2	1.5	2	2	3	72.00	22.00
Sequence	1	1	1.5	2	2	3	18.00	8.50
Pedestrian Locomotion								
Velocity	2.5	2.5	1.5	2	2	3	112.50	32.13
Direction	3	3	3	2	2	3	108.00	31.00
Acceleration	2	2	1	2	2	3	48.00	16.00
Position	1.5	1.5	1	2	2	3	27.00	10.75
Driver Search								
Object	2	2	2.5	2	2	3	120.00	34.00
Direction	3	3	2.5	2	2	3	270.00	71.50
Duration	1.5	1.5	1.5	2	2	3	40.50	14.13
Location	1.5	1.5	1.5	2	2	3	40.50	14.13
Sequence	1	1	1.5	2	2	3	18.00	8.50
Driver Control--Direction	1	1	1.5	2	2	3	18.00	8.50
Driver Control--Velocity	1.5	1.5	1.5	2	2	3	40.50	14.13
Vehicle Path	2	2	2.5	2	2	3	120.00	34.00
Vehicle Speed	2	2	2.5	2	2	3	120.00	34.00

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Road Tube

	Effectiveness Dimension						Figure of Merit	
Behavioral Parameter	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object								
Direction								
Duration								
Location								
Sequence								
Pedestrian Locomotion								
Velocity								
Direction								
Acceleration								
Position								
Driver Search								
Object								
Direction								
Duration								
Location								
Sequence								
Driver Control--Direction								
Driver Control--Velocity								
Vehicle Path								
Vehicle Speed	3	3	3	1.5	1.5	2.75	167.06	76.50

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Doppler Radar

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object								
Direction								
Duration								
Location								
Sequence								
Pedestrian Locomotion								
Velocity								
Direction								
Acceleration								
Position								
Driver Search								
Object								
Direction								
Duration								
Location								
Sequence								
Driver Control--Direction								
Driver Control--Velocity								
Vehicle Path								
Vehicle Speed	3	3	3	3	2	2.63	425.25	76.87

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Real-Time Film: Ground

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	1.5	1.5	2.5	2	1	2.37	26.72	28.72
Direction	2.5	2.5	2	2	1	2.37	59.37	61.37
Duration	2	1.5	3	2	1	2.37	42.75	44.75
Location	3	2	2.5	2	1	2.37	71.25	73.25
Sequence	2.5	2.5	2	2	1	2.37	59.37	61.37
Pedestrian Locomotion								
Velocity	2.5	2	2	2	1	2.37	47.50	49.50
Direction	3	3	2	2	1	2.37	85.50	87.50
Acceleration	1.5	1.5	1	2	1	2.37	10.69	12.69
Position	3	2	2	2	1	2.37	57.00	59.00
Driver Search								
Object	1	1.5	1	2	1	2.37	7.13	9.13
Direction	2	2	2	2	1	2.37	38.00	40.00
Duration	1.5	1.5	1.5	2	1	2.37	16.03	18.03
Location	2	1.5	1	2	1	2.37	14.25	16.25
Sequence	2	2	2	2	1	2.37	38.00	40.00
Driver Control--Direction	2	1.5	1.5	2	1	2.37	21.37	23.37
Driver Control--Velocity	0	0	0	2	1	2.37	0.00	2.00
Vehicle Path	2.5	2	2	2	1	2.37	47.50	49.50
Vehicle Speed	2	1.5	1.5	2	1	2.37	21.37	23.37

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Real-Time Film: Aerial

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	1.5	1.5	2.5	2	1	2.63	29.53	31.53
Direction	3	3	2	2	1	2.63	94.50	96.50
Duration	2	2	3	2	1	2.63	63.00	65.00
Location	3	2.5	2.5	2	1	2.63	98.44	100.44
Sequence	3	3	2.5	2	1	2.63	118.13	120.13
Pedestrian Locomotion								
Velocity	3	2	3	2	1	2.63	94.50	96.50
Direction	3	3	3	2	1	2.63	141.75	143.75
Acceleration	2	2	1.5	2	1	2.63	31.50	33.50
Position	3	3	3	2	1	2.63	141.75	143.75
Driver Search								
Object	0.5	1.5	1.5	2	1	2.63	5.91	7.91
Direction	2	2	2.5	2	1	2.63	52.50	54.50
Duration	1	1.5	1.5	2	1	2.63	11.81	13.81
Location	2	2	1.5	2	1	2.63	31.50	33.50
Sequence	2	2	2	2	1	2.63	42.00	44.00
Driver Control--Direction	1	1	1	2	1	2.63	5.25	7.25
Driver Control--Velocity	0	0	0	2	1	2.63	0.00	2.00
Vehicle Path	3	3	3	2	1	2.63	141.75	143.75
Vehicle Speed	2.5	2.5	2	2	0.5	2.63	32.81	33.81

Table 5 (Cont'd)

Average Ratings on Each Dimension of Effectiveness for Each Measurement System Used to Measure Each Behavioral Parameter

Measurement System: Time-Lapse Film: Aerial

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	1.5	1.5	2.5	1	1	2.63	14.77	15.77
Direction	2.5	2.5	2	1	1	2.63	32.81	33.81
Duration	1.5	1.5	1.5	1	1	2.63	8.86	9.86
Location	2.5	2.5	3	1	1	2.63	49.22	50.22
Sequence	2	2.5	2	1	1	2.63	26.25	27.25
Pedestrian Locomotion								
Velocity	2	1.5	2.5	1	0.5	2.63	9.84	20.19
Direction	3	3	3	1	1	2.63	70.87	71.87
Acceleration	1.5	1.5	1.5	1	0.5	2.63	4.43	9.36
Position	2.5	2.5	2.5	1	1	2.63	41.02	42.02
Driver Search								
Object	1	1	1	1	1	2.63	2.63	3.63
Direction	1	1.5	1.5	1	1	2.63	5.91	6.91
Duration	1	1	1.5	1	1	2.63	3.94	4.94
Location	1	1.5	1.5	1	1	2.63	5.91	6.91
Sequence	1	1.5	2	1	1	2.63	7.87	8.87
Driver Control--Direction	0.5	1	1	1	1	2.63	1.31	2.31
Driver Control--Velocity	0	0	0	1	1	2.63	0.00	1.00
Vehicle Path	2.5	2.5	2.5	1	1	2.63	41.02	42.02
Vehicle Speed	2	2	2	1	0.5	2.63	10.50	21.50

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Time-Lapse CCTV: Aerial

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	1.5	1.5	2.5	0.1	1	2.63	1.48	14.87
Direction	2.5	2.5	2	0.1	1	2.63	3.28	32.91
Duration	1.5	1.5	1.5	0.1	1	2.63	.89	8.96
Location	2.5	2.5	3	0.1	1	2.63	4.92	49.32
Sequence	2	2.5	2	0.1	1	2.63	2.63	26.35
Pedestrian Locomotion								
Velocity	2	1.5	2.5	0.1	0.5	2.63	.98	19.74
Direction	3	3	3	0.1	1	2.63	7.09	70.97
Acceleration	1.5	1.5	1.5	0.1	0.5	2.63	.44	8.91
Position	2.5	2.5	2.5	0.1	1	2.63	4.10	41.12
Driver Search								
Object	1	1	1	0.1	1	2.63	.26	2.73
Direction	1	1.5	1.5	0.1	1	2.63	.59	6.01
Duration	1	1	1.5	0.1	1	2.63	.39	4.04
Location	1	1.5	1.5	0.1	1	2.63	.59	6.01
Sequence	1	1.5	2	0.1	1	2.63	.79	7.97
Driver Control--Direction	0.5	1	1	0.1	1	2.63	.13	1.41
Driver Control--Velocity	0	0	0	0.1	1	2.63	0.00	.10
Vehicle Path	2.5	2.5	2.5	0.1	1	2.63	4.10	41.12
Vehicle Speed	2	2	2	0.1	0.5	2.63	1.05	21.05

Table 5 (Cont'd)

Average Ratings on Each Dimension of
Effectiveness for Each Measurement System
Used to Measure Each Behavioral Parameter

Measurement System: Real-Time CCTV: Memory

Behavioral Parameter	Effectiveness Dimension						Figure of Merit	
	(A) Val	(B) Rel	(C) Acc	(D) Impl	(E) Eff	(F) Envir	(1) A B C D E F	(2) A B C F+D E
Pedestrian Search								
Object	1.5	1.5	2.5	0.1	1	2.63	1.48	14.87
Direction	3	3	2	0.1	1	2.63	4.73	47.35
Duration	2	2	3	0.1	1	2.63	3.15	31.60
Location	3	2.5	2.5	0.1	1	2.63	4.92	49.32
Sequence	3	3	2.5	0.1	1	2.63	5.91	59.16
Pedestrian Locomotion								
Velocity	3	2	3	0.1	1	2.63	4.73	47.35
Direction	3	3	3	0.1	1	2.63	7.09	70.97
Acceleration	2	2	1.5	0.1	1	2.63	1.57	15.85
Position	3	3	3	0.1	1	2.63	7.09	70.97
Driver Search								
Object	0.5	1.5	1.5	0.1	1	2.63	.29	3.05
Direction	2	2	2.5	0.1	1	2.63	2.63	26.35
Duration	1	1.5	1.5	0.1	1	2.63	.59	6.01
Location	2	2	1.5	0.1	1	2.63	1.57	15.85
Sequence	2	2	2	0.1	1	2.63	2.10	21.10
Driver Control--Direction	1	1	1	0.1	1	2.63	.26	2.73
Driver Control--Velocity	0	0	0	0.1	1	2.63	0.00	.10
Vehicle Path	3	3	3	0.1	1	2.63	7.09	70.97
Vehicle Speed	2.5	2.5	2	0.1	0.5	2.63	1.64	32.86

Cell entries designate the fact that the system cannot be used to measure a behavior under a particular environmental situation. The use of this table allows for certain measurement systems to be eliminated from consideration regardless of their cost-effectiveness, if the circumstances under which the measurement must take place create limitations which the system cannot tolerate. Thus, for example, "direct observation" cannot be used to measure many parameters of pedestrian search when there is a heavy pedestrian volume and therefore should not be considered for these purposes. This is true despite the fact that "direct observation" has relatively high cost-effectiveness ratios for these parameters.

Subsequent to the generation of ratings for each of the six components of effectiveness, mean ratings were combined into a single index of overall system effectiveness. This combining of ratings was accomplished by multiplying the scores for validity, reliability, accuracy, and environmental range and adding to this product the result of multiplying the scores for efficiency and ease of implementation. Such an equation gives differential weights to those components of effectiveness having to do with data quality as compared to those which do not. We believe this to be a rational, though arbitrary, means of generating an overall index of effectiveness. A second method for arriving at an overall index of system effectiveness was to multiply scores on all six components of effectiveness together, thus giving equal weight to each component. Because we are unable to justify choosing one approach over the other, we have computed effectiveness indices (figures of merit) using both equations.

Table 5 presents the average ratings on each dimension of system effectiveness and the two figures of merit for each measurement system in measuring each behavioral parameter. The higher the figure of merit, the more effective is the measurement system. This table can be used to determine which parameters any given measurement system is most effective at measuring by simply reading down either figure of merit (FOM) column. More importantly, the table can be used to compare the effectiveness of several measurement systems in terms of their ability to measure a particular behavior of interest. This is accomplished by searching through the pages of the table, using either FOM column, to find the measurement system with the highest value for the particular behavioral parameter of interest. It should be noted that the blank entries for Road Tube and Doppler Radar in Table 5 represent zero values and that this arises because these systems can only be used to measure vehicle speed among the 18 behavioral parameters.

System Cost

The second component of cost-effectiveness is system cost. We have identified five separate components, or cost factors, which jointly determine the overall cost of a system.

* Initial costs for acquiring needed equipment ("Purchase Price"),
* Manpower costs accrued for training of equipment operators, technical personnel needed for equipment installation, and additional supplies and material needed for system implementation ("Implementation"),
* Manpower costs accrued for regular system maintenance ("Maintenance"),
* Manpower costs accrued for data reduction, interpretation, and analysis ("Reduction"), and
* Manpower costs accrued for system operation, and additional supplies and materials needed for system operation ("Operation").

In order to provide more analytic information than would a simple presentation of total costs and to enable more direct cost comparisons, estimates of cost requirements for each of the various measurement systems for each cost component as well as total system cost are provided in Table 6. These figures have been compiled from two principal sources: (1) the most current equipment price listings we could obtain, plus the expertise of several film and CCTV system specialists in selecting appropriate equipment; and (2) our best estimates of manpower costs accrued in data gathering, based on extensive staff and corporate experience. The last column of Table 6 represents estimated system costs for a typical data collection period, based on the scenario described earlier. These cost figures are used later in the computation of cost-effectiveness ratios.

Although the numbers entered in Table 6 are directly interpretable as dollar amounts, several factors must be considered before conclusions can be unambiguously drawn. The first and most obvious factor is that, no matter how current the equipment prices referenced, these costs are subject to substantial variance as a function of local economics (e.g., availability), inflation, on-hand equipment, and technological advances that would lower purchase costs. Secondly, the cost estimates will vary whenever personnel costs do not match our arbitrary values. Thirdly, costs will vary as a function of the degree of non-correspondence between our data-gathering scenario and a specific implementation increases. As a simple example, suppose that instead of 20 days for data collection, 60 days are envisioned. The effect on total cost for each system is computable from the information provided (although, in this case, total cost is not simply triple the given cost, since already included are the one-time-only expenses such as training time for observers).

On the other hand, confidence can be placed on the relative expense of measurement systems, regardless of parameters to be measured, or specific data-collection scenario (within the limitations specified in Table 4). The basic reason why the former is true is that the system

Table 6

Costs for Each Component of Cost Model for Each Measurement System

Measurement System	Purchase Price*	Implementation[1]	Maintenance[1]	Reduction[1]	Operation[1]	Total Dollars
Direct Observation	100[2]	164[3]	0	60[4]	640[5]	$ 964
Interview	100[2]	448[6]	0	60[4]	480[7]	1088
Road Tube	58[8]	320[9]	32[10]	120[11]	470[12]	1000
Doppler Radar	66[13]	24[14]	80[15]	60[4]	370[16]	600
Real-Time Film: Ground	2175[17]	24[14]	0	80[18]	320[19]	2599
Real-Time Film: Aerial	2183[20]	24[14]	0	80[18]	320[19]	2607
Time-Lapse Film: Aerial	492[21]	184[22]	32[23]	160[24]	320[19]	1188
Real-Time CCTV: Ground	269[25]	836[26]	160[27]	80[18]	320[19]	1665
Real-Time CCTV: Aerial	300[28]	836[26]	160[27]	80[18]	320[19]	1696
Time-Lapse CCTV: Aerial	350[29]	836[26]	160[27]	160[24]	0	1506
Real-Time CCTV: Memory	406[30]	836[26]	192[31]	80[18]	320[19]	1834

Table 6 (Cont'd)

Notes

*All hardware item purchases have been corrected for an estimated useful life expectancy of two years. Therefore, all hardware costs have been divided by 24, or one month of actual usage.

1 Personnel costs for implementation, maintenance, reduction, and operation are based upon the following categories and hourly rates:

A: observer @ $4.00
B: interviewer @ $6.00
C: clerk @ $3.00
D: technician @ $8.00
E: professional @ $12.50

2 Includes costs for acquiring personnel--advertisements, job interviews, personnel officer time.

3 Based on 8 hours E (trainer), 8 hours for each of 2 A's.

4 Based on 1 hour C per day for 20 days.

5 Based on 2 A's, 4 hours per day for 20 days.

6 Based on 8 hours E (trainer), 8 hours B, 3 days E for questionnaire development.

7 Based on 4 hours B per day for 20 days.

8 Approximate price based on $1400 hardware (pen recorder, batteries, connections, cables, clamps, switches).

9 Based on 2 hours D per day for 20 days.

10 Based on 1 hour D per week for 4 weeks.

11 Based on 2 hours C per day for 20 days.

12 Based on 4 hours A per day for 20 days, $150 supplies (ink, paper, tubing).

13 Approximate price based on estimate obtained from the Maryland State Police for a "Speed Gun 6" at $1600.

14 Based on 2 hours A, 2 hours D for training.

15 Based on 1/2 hour D per day for 20 days.

16 Based on 4 hours A per day for 20 days, $50 supplies (recording sheets, pens).

[17] Based on $4195 hardware as follows:

Camera	$1500
400' drive	600
Lens	1270
Screen	50
Projector	775
	$4195

plus $2000 non-reusable film ($50 purchase, $50 developing and processing per day).

[18] Based on 1 hour A per day for 20 days.

[19] Based on 4 hours A per day for 20 days.

[20] Based on equipment listed in note 17 plus $200 additional hardware costs (tripod, mounts) = $4395 + $2000 non-reusable film.

[21] Based on equipment listed in note 20 ($4395) plus:

Intervalometer	$200
Solenoid	100
Mounting armor	50
Motor	1075

$1425 + 4395 = 5820 hardware + 250 non-reusable film (i.e., 1/8 of $2000).

[22] Based on 2 hours D and 2 hours A (training), 1 hour D per day for 20 days.

[23] Based on 1 hour D per week for 4 weeks.

[24] Based on 2 hours A per day for 20 days.

[25] Based on $3565 hardware as follows:

Camera	$1325
Lens	810
Recorder	1095
Monitor	335
	$3565

plus $120 for reusable video tapes.

[26] Based on 3 hours A, 3 hours D training, 5 hours D per day for 20 days.

[27] Based on 1 hour D per day for 20 days.

Table 6 (Cont'd)

[28] Based on equipment listed in note 25 plus $750 additional hardware costs (tripod, mounts, cables) = $4315 + 120 for video tapes.

[29] Based on $5515 hardware as follows:

Camera	$1325
Lens	810
Time-lapse recorder	2295
Monitor	335
Tripod, mounts, cables	750
	$5515

plus $120 for video tapes.

[30] Based on equipment listed in note 25 plus $1095 for an additional recorder, $500 for additional wiring, and $750 for tripod, mounts, and cables = $5910 hardware plus $160 for video tapes.

[31] Based on 1 hour D per day for 20 days and 1 hour D per week for system check for 4 weeks.

configurations do not vary as a function of which parameter is being measured; the latter is true basically because changes in the situation do not differentially impact on measurement systems. When selecting equipment, care was taken to choose the most flexible arrangement for each system configuration, so that no further equipment would be necessary for scenario variations.

Cost-Effectiveness Ratio

With an index of system effectiveness and an estimate of system cost, the ratio of one to the other was computed in order to generate the measure of cost-effectiveness for each of the measurement systems in terms of its ability to measure each of the 18 behavioral parameters. These results are presented in Table 7. This table summarizes the data on Figures of Merit (Table 5) and Cost (Table 6), in addition to providing the critical cost-effectiveness ratio information. The two columns of cost-effectiveness correspond to the two different figures of merit. The cost-effectiveness ratio data is used to determine the best measurement system for use in measuring any particular behavioral parameter of interest. The higher the ratio, the better the system. Which of the two columns of data on cost-effectiveness to use is up to the user of this handbook and depends upon which model for combining effectiveness dimensions he feels more comfortable with. We prefer the strictly multiplicative approach represented by FOM_1 in Table 7.

Table 7 is designed to be used when the behavior(s) of interest has already been determined and the question is to select a cost-effective measurement system for the study of that behavior (and if the measurement scenario is the same as given on page 25 and there are no environmental constraints). For example, if "direction of pedestrian locomotion" was the behavior of interest, a search through the pages of Table 7 using the first column of cost-effectiveness data would lead to the choice of "direct observation" as the best system.

The cost-effectiveness ratios are expressed in "effectiveness per dollars" units; they are not percentages (although computed values did not exceed 1.0), nor should they be assumed to have any scalar properties other than ordinality. That is, a cost-effectiveness ratio of .20 is not necessarily twice as good as a ratio of .10; however, .20 is "better than" .10, which is "better than" .05. Furthermore, we cannot determine what a significant difference in cost-effectiveness would be. Nevertheless, these data are useful as a summary statistic of our judgments regarding the effectiveness and relative cost of these systems.

Table 7

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Direct Observation

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost Effectiveness$_1$	Cost Effectiveness$_2$
Pedestrian Search					
Object	196.87	53.22	$964	.204	.055
Direction	63.00	19.75		.065	.020
Duration	47.25	15.81		.049	.016
Location	105.00	30.25		.109	.031
Sequence	78.75	23.69		.082	.025
Pedestrian Locomotion					
Velocity	141.75	39.44		.147	.041
Direction	236.25	63.06		.245	.065
Acceleration	23.63	9.91		.025	.010
Position	196.87	53.22		.204	.055
Driver Search					
Object	35.44	12.86		.037	.013
Direction	47.25	15.81		.049	.016
Duration	10.50	6.63		.011	.007
Location	35.44	12.86		.037	.013
Sequence	10.50	6.63		.011	.007
Driver Control--Direction	21.00	9.25		.022	.010
Driver Control--Velocity	0.00	4.00		.0	.004
Vehicle Path	157.50	43.37		.163	.045
Vehicle Speed	105.00	30.25		.109	.031

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Interview

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object	187.50	50.87	$1088	.172	.047
Direction	270.00	71.50		.248	.066
Duration	24.00	10.00		.022	.009
Location	72.00	22.00		.066	.020
Sequence	18.00	8.50		.017	.008
Pedestrian Locomotion					
Velocity	112.50	32.13		.103	.030
Direction	108.00	31.00		.099	.028
Acceleration	48.00	16.00		.044	.015
Position	27.00	10.75		.025	.010
Driver Search					
Object	120.00	34.00		.110	.031
Direction	270.00	71.50		.248	.066
Duration	40.50	14.13		.037	.013
Location	40.50	14.13		.037	.013
Sequence	18.00	8.50		.017	.008
Driver Control--Direction	18.00	8.50		.017	.008
Driver Control--Velocity	40.50	14.13		.037	.013
Vehicle Path	120.00	34.00		.110	.031
Vehicle Speed	120.00	34.00		.110	.031

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Road Tube

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object					
Direction					
Duration					
Location					
Sequence					
Pedestrian Locomotion					
Velocity					
Direction					
Acceleration					
Position					
Driver Search					
Object					
Direction					
Duration					
Location					
Sequence					
Driver Control--Direction					
Driver Control--Velocity					
Vehicle Path					
Vehicle Speed	167.06	76.50	$1000	.167	.076

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Doppler Radar

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object					
Direction					
Duration					
Location					
Sequence					
Pedestrian Locomotion					
Velocity					
Direction					
Acceleration					
Position					
Driver Search					
Object					
Direction					
Duration					
Location					
Sequence					
Driver Control--Direction					
Driver Control--Velocity					
Vehicle Path					
Vehicle Speed	425.25	76.87	$600	.709	.128

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Real-Time Film: Ground

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost Effectiveness$_1$	Cost Effectiveness$_2$
Pedestrian Search					
Object	26.72	28.72	$2599	.010	.011
Direction	59.37	61.37		.023	.024
Duration	42.75	44.75		.016	.017
Location	71.25	73.25		.027	.028
Sequence	59.37	61.37		.023	.024
Pedestrian Locomotion					
Velocity	47.50	49.50		.018	.019
Direction	85.50	87.50		.033	.034
Acceleration	10.69	12.69		.004	.005
Position	57.00	59.00		.022	.023
Driver Search					
Object	7.13	9.13		.003	.004
Direction	38.00	40.00		.015	.015
Duration	16.03	18.03		.006	.007
Location	14.25	16.25		.005	.006
Sequence	38.00	40.00		.015	.015
Driver Control--Direction	21.37	23.37		.008	.009
Driver Control--Velocity	0.00	2.00		.000	.001
Vehicle Path	47.50	49.50		.018	.019
Vehicle Speed	21.37	23.37		.008	.009

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Real-Time Film: Aerial

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object	29.53	31.53	$2607	.011	.012
Direction	94.50	96.50		.036	.037
Duration	63.00	65.00		.024	.025
Location	98.44	100.44		.038	.039
Sequence	118.13	120.13		.045	.046
Pedestrian Locomotion					
Velocity	94.50	96.50		.036	.037
Direction	141.75	143.75		.054	.055
Acceleration	31.50	33.50		.012	.013
Position	141.75	143.75		.054	.055
Driver Search					
Object	5.91	7.91		.002	.003
Direction	52.50	54.50		.020	.021
Duration	11.81	13.81		.005	.005
Location	31.50	33.50		.012	.013
Sequence	42.00	44.00		.016	.017
Driver Control--Direction	5.25	7.25		.002	.003
Driver Control--Velocity	0.00	2.00		.000	.001
Vehicle Path	141.75	143.75		.054	.055
Vehicle Speed	32.81	33.81		.013	.013

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios for Each System x Parameter Combination

Measurement System: Time-Lapse Film: Aerial

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object	14.77	15.77	$1188	.012	.013
Direction	32.81	33.81		.028	.028
Duration	8.86	9.86		.007	.008
Location	49.22	50.22		.041	.042
Sequence	26.25	27.25		.022	.023
Pedestrian Locomotion					
Velocity	9.84	20.19		.008	.017
Direction	70.87	71.87		.060	.060
Acceleration	4.43	9.36		.004	.008
Position	41.02	42.02		.035	.035
Driver Search					
Object	2.63	3.63		.002	.003
Direction	5.91	6.91		.005	.006
Duration	3.94	4.94		.003	.004
Location	5.91	6.91		.005	.006
Sequence	7.87	8.87		.007	.007
Driver Control--Direction	1.31	2.31		.001	.002
Driver Control--Velocity	0.00	1.00		.000	.001
Vehicle Path	41.02	42.02		.035	.035
Vehicle Speed	10.50	21.50		.009	.010

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Real-Time CCTV: Ground

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object	13.36	14.36	$1665	.008	.009
Direction	29.69	30.69		.018	.018
Duration	21.37	22.37		.013	.013
Location	35.63	36.63		.021	.022
Sequence	29.69	30.69		.018	.018
Pedestrian Locomotion					
Velocity	23.75	24.75		.014	.015
Direction	42.75	43.75		.026	.026
Acceleration	5.34	6.34		.003	.004
Position	28.50	29.50		.017	.018
Driver Search					
Object	3.56	4.56		.002	.003
Direction	19.00	20.00		.011	.012
Duration	8.02	9.02		.005	.005
Location	7.13	8.13		.004	.005
Sequence	19.00	20.00		.011	.012
Driver Control--Direction	10.69	11.69		.006	.007
Driver Control--Velocity	0.00	1.00		.000	.001
Vehicle Path	23.75	24.75		.014	.015
Vehicle Speed	10.69	11.69		.006	.007

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Real-Time CCTV: Aerial

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost Effectiveness$_1$	Cost Effectiveness$_2$
Pedestrian Search					
Object	14.77	15.77	$1696	.009	.009
Direction	47.25	48.25	↓	.028	.028
Duration	31.50	32.50		.019	.019
Location	49.22	50.22		.029	.030
Sequence	59.06	60.06		.035	.035
Pedestrian Locomotion					
Velocity	47.25	48.25		.028	.028
Direction	70.87	71.87		.042	.042
Acceleration	15.75	16.75		.009	.010
Position	70.87	71.87		.042	.042
Driver Search					
Object	2.95	3.95		.002	.002
Direction	26.25	27.25		.015	.016
Duration	5.91	6.91		.003	.004
Location	15.75	16.75		.009	.010
Sequence	21.00	22.00		.012	.013
Driver Control--Direction	2.63	3.63		.002	.002
Driver Control--Velocity	0.00	1.00		.000	.001
Vehicle Path	70.87	71.87		.042	.042
Vehicle Speed	16.41	33.31	↓	.010	.010

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Time-Lapse CCTV: Aerial

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost Effectiveness$_1$	Cost Effectiveness$_2$
Pedestrian Search					
Object	1.48	14.87	$1506	.001	.010
Direction	3.28	32.91		.002	.022
Duration	.89	8.96		.001	.006
Location	4.92	49.32		.003	.033
Sequence	2.63	26.35		.002	.017
Pedestrian Locomotion					
Velocity	.98	19.74		.001	.013
Direction	7.09	70.97		.005	.047
Acceleration	.44	8.91		.000	.006
Position	4.10	41.12		.003	.027
Driver Search					
Object	.26	2.73		.000	.002
Direction	.59	6.01		.000	.004
Duration	.39	4.04		.000	.003
Location	.59	6.01		.000	.004
Sequence	.79	7.97		.001	.005
Driver Control--Direction	.13	1.41		.000	.001
Driver Control--Velocity	0.00	.10		.000	.000
Vehicle Path	4.10	41.12		.003	.027
Vehicle Speed	1.05	21.05		.001	.014

Table 7 (Cont'd)

Figures of Merit, Cost, and Cost Effectiveness Ratios
for Each System x Parameter Combination

Measurement System: Real-Time CCTV: Memory

Behavioral Parameter	FOM_1	FOM_2	Cost	Cost $Effectiveness_1$	Cost $Effectiveness_2$
Pedestrian Search					
Object	1.48	14.87	$1834	.001	.008
Direction	4.73	47.35		.003	.026
Duration	3.15	31.60		.002	.017
Location	4.92	49.32		.003	.027
Sequence	5.91	59.16		.003	.032
Pedestrian Locomotion					
Velocity	4.73	47.35		.003	.026
Direction	7.09	70.97		.004	.039
Acceleration	1.57	15.85		.001	.009
Position	7.09	70.97		.004	.039
Driver Search					
Object	.29	3.05		.000	.002
Direction	2.63	26.35		.001	.014
Duration	.59	6.01		.000	.003
Location	1.57	15.85		.001	.009
Sequence	2.10	21.10		.001	.012
Driver Control--Direction	.26	2.73		.000	.001
Driver Control--Velocity	0.00	.10		.000	.000
Vehicle Path	7.09	70.97		.004	.039
Vehicle Speed	1.64	32.86		.001	.018

PROCEDURES FOR HANDBOOK USE

The selection of a cost-effective measurement system for use in detecting and recording particular pedestrian, driver, or vehicle behavior from Table 7 is the outcome of a series of decisions facing the potential user of this handbook. In order to meaningfully access an entry in Table 7, the user must have resolved several prior issues associated with countermeasure evaluation. This section of the report elaborates these issues and provides data for their resolution. Wherever existing data are incomplete for a particular use, procedures for modifying the current tables are also provided. It should be emphasized that most of the information contained in this handbook is the result of the opinions, judgments, and assumptions of the project staff. We urge, so far as it is possible, that each user of this handbook carefully analyze the preceding sections so that he can generate his own cost-effectiveness judgments. Illustration 4 summarizes the sequence of decisions involved, the use of key tables in this handbook relevant to each decision, and alternative procedures for situations in which current data do not suffice.

1. Specification of Accident Type

The first issue to be resolved is the specification of the particular accident type for which frequency of occurrence is desired to be reduced. Throughout this handbook, we have focused on 11 of the most frequently occurring accident types as described by Snyder and Knoblauch (1971). Table 1 describes the behavioral sequences associated with each of these accident types. If, however, the user is concerned with an accident type not included in the table, he must supplement Table 1 with a description of the sequence of behaviors for that accident in terms of the behavioral parameters indicated by Table 1 column headings. So, for example, suppose that, through a study of accident records over a period of time, the user recognizes a general pattern of pedestrian accidents. He would then scan the accident descriptions in Table 1 in order to determine if his accident pattern is one of those considered. If it is not, he should describe the typical sequence of behaviors leading to the accident in terms of the parameters listed on Table 1.

2. Specification of Countermeasure

Given a particular accident type as the focus of interest, the next issue is the determination of an appropriate potential countermeasure to consider for implementation. A set of 24 actual or proposed countermeasures suggested by Snyder and Knoblauch (1971) and Berger (1975) has been included in this handbook. This set of countermeasures is by no means exhaustive. In fact, it is anticipated that a large segment of potential users of this handbook will be concerned with new countermeasure development. Thus, the user should examine Table 3 and Appendix C in order to determine which countermeasure he should implement. For example, suppose that the user is concerned with "Intersection Dash" accidents. Consulting Table 3, he finds that several countermeasures considered in this handbook have been judged to have a potential impact on this accident, including "Signal retiming or modification," "Specific driver training," "Specific adult education," "Specific preschool and primary grade education," "Stop line modification," "Preventive markings ("Caution")," and "Crosswalk setbacks." The user could select one of these for implementation or select (or develop) another countermeasure.

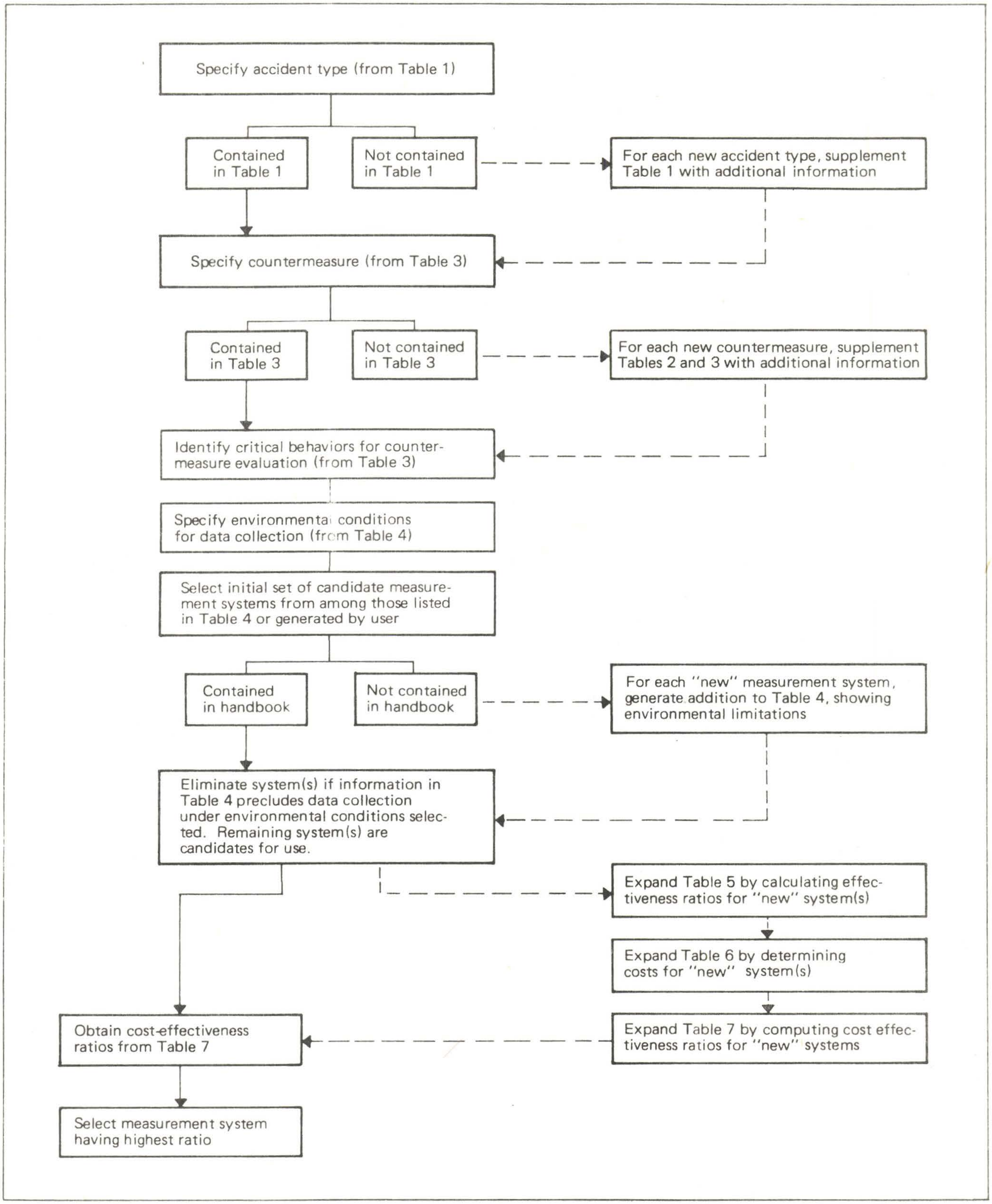

Illustration 4. Flow Chart of Procedures for Handbook Use

3. Identification of Critical Behaviors

The principal reason for the first two steps--specification of accident type and countermeasure--is to enable the user to identify critical behaviors to be measured. For the 11 accident types and 24 countermeasures considered, this step was accomplished in two stages. The first was to identify, for each accident type by countermeasure intersection, all the behaviors which we expected would be affected. The second was to select, from the set of all affected behaviors, those most critical to assess for countermeasure evaluation. The results of the first stage are shown in Table 2, those from the second stage in Table 3. Therefore, if the accident type and countermeasure under consideration by the user is in the present set, our judgments of critical behaviors can be accessed directly in Table 3. Continuing the same example as above, suppose we have selected "Signal Retiming or Modification" as the countermeasure for the reduction of Intersection Dash accidents. Consulting Table 3 (p. 16), we find that, in our judgment, the critical pedestrian behavior to measure is "Locomotion: Velocity" at the curb. If a new countermeasure is under consideration, the user must complete Tables 2 and 3 by obtaining consensus judgments of the behaviors likely to be impacted upon and of primary importance in evaluating countermeasure effectiveness. All behavioral parameters shown across the column headings of Table 3 should be considered in the judgments.

4. Specification of Conditions of Measurement

This step and the following several steps are designed to select the most cost-effective measurement systems with which to study the behaviors of interest. The initial consideration in this regard is the specification of the environmental conditions under which the data will be gathered. In order to maximize the usefulness of this handbook, the description of the data collection circumstances should be phrased in the terminology of the headings of Table 4. That is, the measurement scenario should be described in terms of Location, Crossing Zone, Area, Lighting, Traffic, Pedestrian Volume, Vehicle Speed, and Predisposing Factors.

5. Initial Screening of Measurement Systems

The purpose of this step is to eliminate from consideration any measurement system that cannot be used in the particular environmental conditions stipulated in the previous step. If the environmental description of the data gathering situation is in terms of the descriptors used in Table 4 and the user is considering only those measurement systems evaluated in this handbook, this step is accomplished directly: the user simply locates the appropriate columns in Table 4 and eliminates from consideration any system that is shown to be inappropriate. For example, suppose the behavioral parameter to be measured is Pedestrian Locomotion: Velocity and the data gathering situation is described as follows:

Location:	Intersection
Crossing Zone:	Traffic boundary
Area:	Commercial
Lighting:	Day
Traffic:	medium
Pedestrian Volume:	medium
Vehicle Speed:	medium
Predisposing Factors:	Trees

By examination of Table 4 for Pedestrian Locomotion: Velocity under each of these descriptors, it can be found that, in our judgment, four measurement systems should be eliminated from consideration--Road Tube, Doppler Radar, Real-time Filming: Ground, and Real-time Closed Circuit Television: Ground.

A user might want to consider a different measurement system or a variant of one of the present set. If this is the case, the user must add the "new" system as an additional row in Table 4 and specify the conditions under which this new system cannot be used. Only then can the user eliminate from consideration any measurement system which cannot be used under the particular conditions.

The next step in the decision process is to consider whether the resulting set of candidate measurement systems includes any not evaluated in this handbook. If there are no "new" systems, the user can proceed to step #8 below in order to find our judgment as to the most cost-effective measurement system for use in assessing the behaviors selected. If, on the other hand, a new measurement system is a candidate for use, or the user would like to exercise his own effectiveness judgments and provide his own cost estimates, the following additional activities must be carried out.

6. Determining System Effectiveness

For each new measurement system remaining as a candidate for use, an effectiveness score (figure of merit) must be determined. This is accomplished by rating the system on all the effectiveness dimensions (using the form shown in Illustration 1) for each behavioral parameter of interest identified at the conclusion of step 3. The figure of merit is computed as the product of the ratings on the six effectiveness dimensions. More detail is given in the earlier sections of the handbook (p. 27ff.).

7. Determine System Cost

For each new measurement system remaining as a candidate for use (after the initial environmental screening), cost information must be obtained, in accordance with the format shown in Table 6. It is important that the user who is generating new system effectiveness and cost estimates employ the same set of conditions of use that were used in judging the other systems. It would be impossible to compare systems unless the same conditions applied for both sets of judgments. The cost and effectiveness data provided in Tables 5 and 6 were generated within the context of a particular scenario, thereby enabling one to directly compare systems. A user who is faced with a set of circumstances markedly different from the given scenario may desire to obtain cost and effectiveness judgments for all candidate systems, both existing and new, based on a new scenario. Alternately, the user could generate data for a new system based upon the data collection scenario described in this handbook in order to permit relative comparisons among new and existing systems. This can be done since the measures of cost and effectiveness will vary in absolute magnitude but not relative to one-another as a function of the data collection scenario.

8. Compute Cost-Effectiveness Ratio

For each measurement system remaining, cost-effectiveness ratios must be obtained for each system on each behavioral parameter of interest. If the user is considering one of the systems evaluated in this handbook, the ratio can be obtained directly by accessing Table 7 for the appropriate system and parameter. For new systems, it is calculated as the ratio of effectiveness to cost as detailed in an earlier section (p. 56) of this handbook. Thus, to complete our example above, we would obtain cost-effectiveness ratios for the remaining seven measurement systems for Pedestrian Locomotion: Velocity from Table 7. These data are as follows:

Measurement System	FOM_1	FOM_2	Cost	Cost Effectiveness$_1$	Cost Effectiveness$_2$
Direct Observation	141.75	39.44	964	.147	.041
Interview	112.50	32.13	1088	.103	.030
Real-Time Film: Aerial	94.50	96.50	2607	.036	.037
Time-Lapse Film: Aerial	9.84	20.19	1188	.008	.017
Real-Time CCTV: Aerial	47.25	48.25	1696	.028	.028
Time-Lapse CCTV: Aerial	.98	19.74	1506	.001	.013
Real-Time CCTV: Memory	4.73	47.35	1834	.003	.026

9. Select Measurement Systems

The obvious criterion for the selection of the "best" measurement system for a given parameter is that system with the highest cost-effectiveness ratio. However, each user could have his own particular constraints that would further reduce measurement system options. Therefore, for this final step of system selection, each user should determine his own criteria and their weighting before making a final decision. For example, another system selection procedure might be to select the system with the highest effectiveness figure of merit, regardless of cost. For this procedure, data contained in Table 5 would be used as the sole determinant. Alternatively, system cost might be predetermined by budgetary constraints; the selection criterion might be to select the most effective systems within a particular price limit.

So, for example, suppose our criterion was the system with the highest cost-effectiveness$_2$ rating. According to the table, the direct observation system would be selected. However, suppose we wanted the most effective system (FOM_2), regardless of cost. In that case, Real-Time Filming: Aerial would be chosen.

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APPENDIX A

Measurement System Descriptions

DIRECT OBSERVATION

Direct observation by a human observer is one of the most frequently used measurement techniques for driver, vehicle, and pedestrian behavior. Little, if any, special equipment is needed for this technique, although sometimes simple mechanical devices such as a hand tally counter, a conventional speed meter, or a stopwatch are employed to aid in the data collection. Human observers may be deployed for observations either afoot or in cars; they may work singly, in pairs, or as a team. Sometimes the observers are visible on the street, while at other times their observations are made covertly from a parked observation vehicle. The technique of human observation may be performed in virtually any location or zone. It may be used to observe behaviors midblock, at intersections, or on freeways; in residential, commercial, and industrial areas; and in urban or rural settings. Observers may work independently at the same location to record all the behaviors of interest, or they may be assigned different tasks, as when one observer counts traffic conflicts or violations and the other monitors traffic flow to determine volume. Observation periods may vary in length from only a few minutes to as much as eight hours.

The position taken by the observer is largely determined by visibility considerations and the nature of the behavior he desires to observe. For intersection observations, the observer may be situated either at the corner of the intersection or in an observation car parked up- or downstream from the intersection. A position must be found which not only offers a good overview of the intersection and its approaches, but also is suitable for observation of those behaviors in which the observers are interested. Certain behaviors such as those involved in pedestrian search and locomotion require observation from a fairly close vantage point, while other behaviors, such as vehicle speed or path, require the observers to be stationed at a point with a long-range view.

Where observations are made at midblock, the position of the observer(s) is again influenced by visibility and task requirements. Observers may be spaced several hundred feet apart in order to observe when a pedestrian becomes completely visible to an oncoming car approaching at a set speed; or they may simply be stationed "near" schools, banks, stores, bus stops, etc., in order to observe general crossing behavior midblock. Observation sites may also be demarcated in some way to assist observers in classifying and recording their observations (e.g., the roadway may be subdivided or sectioned so that the position of a pedestrian while crossing can be coded). Although the observer's position may be relatively fixed, he may need to change his position as moving objects (pedestrians or cars) impede his view. The outer limits of the observational field are usually set.

Where direct observations are made by a mobile observer (as opposed to a stationary observer), the location of the observer may or may not be determined by a prescribed route. Likewise, the observer may or may not be bound by a set schedule. Cars can be used to follow other cars or to accompany subjects being observed. Cars are used mainly to detect and record driver and vehicle parameters, while pedestrian parameters are more often observed by observers afoot. The driver may act as both observer and recorder if traffic is not too heavy. For nighttime observations either another passenger is needed to record, or a recording device is used.

The behaviors measured by direct observation differ somewhat with the mode of deployment. The kinds of behaviors which have been looked at via the mobile observer range from the very general (e.g., the "suitability" of a driver's performance over a fixed course, categorized in terms of "good" and "bad") to very specific (e.g., a specific characterization of a child's walking trip home from school, including such behaviors as hesitation on curb, running, false starts, looking, size of gap in traffic accepted, and safety gap).

With varying degrees of accuracy, nearly all of the parameters of driver, pedestrian, and vehicle behavior can be measured with the direct observation technique. In the category of pedestrian search, for example, the following kinds of variables can be measured: (1) Did pedestrian track the approaching car (object); (2) Did pedestrian look adequately, inadequately, or not at all (duration); and (3) Did pedestrian search L-R-L or R-L-R, L-R or R-L, R only, or not at all (direction and sequence). Examples of pedestrian locomotion variables include: (1) At the curb did pedestrian stop completely before entering traveled portion of roadway, did he stop or pause momentarily, hesitate with no stop, slow down, or never break stride (acceleration); (2) Did pedestrian cross directly or diagonally (direction); (3) Did pedestrian approach the curb running, walking, skipping, or other (velocity); and (4) How long and how many steps did it take the pedestrian to traverse the measured test site (position). Data on driver search variables can be obtained from the following type of question: While making a turn at an intersection, did the driver look both ways and back again, did he merely look both ways, did he look toward the observer only, did he look away from the observer only, or did he just look straight ahead (object, direction, location, and sequence). Examples of vehicle characteristics which can be observed include: (1) vehicle weaving as indicated by change in lane (driver control direction and vehicle path); (2) vehicle braking, as indicated by operation of brake lights (velocity); and (3) high or low speed in relation to a following observation vehicle (speed). The unit of measurement used most often with the direct observation technique is frequency or count. Examples of other less frequently used measurement units include: cadence (steps/min.); velocity (mph); step length (in.); and distance (ft.). Among the judgmental rating categories which have been used are type of traffic conflict, safe/unsafe, good/bad, etc.

Behavior is sensed visually by the observer and generally recorded manually (though tape recorders can also be used). For carborne observations, a portable dictating machine can be used to reduce manpower requirements. Data reduction is essentially a manual operation.

The information collected via the human observer may be analyzed alone or in conjunction with information obtained through other data-gathering techniques such as an interview or photography. Observations are usually structured by a recording format.

The reliability of measurements obtained by using the direct observation technique is a function of the reliability of the observers. Observers may be given intensive training in an attempt to keep the variability of responses across observers as low as possible. Multiple observers may also be used to help improve reliability. Reliability is a complicated issue, affected not only by the observers themselves but also by the type of behavior which is being observed, the level of precision needed to measure it, the degree of subjectivity involved, the measurement unit, and other factors.

The primary cost of a direct observation system is in terms of labor, both in data collection and analysis. Labor costs vary, depending on the type and competence of persons used. Naturally, the more training which observers are given, the greater the cost will be.

In summary, the human observer constitutes a versatile sensor and recorder in terms of the range of behaviors which, potentially, he can observe. Materials and setup time are minimal. Compared to other measurement systems, the human observer attracts little or no attention from the public. The data which he records requires a minimum of manipulation for analysis. On the other hand, the highly subjective and judgmental nature of human observation introduces varying amounts of error. Although observers may be trained, it is difficult to know how accurately they are recording what they observe, particularly in a questionable situation or when observations require a high level of detail. Depending on motivational factors, behaviors either may be missed or overreported. Observers may also be required to work for odd and irregular hours, sometimes involving exposure to bad weather.

The direct observation technique appears to be best in well-lighted areas, on clear days, when traffic volume is low and pedestrian density is low-to-moderate, in areas with few sight restrictions and with observers who have been trained. When these conditions are not present, there is either too high a rate of information flow for observers to handle or the information flow is disrupted.

INTERVIEW

The interview is a measurement technique which has been used to obtain post-facto and attitudinal information about a variety of highway situations. The physical setup for an interview may be on- or off-site: For example, interviews may be administered "on-the-street"; interview stations may be set up along the roadway and drivers signaled to stop and take a questionnaire; or individuals may meet as a study group at a nonhighway site. The interview format may be quite formal, with individuals being asked a prescribed set of highly specific questions including socioeconomic and pedestrian travel data, or informal (diary approach), with individuals being asked to recall and describe unsafe behaviors or unsafe conditions which may have come to their attention.

The interview is flexible in terms of its conditions of use. It is not restricted as to location or area; it may be conducted equally well at an intersection, midblock, or on a freeway; in residential, commercial, or industrial areas. Its use is not limited to any particular time of day or traffic flow. Obviously, the appropriate zone for obtaining measurements via interview is off the roadway.

No special equipment is needed with this type of measurement system. Only the presence of an interviewer and the cooperation of interviewees is required. Unlike other measurement systems which operate without the knowledge of those whose behavior is being measured, the interview is overt and direct. The interviewee either fills out some type of questionnaire or provides verbal responses which the interviewer records. Interviews may be conducted individually or in groups, depending on how much interaction between the interviewer and the interviewee is required. Except for attitudinal and personal information, the data collected usually pertains to events or situations which occurred at some time in the past. Although hypothetical situations can be presented in an interview, it is more common for the interview to be removed in time from an actual event. The time proximity between the event and the interview may vary considerably.

Interviews have been used to obtain a wide range of information about driver, vehicle, and pedestrian behavior and attitudes. Data recording and reduction usually are a manual operation, although it is possible for a tape recorder to be used in the data collection stage. The data obtained through use of the interview technique may also be used in conjunction with data collected by other measurement systems such as direct observation.

In order to assess the potential effectiveness of interviews in measuring pedestrian and driver behaviors, it is useful to know which characteristics and problems of the interview technique might apply in the particular context it is to be used. Perhaps the greatest advantage of the interview technique is its capability of obtaining information on all parameters in the Behavioral Classification System, including behaviors which can only be inferred from observables in other measurement systems. To be given equal consideration, however, is the high probability of encountering problems in the areas of validity, reliability, and accuracy.*

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*Many ideas in the forthcoming paragraphs were derived from Cannell and Kahn (1968).

systems, and radar is essentially identical to other systems requiring either magnetic field or sound energy changes.

Road Tube

The road tube (or pneumatic tube sensor) consists basically of a rubber hose which is laid across the roadway, usually in pairs spaced four or more feet apart. One end of the tube is closed, and the other end is attached to an air switch. When a vehicle crosses the tube, pneumatic air pressure is set up against a diaphragm in the air switch causing an electrical contact to be closed. Whenever a vehicle axle passes over the tube, closing the contact points, the resulting electrical signal is picked up by a recording device. Vehicle speed can be determined from the arrival time of each set of axles at each tube. When measuring speed, road tubes are accurate to within 5% at 60 mph.

Numerous configurations are available for the installation of road tubes, and the actual configuration used will depend on the type of vehicle behavior to be detected and recorded. Although it is possible to use road tubes to measure erratic vehicle behavior, tailgating, and specific lane changes within a restricted length of roadway, complex arrangement of tubes is required in order to study these behaviors and thus is rarely performed. Road tubes are fastened to the roadway with clamps, usually where natural expansion lines of roadway exist in order to minimize their noticeability. The tubes are less visible on blacktop roadways. While they can be placed at all locations, they are not as effective at intersections since multiple vehicles are simultaneously present.

Vehicle data can be collected either on-site or transmitted by means of a communications link to a central facility. Processing may be accomplished simultaneously with data recording or stored for use at a later time. From a practical point of view, on-the-scene recording is considered more desirable because of its relative low cost, portability, and short set-up time. The reduction of data is usually done manually, unless a digital tape recorder is used in lieu of a strip recorder. In such cases commercially available digital computers are used. To facilitate their use, the data optimally should be recorded in digital form.

The biggest shortcoming with respect to the use of road tubes concerns their noticeability to the motorist and the relatively short life span of the tubes.

Doppler Radar

Doppler radar, like all on-the-roadway sensory systems, cannot be used to measure pedestrian or driver behaviors, but only certain vehicle characteristics--most commonly vehicle speed. The principle of radar is to measure speed at two points in order to compute mph. The system is most often used with an attended real-time display for speed readouts (as in the case of "speed guns") but can also be tied to an unattended pen chart time recorder to chart the speed of all passing vehicles for a fixed time period. Radar can be set up in any location, zone and area for any kind of traffic flow or lighting conditions. The only restriction on conditions of use is that a direct line of sight must be available for the beam.

For the measurement of speed, radar is quite reliable. When used with an unattended chart recorder, the data must be recorded and reduced manually. The recorder unit must be checked periodically and resupplied with paper. Radar sensors can also be used in conjunction with digital tape recorders for a permanent record of information which can be reduced and analyzed directly by computer.

Among the merits of this system are its familiarity to users (especially police), the ease and convenience of testing and repairing equipment, and the rapid recording of data.

OPTICAL SENSORY SYSTEMS

Systems using optics offer most of the advantages of human observation systems, plus the added benefit of permanent records of behavioral events. Optical systems can be classified according to whether they involve filming or closed circuit television (video tape), whether they operate in a real-time or time-lapse mode, and whether they are ground-based or elevated. This 2 x 2 x 2 arrangement is shown below. Since most time-lapse

	Time Lapse		Real Time	
	Ground	Aerial	Ground	Aerial
Film	X	√	√	√
CCTV	X	√	√	√

X = not considered
√ = measurement system evaluated

configurations are unattended, they rarely, if ever, are ground-based where they can be vandalized. Therefore, these possible systems were not included in our evaluation.

Although the remaining six configurations have been evaluated, detailed descriptions are provided in the following paragraphs only for time-lapse photography and real-time closed circuit television (CCTV). Distinctions concerning ground- vs. aerial-based arrangements have not been made for the purpose of system descriptions since their configurations essentially do not vary (i.e., the cameras used are identical; only implementation hardware may differ) on this basis. Likewise, configurations are identical whether the system operates in a real-time or time-lapse mode (except for differences in hardware needed for time-lapse operation). For these reasons, only one filming and one CCTV system configuration is discussed in detail.

Time-Lapse Photography

A time-lapse photographic system is an approximation to the capability of the human observer to detect the full range of pedestrian, driver, and vehicle parameters. In addition, film-based systems have the advantage of providing a permanent record of entire behavioral sequences. Since many of the parameters under consideration may either be short in duration, or require an accurate time or distance judgment, or occur simultaneously, the potential benefits of a permanent record are obvious. Furthermore, instead of being located in the traffic environment, the "observer" in a time-lapse photography system usually serves as a movie film viewer--reviewing, for example, four hours of pedestrian and vehicle behaviors which have been reduced on film to less than an hour. However, these advantages are obtained at the direct and indirect expense of necessary equipment purchases, implementation costs, and maintenance costs.

The basic hardware components of a time-lapse photography system include:

1. a movie camera with provision for single-frame operation (preferably with a variety of shutter speeds)

2. a large (400 ft.) film magazine

3. a motorized film advance

4. an intervalometer for shutter operation (preferably with the capability for accepting external signals to initiate time-lapse sequences) and

5. a projector (preferably variable speed and reversible) and screen for use in viewing the film.

When time-lapse photography systems are employed, a major consideration is the frame rate. The variables which determine the optimum rate including the average time duration of the behavior--that is, the average length of time during which a pedestrian, vehicle, or driver is engaged in the behavior of interest or during which they can be seen by the camera. Another variable is the rate or frequency with which behaviors occur. Other important considerations are the field of view of the camera and the slowest frame rate which will still permit relatively rapid playback giving an approximately natural perception of the behaviors.

Of the variables just cited, the camera field of view and the slowest acceptable frame rate are determined by the parameter(s) chosen for measurement. It is not necessary to set precise values for these variables, since actual equipment will limit to some extent the choice of both field of view and frame rate. For example, time-lapse rates are available from off-the-shelf intervalometers at rates of one exposure each 1/2 second, one per second, one every two seconds, etc. Other fixed rates are also available, and continuously variable rates can be employed at some sacrifice of accuracy. Similarly, various fields of view can be selected by having available a variety of lenses or a turret arrangement.

The probability of recording behaviors using time-lapse photographic techniques is a function of the camera frame rate and the duration of the behavior to be recorded. Suppose that the exact duration, T, of a behavior is known. Let R be the camera frame rate and P_{det} the probability of detection. As Bissel et al. (1970) have demonstrated,

$$P_{det} = 0 \qquad 0<T<1/R$$
$$P_{det} = R(T-1/R) \qquad 1/R<T<2/R, \text{ and}$$
$$P_{det} = 1 \qquad T>2/R$$

The expression for P_{det} when $1/R<T<2/R$ is obtained by noting that the probability of detection must increase linearly as T or R is increased between the limits given by the first and third expressions. Since all behaviors are detected when $T\geq 2/R$, nothing is gained by operating at faster frame rates. A more realistic analysis must account for a distribution of values for T, but results are similar provided that behaviors are unlikely which are shorter than half of the average duration.

It is clear that the time-lapse photography system is most efficient for parameters which have the longest duration. Another factor of great importance is the rate at which behaviors are expected to take place, and advantage can be gained in this regard by employing an observer to actuate the camera during periods when the behavior rate is expected to be high.

The measurement of distance in time-lapse photography creates considerable problems. For example, in installation, grid points must be carefully located on the ground and marked and photographed so that a perspective grid can be constructed for the study area. This degree of site preparation is expensive, and may not be justified for the general case in which the time-lapse system will be used at different locations for relatively short time periods.

In general, the data extraction and reduction procedure is to review the film at a projection speed which is fast enough to give the analyst an approximately natural impression of the vehicles and pedestrians in motion and to permit the detection of selected behaviors through ordinary perceptive abilities. Accordingly, if the data reduction procedure for a particular parameter is simply one of counting, it is not expected to be a time-consuming operation. On the other hand, some parameters may require substantially more review time.

In addition to equipment purchases (which, if amortized over the expected lifetime of the equipment is actually a relatively minor expense) and implementation costs, a major cost consideration is film purchase and processing. Film costs can be roughly estimated at $50.00 per 400 ft. roll for purchase and an equivalent sum for processing. It is crucial, from a budgetary perspective, to minimize the amount of wasted film. Among alternative film system configurations, the least costly is an attended time-lapse system: a time-lapse camera, triggered by a human observer. Other configurations (e.g., a completely unattended system or observer-triggered real-time filming), while having unique advantages and disadvantages, are substantially more costly.

Real-Time Closed Circuit Television (Video Tape)

Closed circuit TV has been or potentially can be employed in a real-time configuration for the monitoring and recording of pedestrian, driver, and vehicle behavior without being prohibitively expensive. The basic hardware components are a video camera equipped with a suitable lens, a video recorder, and a receiver/monitor unit. (For other configurations evaluated below, additional hardware elements include a time-lapse video recorder, additional monitors, and assorted connections and mountings.) The system, as generally envisioned, uses a human observer, sighting through the camera lens, and triggering a video recording of selected behavioral events (e.g., a pedestrian crossing). After a period of recording, the tape is then played back through the monitor and analyzed. A unique aspect of video tape systems is that the tape can be reused, thereby saving considerable costs over equivalent film systems.

Similar to human observers, closed circuit TV with video tape recording can potentially be employed in virtually all locations and zones. The major limitation to its use are its relative non-portability and the necessity for adequate lighting. Since the camera and recording unit are separate, it is not feasible for the observer to change his position substantially across a data recording session. Closed circuit television is effective in the detection of all those behaviors discussed previously in connection with time-lapse photography. Not only does it approximate the capability of the human observer to detect the full range of parameters, but it also has the advantage of being able to store a large number of pictures per reel compared to photography.

In comparison with time-lapse photography, a real-time system avoids the possibility that a particular short-duration behavior will be missed. Other advantages accrue from the use of video tape instead of standard film: There is no processing delay for video tape; and tape cassettes are easier to handle and operate for playback and data analysis, and are also easier to store.

The major difficulty with CCTV systems is that they require more equipment than other systems previously considered. This is reflected in high initial equipment purchase costs, implementation difficulties, and high probability of significant maintenance expenses. However, video tape is one of the fastest-growing communication industries; new product developments and increased familiarity with the medium may serve to assuage these difficulties.

APPENDIX B

Accident Type Descriptions*

*Taken (with minor modifications) from Snyder and Knoblauch (1971).

Dart-Out First Half

A pedestrian, <u>not</u> in an intersection crosswalk, appears suddenly from the roadside. His quick appearance and short-time exposure to the driver are the critical factors. The pedestrian may often be running, and parked cars often obstruct vision, but neither need be present if the basic condition of sudden appearance to the driver's view is met. The prime example of the dart-out is a school-age child running out from between parked cars on his own block, in a residential area in the center city in the afternoon after school. He heads straight across the relatively narrow street, looking where he is going and is struck less than half way across. The driver, traveling at a normal rate of speed, did not have enough time to stop after detecting the child.

Dart-Out Second Half

This is the same as the dart-out described for the first half above, except that the pedestrian covers half of a normal crossing before being struck. The distinction is made because of the possible differences in the opportunities or problems relative to driver detection and recognition of danger if the roadway is clear. However, this label is used even if traffic obscured the driver's vision. This label may be used even if the pedestrian crosses a medium-size median strip of a boulevard.

Intersection Dash

This category covers cases similar to dart-outs with regard to pedestrian exposure to view, but the incident occurs in a marked or unmarked crosswalk at an intersection. Cases are included if the pedestrian is running across the intersection even though his exposure to possible driver view is not extremely short. (His speed will, in effect, limit his actual exposure to the driver.)

Vehicle Turn/Merge With Attention Conflict

The driver is turning into or merging with traffic; the situation is such that he attends to auto traffic in one direction and hits the pedestrian who is in a different direction from his attention. A critical feature is that the attention conflict is built into the situation. Usually the driver directs his attention in a given direction to determine an acceptable gap into which he will enter.

Pedestrian Strikes Vehicle

This classification covers crashes <u>not</u> covered by other clear types (e.g., dart-out), in which it has been determined that the pedestrian ran or walked into the car.

Multiple Threat

The pedestrian is struck by car X after other cars blocking the vision of car X stopped in other lanes, going the same direction, and avoided hitting the pedestrian. For example, cars in lanes 1 and 2 stop and permit the pedestrian to cross; car X in lane 3 going in the same direction hits the pedestrian as he steps out in front of the car in lane 2. This classification is not used if the striking vehicle is going in the opposite direction from the stopping cars. (In that situation the stopping cars would not block the driver's vision.)

Bus Stop Related

This type does not include those cases that may be considered as exiting from a vehicle, nor does it include cases that may be described as rear-wheel truck or bus. It does include all other cases whose occurrence revolves around a bus (taxi, trolley, etc.) stop, unless the stop is only an attraction or distraction. In other words, the location or design of the stop appears to be a major factor in the causation; e.g., the pedestrian crosses in front of the bus standing at a stop on the corner, and the bus blocks the view of cars.

Vendor--Ice Cream Truck

The pedestrian is struck going to or from a vendor in a vehicle on the street. This is usually similar to a dart-out, with ice cream trucks being the most frequent attraction. This more specific classification is given precedence over dart-out when assigning cases to types.

Backing Up

The pedestrian is struck by a vehicle which is backing up. A case would not be so classified if the pedestrian were clearly aware of the movement of the vehicle; detection failure is important. This type is used even if the accident occurs off the street.

Nonpedestrian Activity in Roadway

The victim is performing a specified activity in the roadway, such as repairing the street, painting the curb, etc. A person who goes into the street to retrieve an object or avoid a danger is not included.

Freeway/Expressway--Crossing

The victim is a true pedestrian going somewhere and crossing the freeway. He was not a passenger or driver who exited from a car on the freeway.

APPENDIX C

Countermeasure Descriptions*

*Taken (with minor modifications) from Snyder and Knoblauch (1971) and Berger (1975).

Street Parking Redeployment

This countermeasure is aimed primarily at the dart-out accident types. The objective is to use parking control to remove some of the visual obstruction, provide a partial barrier to physically control the pedestrian course, and increase the likelihood of detection. This countermeasure is suggested for consideration on certain residential streets, not main arteries. Its application is described for a one-way three-lane street with two lanes of parallel parking, but other existing situations could be modified to achieve the same result.

Two steps would be taken. First, parking would be removed from one side of the street, preferably the left. Second, head-in diagonal parking would replace parallel parking on the right.

Prohibition of On-Street Parking

This countermeasure appears likely to be effective, but not likely to be feasible, except in certain cases. It would reduce dart-outs and to a lesser extent intersection dashes. The areas that would benefit most, the crowded center city areas, have the worst parking situation and highest on-street parking requirements. Off-street facilities would have to be provided.

Meter Post Barrier

In commercial areas with on-street parking meters, small fences or railings extending out a few feet from either side of the meter post could combine with parked cars to form a barrier to prevent dart-outs. Two variations are possible. In one arrangement the barrier would be designed to permit a pedestrian to go between it and the car. He could exit between parked cars to the street; however, it would be difficult for him to run out between the parked cars. This arrangement would permit the driver to get out his side of the car and get to the sidewalk. In the second arrangement, the small barrier would be placed in such a manner that it would be extremely difficult, if not impossible, for a person to pass between it and a parked car. This would be more effective against dart-outs, since it would also eliminate the cases with short-time exposure that did not involve running. Drivers, however, would not be able to get out their side (on a two-way street) and get to the curb without walking in the street for a distance. This might be viewed as an advantage if it induced drivers to slide over and exit on the curb side instead of the street side of the car, thus reducing street side accidents. Further design and study are needed to determine which option is best.

Signal Retiming or Modification

One of the predisposing factors identified for the intersection dash was the inducement to risk-taking coming from the traffic signal. The pedestrian is wrong to cross against the light. He should wait until he has the proper signal, but it is apparent that some will become impatient when they must wait. In some locations, longer than usual waiting periods are involved in order to move heavy traffic volumes. However, it must now be recognized that this may induce pedestrians to take risks because they are impatient. Standard time periods cannot be recommended on the basis of this study. The best specific treatment will depend on the individual nature of the intersection and its vehicle and pedestrian volumes.

Specific Driver Training

Driver training should be expanded to include two areas relevant to avoiding dart-out and dash type accidents. First, there should be concise coverage of basic information about the accident types included in this group so that drivers will be aware of the extent of the problem, the patterns of pedestrian behavior they may expect, and the times and locations in which they may be expected. All this is directed at improving "normal" driver search and detection of the dart-out and dash types. In addition, the second area would deal specifically with recognition of potential "pedestrian strikes vehicle" cases and the use of the horn to induce evasive action by the pedestrian.

Sidewalk Parks

This countermeasure is aimed primarily at the reduction of dart-outs. Streets which are adequate in width from curb to building line could be improved by providing a park type area physically separated from vehicle traffic. Physical barriers by themselves are unattractive and politically unfeasible. However, a park fence with a park is something different. The objective would be to provide small play areas for preschool and primary grade children (e.g., a concrete pipe fixed in cement) that would still permit pedestrian traffic. Shrubs and trees would make the fence more acceptable.

Specific Adult Education

Adult education on the nature and seriousness of the problem with respect to types in this group can do two things. First, it can help develop the motivation for individual action and enlist the community support to implement other countermeasures. Secondly, it can provide specific suggestions to parents about (a) the manner of preschool-age child pedestrian supervision required and (b) instructions for parents to give school-age children going on specific pedestrian trips. (The former is directed at certain dart-outs and the latter is directed primarily at intersection dashes.)

Specific Preschool and Primary Grade Education

Preschool education, whether face-to-face, or by public television should focus on sidewalk play activity in relation to pedestrian accidents. Rather than how to cross the street, the more important message is how to play (to keep from running into the street and becoming a dart-out). At school age, additional emphasis can be put on purposeful trip making and problems in commercial areas (related to dart-outs and intersection dashes).

Stop Line Modification

This countermeasure is directed primarily at multiple threat accidents occurring at signalized intersections in commercial areas. In order to reduce the incidents where cars stopped at the stop line obscure the view from the striking car, a wide stop or limit line should be placed a number of feet prior to the crosswalk. Although specific design would depend on a number of factors at the particular location, the objective is to stop the cars far enough back so that a pedestrian in the walk is likely to be noticed by cars other than the ones facing him. The recommendation given by the Manual on Uniform Control Devices for a stop line about 4 feet in front of the nearest crosswalk may not go far enough.

Driver Procedures and Traffic Ordinance

This countermeasure is aimed at those multiple threat accidents that occur midblock or at noncontrolled intersections. Such accidents happen because some driver(s) yields to a pedestrian. The model traffic ordinance states that "whenever any vehicle is stopped at a marked crosswalk or at an unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway, the driver of any other vehicle approaching from the rear shall not overtake and pass such stopped vehicle. A similar restriction probably applies in most cities that require a driver to yield to a pedestrian at other locations. The driver apparently fails to obey the overtaking and passing restriction because he is not aware of the pedestrian.

The driver of the vehicle that has stopped is aware of the pedestrian and has demonstrated his willingness to follow the accepted procedure to assist the pedestrian. In such situations, he is a prime candidate for rendering assistance. This driver could further assist by warning drivers coming behind him by signaling them to stop. Any driver yielding to a pedestrian in the absence of a control device should be trained and required to signal any cars approaching from his rear to stop. This countermeasure calls for a combination of the development of a standard hand signal (meaning more than just that the vehicle has stopped or is stopping); local ordinances, and appropriate public education and driver training so that drivers yielding to pedestrians protect them from overtaking vehicles.

Intersection Lighting and Removal of Visual Obstructions

Although the improvement of lighting at intersections is a general countermeasure that would be expected to reduce various nighttime accidents, it is noted here because it is about the only feasible action to take to reduce pedestrian waiting to cross accidents.

It is recommended that special attention be given to provide adequate illumination of the intersection crossings in commercial, and mixed commercial-residential areas as well as apartment areas from which people are likely to walk to social activities. At the same time that sites are reviewed for adequacy of lighting, visual obstructions such as sign posts and street parking near intersections should be identified and removed or relocated when possible.

Right Turn Attention Conflict Reduction

This countermeasure is aimed at the reduction of a portion of the accident type labeled vehicle turn/merge with attention conflict--specifically those involving right turns at nonsignalized intersections or at signalized intersections with right turn on red permitted. It involves the review of intersections in commercial areas with the objective of removing the basic attention conflict situation for the driver by selecting one of a number of possible actions. Those which may be considered are:

- Removal of right turn on red
- Signalization of intersection
- Control of cross traffic by stop sign
- Effect one-way traffic on street to right, coming from the right
- Pedestrian barrier if right turn on red needed
- Pedestrian-only signal phase.

Preventive Markings

This countermeasure consists of the word "CAUTION" painted on the curb or road. Also, signs stating "Watch out for Vehicles" are posted alongside the roadway.

Median Barrier

This countermeasure consists of installing a barrier located on the median of a road.

Crosswalk Set-Back

For this countermeasure, the crosswalk is moved toward midblock. It may also include the installation of pedestrian barriers at the corners.

Midblock Crosswalk

A pedestrian crosswalk is installed at or near midblock.

Bus Stop Relocation

It is suggested that bus stops be located at the far side of the intersection so as to minimize visual interference. It should be noted that one city in the Berger (1975) study had no bus stop related accidents. Upon investigation it was determined that over 90% of its bus stops had already been relocated to the far side.

Backup Warning Devices

It is suggested that all new vehicles be equipped with an auditory warning device that is activated when the car is in reverse, as are backup lights. A pulse type "beep" signal similar to that used on many construction vehicles appears most effective. Frequency requirements should be set considering the pattern of hearing loss that accompanies old age. In addition, consideration should be given to the placement of backup lights so that they, too, can be more effective as a warning during daylight hours.

Freeway Design For Vehicle Repair

This countermeasure is directed at freeway drivers who become pedestrians when they have vehicle trouble. Space must be provided to permit and induce the driver/pedestrian to pull off far enough from the traveled portion of the roadway to be safe.

Freeway Repair Regulation and Warning Signs

This countermeasure is also directed at the pedestrian who leaves his car on the freeway. Effective alternative means for repairs to cars that become disabled on the freeways should be provided. In addition, personal repair work on freeways might be prohibited. Motorists would have to be informed of the specifics by signs and other means. Adequate communications to secure aid would have to be provided (e.g., call boxes, vehicle and helicopter patrols).

Roadway Worker Protection Requirements

Various warning devices and protective measures are available to limit the possibility of workers in the road being struck. These include the use of flashing lights on vehicles and barriers, warning flags raised above car top level, bright reflective vests, advance warning signs, and placement of work vehicles in the roadway as a warning and barrier. While some private organizations, like the telephone company, appear to have excellent programs, it is recommended that local jurisdictions establish specific standards that will require all who are permitted to work in the street to adhere to the same kinds of procedures.

Left Turn Attention Conflict Reduction

The problems and actions for left turn attention conflict reduction are the same as for the right turn with one difference. The left turn problem also includes the situation in which a driver is proceeding on the green and must select a gap in oncoming traffic in order to make his left turn. Additional actions to be considered are:

- Prohibition of left turns
- Use of left turn only arrows (protected from oncoming traffic)
- Use of leading or lagging green with notice to driver

Pedestrian and Driver Education--Legal Intersection Conflicts

This countermeasure involves the provision of specific information about the nature of the vehicle turn/merge conflict type and other legal turn conflicts along with the correct search pattern for the pedestrian and driver. A particular objective would be to get pedestrians to attend to the potential turning vehicle threat.