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THE GENERAL DETERRENCE OF DRIVING WHILE INTOXICATED
Volume I: System Analysis And Computer-Based Simulation

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The report consists of Volumes 1 and 2. Volume 2 describes detailed subsystem analyses. In addition, a user's manual was provided to accompany the computer-based simulation program. The Contract Technical Manager was Mr. Ted Anderson.

16. Abstract

A system analysis was completed of the general deterrence of driving while intoxicated (DWI). Elements which influence DWI decisions were identified and interrelated in a system model; then, potential countermeasures which might be employed in DWI general deterrence programs were examined by means of a computer-based simulation based on the model.

The simulation program, DETER, employed fixed-time step simulation in which the processing of events, within a time step, was based on an expected value Poisson flow model. Simulation experiments assessed the sensitivity of system parameters and evaluated alternative countermeasure approaches.

Two types of results are presented: Those which specified the nature of general DWI deterrence and the relative potential of alternative countermeasures; and those which identified gaps in existing knowledge and suggested the need and direction for further research.

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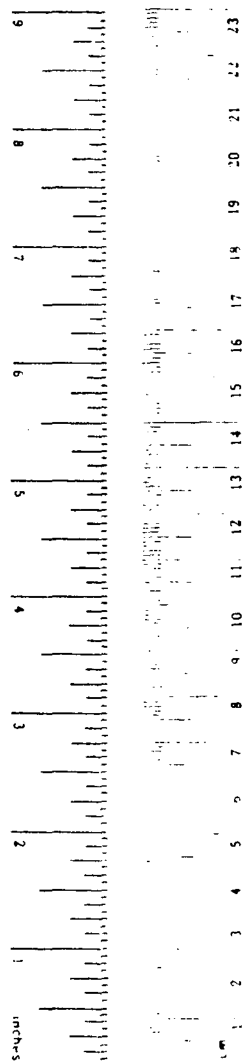
METRIC CONVERSION FACTORS

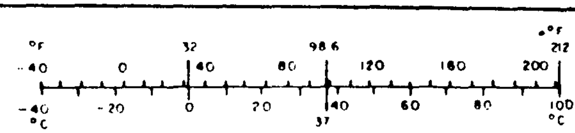
Approximate Conversions to Metric Measures

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



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



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INTRODUCTION AND SUMMARY

A system analysis was completed of the general deterrence of driving while intoxicated (DWI). The analysis identified system elements relevant to the DWI decision and assessed the potential of countermeasures that might be employed in general deterrence programs. This report defines the DWI general deterrence framework, describes the analytical methods employed, and presents the conclusions and recommendations derived from the project results. Of even more importance, the report presents a system model for interrelating factors which influence DWI deterrence and an associated computer-based simulation program for examining DWI deterrence alternatives. The model and simulation should be useful tools for traffic safety program managers to guide future research and countermeasure development.

The system analysis and system model development were based on existing data. Therefore, although system elements relevant to DWI general deterrence could be identified with confidence, many of the interrelationships among elements could not. At this time there are many knowledge gaps, and much data to be collected and analyzed before these gaps will be bridged; but a primary value of completing the system analysis at this time was to identify requirements for additional data and to define the nature of needed research. By integrating existing knowledge into a system model and by exercising this model by means of computer-based simulation to determine the relevant sensitivity of system parameters, priorities for future research can be established.

OBJECTIVES

The ultimate purpose of this line of research is to develop a computer-based system model to assess the feasibility and the potential effectiveness of DWI general deterrence programs. Specifically, the objectives of the completed project were:

- To identify system elements relevant to the DWI decision process and to specify factors likely to be influential in DWI general deterrence

- To define countermeasure program components and associated interactions which are capable of influencing the DWI decision process
- To develop a system model of DWI general deterrence
- By means of a computer-based simulation program of the resultant system model, to assess system parameter sensitivity and the potential effectiveness of alternative countermeasure programs in terms of DWI trips and related accidents
- To identify additional data requirements and research studies necessary to determine countermeasure program feasibility and effectiveness.

DWI GENERAL DETERRENCE

The deterrence of DWI is promoted through the employment of law enforcement measures and the imposition of sanctions on those found to be in violation of the law. Within this context, deterrence operates at two levels--general and specific. General deterrence is the effect of a threatened sanction on behavior in the general population to which the law is addressed. It includes the full range of educative and habituative influences which might emanate from the law and its associated sanctions. Specific deterrence, on the other hand, deters not from threat alone, but from the actual application of enforcement actions and sanctions. Because the available enforcement and adjudication resources are limited and attenuated when spread among the motorist population, specific deterrence alone can have only a relatively small impact. Consequently the deterrence of drunk driving is mainly a function of the level of detection, apprehension, and sanction of DWI *and* the awareness of such action by the driving public.

Utility theory provides a useful framework within which to examine DWI general deterrence and the decision processes involved, because it incorporates the counteracting forces at work in the DWI decision process--expected utility of the DWI trip versus the perceived risk of the trip. Expected utility is the value anticipated from making the trip; perceived risk is the assessed probability of arrest or accident combined with the potential severity of the outcome--death, injury, license suspension, jail, embarrassment. The functional relationship between expected utility and perceived risk is of paramount importance to DWI general deterrence. Evidence suggests that most people are characterized by risk avoidance--they tend to avoid severe risks. If the outcome is potentially severe, people tend not to take the risk even though the probability of the outcome might be very low.

Since the DWI decision depends upon the perceived risk of DWI, the expected utility of a DWI trip, and the risk aversion characteristics of drivers, factors likely to influence DWI general deterrence must operate through these primary components of the decision process. Functions of the traffic law system relate mainly to the perceived risk component of the process. Countermeasures are introduced through changes in DWI traffic laws, enforcement, or adjudication. These changes generate information which is channeled directly or indirectly to the driver to influence his perception of risk. The information might come to the driver as a consequence of special deterrence; or by indirect exposure through observation, word-of-mouth, news media accounts, or general educational or persuasive means. A detailed discussion of DWI general deterrence, including a critical examination of relevant literature, starts on page 9 of the report.

DEVELOPMENT OF A SYSTEM MODEL

A system model of DWI general deterrence was developed through the application of system analysis methods. Factors likely to influence the DWI decision were related to each other and to the DWI decision process itself. The resulting model provided the basis for the design of a computer-based simulation to assess the feasibility and potential effectiveness of alternative countermeasure programs. The model is described verbally, schematically, and mathematically in the report. A top-level flow diagram of the model is provided in Figure 3 on page 32.

COMPUTER-BASED SIMULATION

A computer-based simulation program was developed to exercise the DWI general deterrence model. The simulation permitted the dynamic manipulation of system variables likely to affect the number of DWI trips taken and to distinguish among the potential of different countermeasure programs for reducing the number of alcohol-related accidents.

The simulation program incorporates the three main networks of the DWI general deterrence model--the driver-trip network, the adjudication network, and the information feedback network. The different units which flow within these networks are respectively: driver-trips, arrested drivers, and drivers' perceived risk levels. The three network flows are interconnected. For example, the driver-trip network produces DWI arrests which enter both the information and adjudication networks. The adjudication network processes the DWI arrests and produces the ratio of convicted DWI drivers. This ratio, in turn, influences the arrest rate in the driver trip network. The information network processes the arrest rate to influence the driver's perceived risk level in the driver-trip network.

A detailed description of the simulation program, including the various networks and routines of which it is comprised, starts on page 51 of the report.

SIMULATION EXPERIMENTS

Experiments were conducted using the computer-based simulation program to assess the sensitivity of system parameters and to evaluate the potential of different countermeasure approaches. The experiments incorporated the following steps:

1. Baseline perceived enforcement weights were estimated and calibrated using roadside breath test survey data.

2. Confidence limits for analyzing the results of countermeasure program changes were determined from year-to-year variations in performance measures by means of Monte Carlo simulation.

3. Assessments of parameter sensitivity were made by varying parameter values throughout reasonable ranges established for them, and determining the effect of their variability on DWI trips and related accidents.

4. Enforcement, adjudication, and public information countermeasure programs were assessed experimentally in terms of impact on DWI trips and related accidents.

5. Experimental results were compared to known results of actual countermeasure programs to assess the extent to which the computer-based simulation program could have accurately predicted the outcomes.

A detailed description of the simulation experimentation starts on page 69 of the report.

CONCLUSIONS AND RESEARCH RECOMMENDATIONS

The system analysis identified factors which influenced driving while intoxicated, produced a systems model of DWI general deterrence, examined the sensitivity of system parameters relative to DWI trips and accidents, and assessed countermeasure approaches. Results were of two types: those which led to conclusions about the nature of general deterrence and the relative potential of alternative countermeasures; and those which identified gaps in existing knowledge and suggested the need and direction for further research.

Conclusions

- Any significant reduction of DWI trips or related accidents must necessarily be affected through general rather than special deterrence. Because available enforcement and adjudication resources are limited and attenuated when spread over the motorist population, special deterrence alone can have only a relatively small impact.
- DWI general deterrence depends critically upon drivers' perceived risk of DWI trips and on the risk aversion characteristics of potential drinking drivers. Within the framework of utility theory, taking a DWI trip is a decision trade-off between the expected utility and the perceived risk of the trip. The perceived risk, in turn, is influenced by the expected probability of being arrested and convicted, and by the expected severity of the imposed sanction. The functional relationship between utility and risk depends upon the nature and extent of risk aversion--the tendency to avoid severe risks.
- Relatively small changes in perceived enforcement rate are likely to produce large changes in number of DWI trips or related accidents. This conclusion emanated from simulation experiments. However, as shown in these experiments, information feedback on enforcement was required to change the perceived risk of drivers.
- Word-of-mouth feedback from apprehended or sanctioned drivers is not likely to result in any significant reduction in DWI trips or related accidents. The simulation experiments showed that enforcement programs which provided only word-of-mouth feedback did

not significantly deter DWI. The effect was minimal even when assumptions about the extent and effectiveness of word-of-mouth feedback were carried to extremes.

- Increased visibility of enforcement may reduce DWI trips and related accidents only when combined with factors that drastically increase perceived enforcement rate when drivers are exposed. The simulation experiments indicate enforcement visibility deters DWI, if there is a tenfold increase in the perceived enforcement weight. Increased enforcement activity may be effective if it is combined with program changes such as a prearrest screening law or legislation of roadblocks for breath testing.
- The greatest potential for reduced DWI trips or related accidents is through wide-spread dissemination of information emanating from effective and consistent DWI enforcement and adjudication action. Results of simulation experiments indicated that public information is potentially the most effective method of exposing drivers to information on the risk of drinking and driving. The initial effectiveness of the countermeasure program implemented with the 1967 British Road Safety Act and the subsequent loss in effectiveness of this program is consistent with the results of simulation experiments, in this regard.

Research Recommendations

The system analysis showed that additional empirical evidence on basic variables involved in decisions to drive while intoxicated is needed and that programs to increase public awareness of risk of apprehension and sanction need to be developed and evaluated. The following specific research recommendations were derived from the system analysis and the results of the simulation experiments.

- *Perceived Risk of Enforcement.* Empirical evidence is needed to identify factors which influence perceived enforcement, the extent to which perceived enforcement can be modified, and the extent of variability in perceived enforcement rate among drivers and over time.
- *Sanction Awareness.* Research is needed to determine the degree of sanction awareness among potentially drinking drivers, and the degree to which sanction severity influences DWI deterrence.
- *Utility of DWI.* Empirical data are required to determine the relative value placed on driving while intoxicated and to determine what variables influence these values.
- *Nature and Degree of Risk Aversion.* Although DWI general deterrence depends on the risk aversion characteristics of potential drinking drivers, little is known of the shape of the risk aversion curve, the extent of individual differences in risk aversion, the nature

of factors which might influence or modify risk aversion characteristics, or the extent to which risk aversion is correlated with other driver characteristics. Research is required to determine the nature and extent of risk aversion.

- *Increased Visibility of DWI Enforcement.* Enforcement procedures that increase the probability of driver exposure need to be identified and related to perceived enforcement.
- *Evaluate Public Information Messages.* Content and exposure of public information messages need to be related to measures of perceived risk including perceived enforcement and sanction awareness.
- *Evaluate Message Exposure Techniques.* Message insertion rate and population exposure need to be related to measures of message recall.
- *Overall Effectiveness of DWI General Deterrence.* Large scale studies are required to obtain valid estimates of the effectiveness of DWI general deterrence by implementing integrated programs within each of a number of selected jurisdictions and comparing the resultant DWI trip rates and accident rates with those of a number of matched control jurisdictions.

GENERAL DETERRENCE

The Uniform Vehicle Code makes driving a vehicle while intoxicated (DWI) unlawful. This law, and numerous others, make up a traffic law system within the United States which establishes rules to be followed by motorists to advance the safe and orderly flow of traffic. Assuming that the rules are valid, the effectiveness of the system depends upon the extent to which people adhere to the rules and refrain from unlawful driving acts. As a consequence, deterrence of DWI and other unlawful acts is promoted through law enforcement measures and the imposition of sanctions on those found to be in violation of the law.

Within this context, deterrence operates at two levels. *General deterrence* is the effect of a threatened sanction on behavior in the general population to which a law is addressed. It includes the full range of educative and habituative influences which might emanate from the law and its associated sanctions. *Special deterrence*, on the other hand, deters not from threat alone, but from the actual application of a sanction.

The traffic law system, by necessity, must rely upon general deterrence. Because available enforcement and adjudication resources are limited and attenuated when spread over the motorist population, special deterrence alone can have only a relatively small impact. The size of the potential impact on DWI can be seen from the very low probabilities of arrest or alcohol-related accident shown in Figure 1. The probability of each DWI decision outcome was derived from data collected in recent studies. (The calculations and data sources are provided in the Appendix. Each probability shown is for the total events to that point. For example, the combined probability of DWI, arrest, *and* conviction is 0.0000062.

Although the likelihood of having an accident and/or being arrested is six times greater for DWI than for driving while sober (DWS), the combined probability of these outcomes for DWI is only 0.00089. Thus, less than 1 DWI trip in 1000 would lead to the potential application of special deterrence. At this rate, even the cummulative effect over an extended

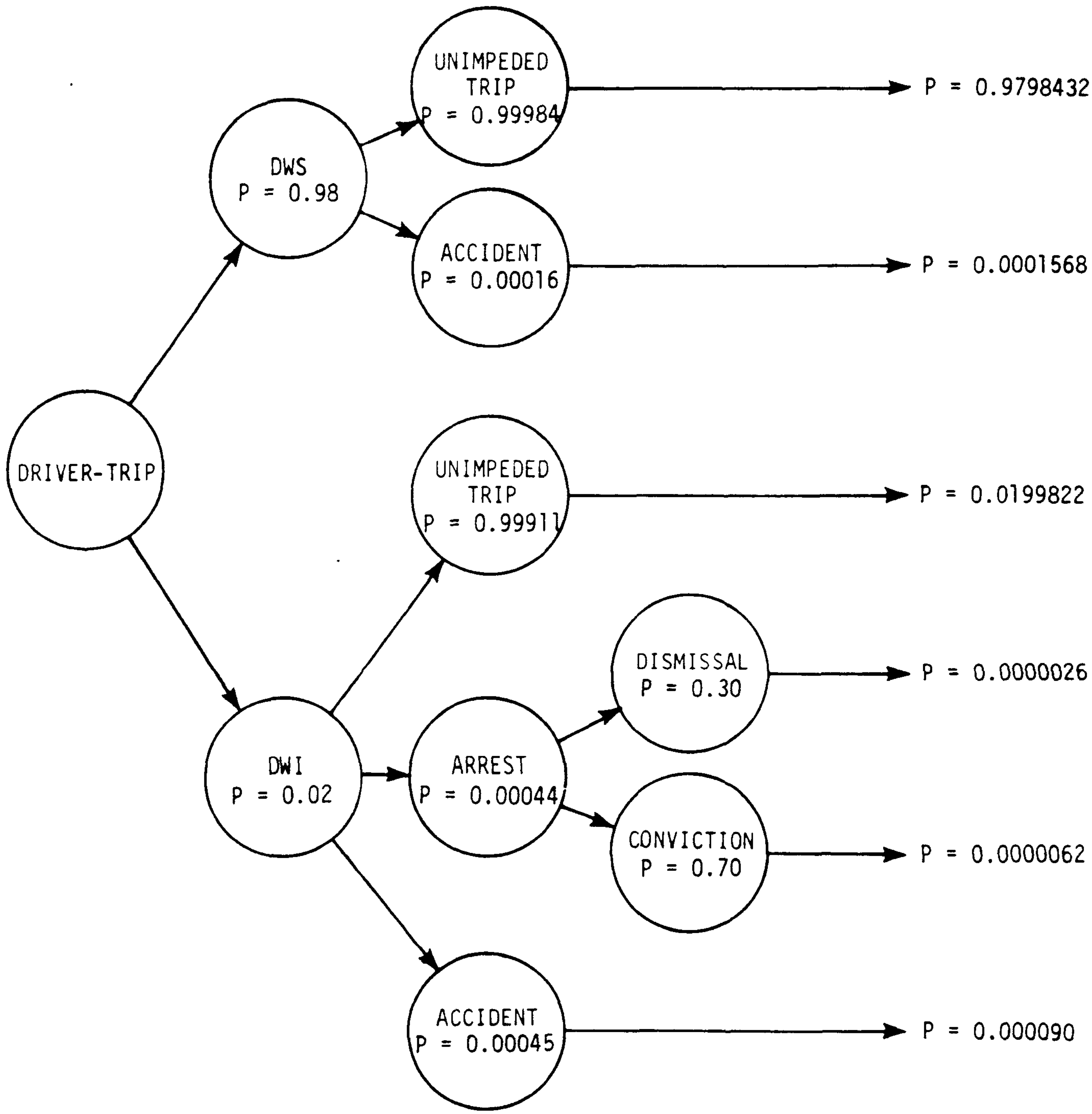


Figure 1. Probabilities of driver-trip outcomes (values in circles are branching probabilities).

time period would be minimal. Stated another way, the probability of an unimpeded trip made DWI is extremely high (0.99911), almost as high as the probability of an unimpeded trip made DWS (0.99984).

Given that special deterrence is applied too infrequently to be effective, what is the potential effectiveness of general deterrence of DWI? How does general deterrence operate? What factors are likely to exert the greatest influence? Definitive answers to these questions do not now exist. However, sufficient work has been completed to make a case for general deterrence and to suggest that answers to these questions will have a significant and long-term payoff.

THE CASE FOR GENERAL DETERRENCE

Legal scholars have justified law enforcement and sanctions (penalties) in terms of the general deterrence that results from their use (Andennas, 1952, 1966; Cramton, 1969; Ball, 1955; Zimring, 1971). They argue that persons refrain from engaging in illegal acts largely as a function of: 1) the perceived risk of detection, apprehension, and conviction; and 2) the severity of the penalty.

Some empirical evidence supports this view. Chambliss (1966) demonstrated the deterrent effect of sanctions on illegal parking. He found that incremental changes in either the apprehension rate or the amount of fines levied produced a greater reduction in the incidence of illegal parking than that accounted for by the number of individuals receiving the sanction. Schwartz and Orleans (1967) found similar results in a study of enforcement and sanctions on public compliance with tax laws. However, Zimring (1971), in a comparison of cross-cultural and interstate crime rates, found that sentence severity alone did not appear to have a significant impact.

Several recent studies have attempted to measure deterrence by correlating the certainty of imprisonment and the severity of punishment to crime rates (Gibbs, 1968; Tittle, 1969; Chiricos and Waldo, 1970; Logan, 1972; and Erickson and Gibbs, 1976). All of the studies used the FBI uniform crime reports and the Federal Bureau of Prisons National Prison Statistics. The certainty of imprisonment was determined from the ratio of the number of state prison admissions for a given year to the average number of crimes known to the police for the same year and the preceding year.

The severity of punishment was determined from the mean and/or median time served by prisoners who were serving time for the same type of crime and released during the same year. The crime rate was the ratio of the number of crimes known to the police in a given year and the population size.

Gibbs found an inverse relationship between certainty of punishment and criminal homicide rate and also a negative or weaker association between severity of punishment and homicide rates. Tittle also found an inverse relationship between certainty of punishment and the crime rate. However, he found only for homicide a negative correlation between severity of punishment and crime rate.

Chiricos and Waldo examined the same relationships for three points in time instead of one and showed that the correlation indices varied from year to year. They were able to show that spurious negative correlations could be produced by random fluctuations in the data since the same value for the number of reported offenses appeared in the denominator of the certainty of punishment estimate and the numerator of the crime rate estimate. They concluded that the use of existing sources of data may be inappropriate for testing the deterrence hypothesis and that new data should be generated. Ehrlich analyzed the same data using regression analysis to cope with the problem of errors in measurement of reported crime rates and spurious correlations between crime rates and certainty of punishment rates. He used a two-stage least squares estimation technique where during the second stage of the estimation procedure the crime rates were regressed on a combination of variables which did not include any current estimates of crime rates. For each crime category he found a significant negative regression coefficient with both certainty and severity of punishment.

A study by Logan and a recent study by Erickson and Gibbs, using a correlation analysis, showed similarities for the same criminal offenses for the 1960 and 1970 time periods. These findings showed a consistent inverse relationship between the rate and certainty of imprisonment but no significant relationship between the rate and severity of punishment.

Despite some evidence to the contrary, empirical evidence pointing to the effectiveness of general deterrence does exist. In addition, theoretical common sense indicates that the absence of all legal sanctions, and the concomitant absence of general deterrence, would lead to chaos.

GENERAL DETERRENCE IN TRAFFIC SAFETY

Several general deterrence programs that have been conducted provide evidence of the potential effectiveness of general deterrence in traffic safety. Despite mixed results, the programs appear to support the viability of general deterrence. Problems in interpreting these results, however, arise from lack of controlled conditions and inadequate measures of effectiveness.

The following programs are summarized and the implications of their results to general deterrence are examined--the 1955 Connecticut speed crackdown, the Lackland Air Force Base Study, the 1967 British Road Safety Act, the Scandinavian DWI Program, the 1969 Canadian Breathalyzer law, the Chicago drunk driving crackdown, and the nationwide 55 mph speed limit.

The 1955 Connecticut Speed Crackdown

Due to the sharp increase in fatalities during 1954, Connecticut increased the sanction for speeding, imposing a minimum penalty of a 90-day license suspension. The 12 percent decrease in number of fatalities during the following year suggested that the increased sanction had a significant effect. However, Campbell and Ross (1968) performed a time series analysis on the data and concluded that the reduction in accidents could be explained by regression and the instability of the data so that the reduction in fatalities was within normal fluctuation ranges. However, it should be noted that during the crackdown period, there was a 30 percent reduction in the number of speeding violations. It appears that a significant number of potential violators may have been deterred from speeding. Incidental findings were that the number of license suspensions due to speeding increased 2½ times over the previous year and the proportion of violators found to be not guilty more than doubled, due, perhaps to judicial laxity.

Lackland Air Force Base Study

To counteract the disproportionate involvement of drinking airmen in injury-producing accidents, the countermeasure program described by Barmack and Payne (1961a) was introduced. The program discouraged driving after drinking by depicting the practice as "sick" behavior. The widely publicized program called for offenders to be given psychiatric screening to determine whether they needed treatment and/or should be discharged from the service. While the countermeasure was in effect, the accident rate dropped abruptly and significantly; by the end of the test year the number of accidents recorded had dropped 50 percent from the previous year. In contrast, the number of accidents in the community at large continued to rise during the same sampling period (Barmack and Payne, 1961b).

The 1967 British Road Safety Act

The most widely known general deterrence program was the British Road Safety Act of 1967. The Act provided two new traffic laws: 1) driving and being in charge of a motor vehicle while blood alcohol concentration exceeded 0.08 mg percent (previously there was no statutory limit), and 2) a prearrest screening law which allowed the police to administer a breath test when they had reason to suspect alcohol in drivers involved in traffic accidents or stopped for moving violations. The sanctions for the first offense included automatic driving disqualification for a year. A massive public information campaign accompanied the enactment of the law.

Using time series analysis corrected for mileage and seasonal variation, Ross (1973) showed an immediate and sharp reduction in the overall casualty rate. Furthermore, the weekend night-time (heavy DWI) casualty rate dropped 66 percent, while the weekday commuting (light DWI) rate remained constant. He concluded that the effect of the Road Safety Act on the casualty rate was due to the general impression that, with a relatively high degree of certainty, a serious penalty awaited a drinking driver. A combination of the following factors contributed to this impression: provision for stopping and testing any driver involved in an accident, regardless of fault; broad language concerning reasonable cause to suspect alcohol in the body; "perceived" accuracy of the breath test; and extensive publicity.

However, casualty rates have now returned to pre-Act levels, probably as a consequence of less extensive publicity and of a public learning process--certainty of apprehension and conviction for the new offense had initially been overestimated. Perceived risk has probably returned to more realistic levels.

Scandinavian DWI Program

The Scandinavian countries have severe sanctions for driving while intoxicated--mandatory jail sentence and license suspension for driving with a blood alcohol concentration (BAC) of .05 mg percent or over. Andennas (1966) concluded that deterrence was effective in Norway. He based this conclusion on the reports that only 4 percent of the fatal accidents there involve drunk driving, as compared to 40 percent in the United States. However, Ross (1975) applied a times series analysis to the casualty data to determine whether any changes occurred in the accident rate after the legal reforms went into effect. He concluded that there was no significant effect.

However, if the number of accidents due to alcohol was low to begin with, alcohol may not have been a major contributing cause of accidents in Norway. This explanation is supported by a roadside survey conducted in Norway during 1970 and 1971 and reported in a review of roadside surveys (Ministry of Transport, 1974). Ninety-nine percent of the drivers cooperated in the survey and out of 1927 persons tested, 2.8 percent had been drinking, and 1.9 percent were above 0.05 BAC level. These percentages compared to 22.7 percent and 13.5 percent in the U.S. National Roadside Breath Test Survey (Wolfe, 1974) provide additional evidence that alcohol is not a major highway safety problem in Norway.

The 1969 Canadian Breathalyzer Law

With the success of the British 1967 Road Safety Act, Canada enacted a breathalyzer law which made operating a motor vehicle at a BAC level of 0.08 or higher an illegal offense. It allowed the police to test a driver if they had reasonable grounds for believing that he was intoxicated. It differed from the British Road Safety Act in that there were no provisions for prearrest screening. A mass media information campaign was used to introduce the new legislation to the driving public. Analysis of the three-year fatality rate after the enactment of the law showed no significant reduction in fatal accidents (Carr, *et. al.*, 1975).

However, the program had several positive results. A survey conducted by Kates, *et. al.*, (1970), showed that the public became more aware of the DWI laws, including the new legislation. There was also an increase in the number of DWI arrests, and the average BAC levels of the arrested drivers decreased from 0.21 to 0.19 BAC level (Carr, *et. al.*, 1974).

The main difference between the British program, and the Canadian program was the prearrest screening law and the success of the British program may have been due to the unknown threat of prearrest screening. The Canadian law, on the other hand, did not differ from similar laws passed in the United States.

The Chicago Drunk Driver Crackdown

The City of Chicago enacted a drunk driving countermeasure program that consisted of increasing the sanction for DWI convicted drivers (imposing a seven-day jail sentence and recommending license suspension). This program was accompanied by a public information campaign. Using Ross's time series analysis to analyze the data, Robertson *et. al.*, (1974) found no change in the fatality rate, arrest rate, or conviction rate of DWI offenders. This would indicate that public information about the threat of the sanction must be accompanied by additional information about the risk of enforcement if a program is to be effective.

55 MPH Nationwide Speed Limit

Another example of general deterrence in highway safety is the nationwide enforcement of the 55 mph speed limit law in the United States. The number of highway fatalities for 1974 (after the law) was found to be 20 percent lower than it was for the corresponding period in 1973 (before the law). Although the results are confounded by the reduction in driving during the energy shortage, Tofany (1975) estimated that about 11 percent of the fatality reduction was due to speed reduction alone. However, the reduction in vehicle speed and consequent reduction in casualties might have been less the result of speed general deterrence measures and more the result of the mass publicity campaign to conserve fuel.

A THEORETICAL MODEL OF DWI GENERAL DETERRENCE

The focal point of DWI general deterrence is the decision process of the driver in taking a trip. General deterrence is successful if the decision process results in a trip DWS, and is not successful if the trip is DWI. Thus, an understanding of DWI general deterrence depends upon an understanding of the decision process and the factors that influence the decision outcome.

DWI Decision Model

Utility theory provides a useful framework within which to examine the DWI decision. This method of examining decisions was originally developed by Von Neumann and Morgenstern (1947). More recent and more directly applicable treatments have been presented by Fishburn (1968) and North (1968). Utility theory is useful because it incorporates the counteracting forces at work in the DWI decision process--*expected utility* of the DWI trip vs. the *perceived risk* of the trip. Expected utility is the value the driver expects to gain from making the trip--attending a party, meeting new people at a bar, relieving tension at a friend's home, etc. The perceived risk of DWI is a function of the probability of arrest or accident, and the potential severity of the outcome--death, injury, license suspension, jail, embarrassment, etc. This is not to say that each decision is a conscious and deliberate weighing of alternatives (habit strength is certainly a factor as well), but that these two opposing forces operate at some level in the decision process.

The functional relationship between expected utility and perceived risk is of paramount importance to DWI general deterrence. Potentially, people can make the trade-off between utility and risk in a variety of ways; however, the evidence derived from business decisions suggests (North, 1968) that people tend to avoid severe risks. If the sanction is sufficiently severe, people tend not to take the risk, even though the probability of being apprehended may be low. In contrast, if a person simply balanced utility against risk, the risk would be taken whenever the expected utility was greater. These two functional relationships--risk aversion and equal payoff--are shown in Figure 2. If, indeed, the risk aversion curve applies to the DWI decision, relatively small changes in perceived risk will lead to relatively large changes in decision outcomes. The greater the risk aversion, the more potentially effective general deterrence countermeasures would be.

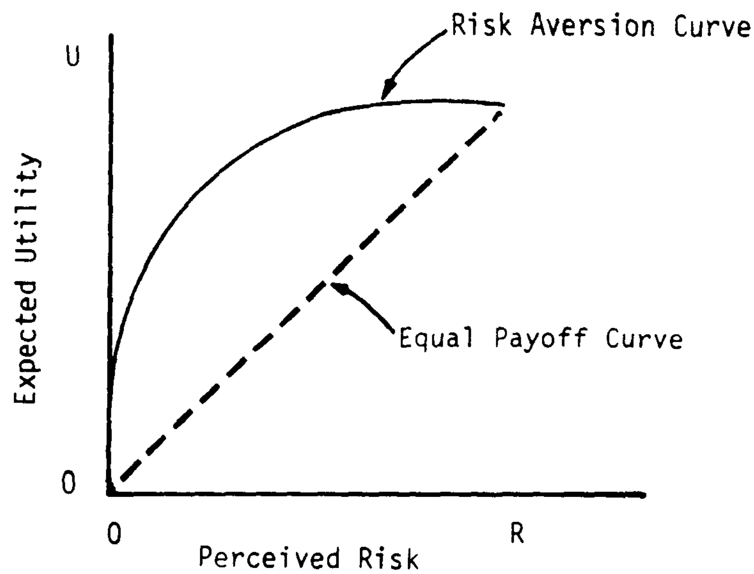


Figure 2. Relationships between expected utility and perceived risk.

Perceived Risk of DWI

The components of perceived risk of DWI are the subjective assessment of the probability of arrest and/or accident and the expected severity of the associated sanction or outcome. The perceived risk of a driver might be modified in a variety of ways: through word-of-mouth descriptions of the experience of others, through observation of arrests or accidents involving others, or from information obtained through generally available media channels.* At this time, few data are available on the nature of perceived risk of DWI, the shape of the risk aversion curve, or how the potentially influencing factors operate in general deterrence.

Some evidence is provided by analyzing the impact of the British Road Safety Act (Ross, 1973). The immediate effectiveness of the Act appeared to be due to the accompanying publicity which increased the perceived assessment of arrest probability and sanction severity. Shepard (1968) found that the penalty most feared was the suspension of the driver's license for a year. Ross (1973) suggested that the publicity accompanying the act greatly affected the subjective likelihood of this penalty. However, with the passage of time, the public learned, through direct experience and from observation of others, that they could drive intoxicated with little chance of arrest, which diminished the effectiveness of the initial deterrence effect.

Additional data were provided by an attitude survey conducted by Little (1968) in Michigan which examined the question of perceived risk of DWI. A non-random sample of 202 drivers participated in this exploratory study. Of the individuals interviewed, 94 percent disapproved in general of DWI; however, only 48 percent of those who admitted to having driven after drinking ever worried about having an accident, and only 23 percent ever worried about being arrested. Furthermore, fewer than 50 percent of those interviewed thought there was any danger to themselves or were deterred from DWI by current law enforcement practices. On the other hand, 70 percent were aware of the penalties and 76 percent thought the

*Special deterrence, the direct experience of arrest and/or accident, would most strongly modify perceived risk.

consequences of the sanctions would be undesirable to them. Thus, although the sanctions were consequential, the probability of arrest was too low for the perceived risk to be great, which appears to point up the need for stepped-up enforcement policies.

FACTORS LIKELY TO INFLUENCE DWI GENERAL DETERRENCE

The DWI decision model provides a structure for examining the factors likely to influence DWI general deterrence. Since the DWI decision depends upon the perceived risk of DWI, the expected utility of a DWI trip, and the risk aversion characteristics of drivers, factors likely to influence the general deterrence of DWI must operate through these components of the decision process. Thus, any factors that influence these components will have a positive or negative impact on general deterrence.

In addition, the traffic law system must be considered. The system consists of three main functions: legislation--the enactment of laws and associated sanctions; enforcement--the arrest and detention of offenders; and adjudication--the hearing and disposition of law violation cases. To a large extent, influences on DWI general deterrence must operate within the potentialities and constraints of these functions and their interactions.

The functions of the traffic law system relate mainly to the perceived risk component of the DWI decision process. Information generated by system functions is channeled directly or indirectly to the driver to influence his perception of risk. The information might come to the driver as a consequence of special deterrence or by indirect exposure to the factors enumerated in the previous section: observation, word-of-mouth, or news media accounts; and general educational or persuasive means, such as public safety campaigns. These factors and evidence of their effects are discussed here in terms of DWI traffic laws, enforcement, adjudication, and public information.

DWI TRAFFIC LAWS

Changes in traffic laws can increase the level of perceived risk by increasing the severity of the sanction, increasing the enforcement rate, and/or modifying the nature of enforcement laws.

Severity of the Sanction

The statutory penalty for disobeying the Uniform Vehicle Code's driving while intoxicated provision varies from state to state. Some states provide mandatory sanctions while others permit judicial discretion. The amount of plea bargaining allowed also varies from state to state. Generally, the following sanctions are imposed for a first offender:

- Jail--a statutory penalty, but with judicial discretion
- Fine--a mandatory penalty with the amount of the fine based on judicial discretion, varying typically between $10 and $500
- License suspension/revocation--either mandatory or with judicial discretion, depending on the state
- Referral program--the Alcohol Safety Action Project (ASAP) program and associated programs employ training and rehabilitation programs in lieu of traditional sanctions.

Available empirical evidence suggests that severity of the penalty has some effect for special deterrence, but there is no evidence of its effect on general deterrence. Comparisons made across states which impose sanctions of varying severity have not shown significant differences in general deterrence (NHTSA, 1972). However, there are inadequacies in the sampling methods and the experimental controls employed by these studies. Other studies show that individuals who actually receive the sanctions are deterred to a greater extent than those who do not. The California Department of Motor Vehicles (1975) compared arrested DWI's who did not receive a sanction with those who did (license suspension/revocation). Results showed that the subsequent driving record of the unsanctioned group was significantly poorer than that of the sanctioned group. Blumenthal and Ross (1973) found that the subsequent driving records of arrested DWI's who were dismissed or received reduced charges were poorer than those of drivers who were sanctioned. On the other hand, there was no difference in recidivism between groups who received different sanctions.

A review of DWI traffic law programs (Cramton, 1972; Borkenstein, *et al.*, 1971; NHTSA, 1972; Voas, 1975) suggests that a backlash effect might occur when DWI sanctions are too severe. The enforcement rate is likely to decrease due to a judicial unwillingness to impose the severe sanctions which ultimately has a negative effect on police enforcement.

Increased Severity of Enforcement Laws

More severe DWI laws would increase the enforcement rate which, in turn, would be likely to increase the perceived risk of DWI, and ultimately influence the general deterrence of DWI. Some proposed changes which may increase DWI enforcement rates are described below:

- *Lowering BAC Level for Presumptive Evidence*

  Several states have changed the presumptive evidence for DWI from 0.15 BAC to 0.10 BAC. Although this change should lead to increased DWI arrests, no data are available at this time to evaluate the impact of this change. The British Road Safety Act's BAC of 0.08 may have had a dramatic effect on the drivers' perceived risk.

- *Prearrest Screening Law*

  Another factor which contributed to increased perceived risk under the 1967 British Road Safety Act was the prearrest screening law which included a fine for drivers refusing to take the test. According to Ross (1973), the prearrest screening law increased the number of arrests by 300 percent. Twelve states now have some form of preliminary breath test law; Nebraska's law is very similar to that of the British.

- *Driving While Impaired Law*

  Eight states now have statutes with lesser drinker driving offenses; they are referred to as driving while ability is impaired by alcohol. These statutes require lower BAC levels (from 0.05 to 0.08) to show presumptive evidence of impairment and permit arrest for a lesser offense than driving while intoxicated. While such a law does not facilitate detection of DWI drivers, it might increase the arrest rate. There is some evidence to support this. Average BAC levels from 1973 ASAP data were 0.178 BAC for ASAP Patrols and 0.195 for regular patrols (NHTSA, 1972). In contrast, the average was only 0.157 for the Denver FARE program which operated under a driving while impaired law. Of the 2,897 drivers tested, 84 percent were in the intoxicated range and 10 percent were in the impaired range (Denver Police Department, 1974).

ENFORCEMENT OF DWI TRAFFIC LAWS

In general, the rate and manner of traffic law enforcement influence a driver's perceived risk of the unlawful act. However, research has produced mixed results on this issue due to the particular laws enforced, the context within which the research was conducted, and the adequacy of the experimental controls applied. Much of the research has been concerned with speed law enforcement, and most of the studies were longitudinal in nature and did not employ control groups.

A traffic control program which increased enforcement conducted in Springfield, Massachusetts during 1945 showed positive results. As reported by Kunz (1950), the number of prosecuted violations increased approximately 250 percent, and the number of traffic injuries was reduced by 40 percent, in spite of increased traffic volume.

A number of studies have shown a direct negative correlation between law violation rate and the visibility of enforcement symbols (Shumate, 1958; Smith, 1962; Council, 1970). Other research (Huffman, *et al.*, 1961; California Highway Patrol, 1972) has shown a decrease in accidents with an increase in enforcement visibility. In a recent, well controlled study by Cooper (1974), an increase in enforcement visibility significantly reduced unsafe driving acts.

However, other research indicates that increased enforcement does not necessarily lead to reduced DWI. With regard to DWI, an evaluation of ASAP operations (NHTSA, 1972) found no correlation between increased enforcement activity and number of drivers on the road at 0.10 BAC or above, although the number of arrests did increase. The enforcement activity included increased number of patrols during evening hours and weekends and additional patrols specializing in DWI detection and arrest procedures. This increased enforcement doubled the DWI arrest rate for the period studied from 0.6 percent of the drivers to 1.2 percent of the drivers per year. However, no correlation was found between this increased enforcement activity and the number of fatal accidents.

Assuming that enforcement does influence perceived risk and that the increased rate and visibility of enforcement is desirable, how might enforcement be enhanced? Several factors which might influence the enforcement of traffic laws have been studied: police attitudes, police training, patrol procedures, and police liaison with the courts.

Police Attitudes

Negative police attitudes toward DWI enforcement have been cited as major contributors to ineffective DWI deterrence (Borkenstein, *et al.*, 1971; Joscelyn and Jones, 1970; Oates, 1974; IACP, 1976; Reese, *et al.*, 1974; Hawkins, *et al.*, 1976). Numerous reasons for these attitudes have been presented as a result of investigations and surveys. They include personal use of alcohol by police officers, lack of police knowledge about alcohol impairment, lack of specialized police training, inadequate departmental enforcement policies, and time consuming arrest processing procedures.

Arrest rate data appear to support the survey findings about police attitude. For example, despite roadside breath test data showing that the number of DWI drivers was relatively constant from one community to another, large variations were found among enforcement agencies in the number of DWI arrests per patrol unit (NHTSA, 1972). Furthermore, after the initiation of special enforcement patrols, the DWI arrest rate of regular patrols increased in the same communities. Although other contributing factors may have been present, these data suggest the influence of attitude or motivation.

Attitudes might affect DWI enforcement performance at each step of the enforcement process--search, detection, and arrest. Consequently, positive attitude changes might significantly increase enforcement rate and visibility without any significant increase in manpower. As suggested by Hawkins *et al.* (1976), improvement could be made through training, changes in arrest procedures, increased liaison with the courts, and modifications in information flow between the enforcement agencies and the courts.

Police Training

Police training is a potential factor in increasing the number and conviction rate of DWI arrests. Training might have two beneficial effects: the change in attitude discussed above, and increased enforcement efficiency. According to Hawkins, *et al.* (1976), police training for ASAP operations in methods of detecting and recognizing alcohol-impaired drivers and in the use of chemical testing procedures contributed significantly to increased rates of arrests and convictions. The development of relevent skills--visual detection, psychophysical testing, and breath testing--would probably improve the police officer's performance, increase his confidence, and enhance the validity of evidence for DWI prosecution.

Patrol Procedures

Changes in patrol procedures can directly affect enforcement rate and visibility. Some possibilities include: using special patrols during periods of high DWI activity; increasing regular patrol activity in areas with high DWI activity; reducing arrest processing time; and providing processing support personnel to increase the amount of available patrol time. ASAP used these approaches successfully to increase the effectiveness of patrol and in turn increase the number of DWI arrests.

Police/Court Liaison

ASAP experience suggests that effective liaison between the police and the courts can directly enhance enforcement efficiency. According to Hawkins, *et al.* (1976), one of the ASAP program's main contributions was to bring about both technical and philosophical changes in this area. Examples of technical changes include the redesign of paper flow systems for better maintenance of case records, changes in court scheduling to reduce demands on police time, and judicial notice of breath testing accuracy to save police witness time. At a more philosophical level, interaction among prosecutors, judges, and police led to greater understanding and efficiencies. Plea negotiation procedures were clarified, arrest policies and procedures were agreed, police case preparation and testimony were improved, and cases were handled in the courts with greater equity and efficiency.

ADJUDICATION

The adjudication process might affect the perceived risk of DWI in two ways. First, if appropriate sanctions are not imposed consistently, negative changes in police enforcement attitudes are likely, with consequent decreases in DWI arrests. Second, in time, drivers will perceive reduced severity of sanctions by court action and inconsistently imposed sanctions, reducing their perceived risk of sanctions.

Conviction rates and distributions of case dispositions vary among states and jurisdictions. For example, in 1972 the conviction rates in ASAP communities ranged from 0.07 to 0.78; the average was 0.50 (NHTSA, 1972). Some investigators have concluded that adjudication is the most troublesome component of the DWI traffic law system. In their review of ASAP, Hawkins *et al.* (1976), identified the following major problems: lack of resources to handle the DWI case backlog; attitudes of the court, the bar, and the public about drunk driving; inequities among jurisdictions; disregard by courts of relevant statutes; and lack of information flow among cognizant agencies.

ASAP directed effort in two primary directions to help alleviate these problems. Direct payment was made for additional staff to bolster the existing court system in handling DWI cases, and a more efficient court-based referral system was implemented. According to an ASAP evaluation (NHTSA, 1974a), these two efforts increased the disposition rate and maintained a favorable conviction rate. Furthermore, they lowered the mean processing time in a majority of the ASAP communities, despite large increases in case load.

PUBLIC INFORMATION

A driver might receive information through mass media communication channels (television, radio, newspapers, magazines, billboards) which might affect his or her perceived risk of DWI. Previous work in public safety campaigns has established a theoretical basis for mass media exposure and provided knowledge gained from experience. Each will be discussed briefly.

Theoretical Basis

An extensive amount of work has been completed in the behavioral sciences and in marketing research on the effects of mass media exposure on attitude change. Much of this research appears directly applicable to the use of mass communications to promote highway safety. However, care should be exercised in the transformation. One of the conclusions from a state-of-the-art review of mass communications for highway safety (NHTSA, 1974b) was that since the goals of marketing and public safety are not necessarily the same--i.e., essentially positive for marketing and negative for public safety--different approaches may be required.

Of greatest relevance to DWI general deterrence is the understanding that has been developed of the effects and timing of message exposure and the retention of the message by target populations. Although research results have also provided a basis for assessing the impact of message content, message format, and message vehicle on attitude change, a review of this literature was considered beyond the scope of the present study.

In general, repeated exposure in the media has been found to achieve a result similar to the exponential nature of the learning curve--that is, it has a greater impact at the outset but then levels off gradually toward a saturation point. In addition, a memory decay between exposures was found to be superimposed on the general shape of the curve (Vidale and Wolfe, 1957; Benjamin and Maitland, 1958; Rohloff, 1966; Zielski, 1959).

A media exposure model developed by Little and Lodish (1969) was adapted and incorporated in the system model of DWI general deterrence developed as part of the present study. This model and its application to DWI general deterrence will be described later. Lodish (1971) applied the media exposure model to empirical data and found that it provided a good description of the empirical results.

Public Safety Campaign Results

At this point, evaluations of public safety campaigns have produced contradictory results. For example, campaigns to promote the use of automobile seat belts have been found to be both unsuccessful (Robertson, *et al.*, 1973; Fleischer, 1972) and successful (Fabry, 1974a, 1974b).

Campaigns in the United States to deter DWI have been assessed as having relatively little impact; on the other hand, campaigns in England appear to have been successful. ASAP provided local funds for public information and education as well as funds for national-level exposure. However, these campaigns focused on problem drinkers rather than the more general target population, emphasized education rather than persuasion, and did not emphasize risks so that results of the ASAP efforts do not relate directly to DWI general deterrence. The overall evaluation of 1972 ASAP operations (NHTSA, 1972) concluded that media campaigns were having a relatively small impact. However, the evaluation of 1974 ASAP operations (NHTSA, 1974a) concluded that knowledge, attitude, and behavior changes associated with projects incorporating public information and education campaigns were greater than those associated with projects without these programs. In its review of mass communications for highway safety, NHTSA (1974b) reported that while a number of public media campaigns have been credited by safety officials with a significant reduction in crashes, this reduction has been difficult to demonstrate in objective, statistical terms.

Perhaps the most successful public information campaign in DWI general deterrence was associated with the British Road Safety Act of 1967. In addition to the large amount of free publicity given by the news media, the government spent £350,000 on the campaign (Ross, 1973). A public opinion survey conducted before and after the legislation went into effect showed that the population quickly learned about the law's penalties and about the prearrest screening breath test (Sheperd, 1968).

The role that the public information campaigns played in implementing the Act and the consequent reduction in accidents was assessed by Ross (1973) as follows:

> One historical event that remains to qualify my basic conclusion is the extensive campaign of publicizing the crackdown which took place simultaneously with the promulgation of the Act. An independent effect of the publicity campaign is doubtful, for there is little evidence that safety propaganda without other measures has any notable effect on accidents. No noticeable fluctuation in casualty statistics occurred in 1964 when a safety campaign of comparable scope was launched in Britain. However, an interaction between the publicity and the Act remains a plausible consideration. It is possible that the Act would have had less effect or even none at all without the accompanying publicity.

However, as stated earlier, the impact of the Road Safety Act was not permanent. Ongoing publicity may not have been as extensive as the original publicity and also the effect of the initial publicity probably decayed with time. Without reinforcement or continued exposure, the public reverted to previous behavior patterns.

An important observation about past public information campaigns is that message content has typically emphasized the penalty or consequences of the unlawful act. As discussed earlier, general deterrence depends on perceived risk, a function of sanction severity and the probability of enforcement. Therefore, even though a driver becomes aware of a penalty, his perceived risk will probably not be altered unless the expected probability of enforcement increases. The British Road Safety Act was probably effective for a time because it was based on increasing both the expected severity of sanction and the perceived probability of enforcement.

DEVELOPMENT OF A SYSTEM MODEL

A system model of DWI general deterrence was developed. Through the application of system analysis methods, factors likely to influence the DWI decision were related to each other and to the DWI decision process itself. The resulting model provided the basis for the design of a computer-based simulation to assess the feasibility and potential effectiveness of DWI general deterrence programs.

The system model of DWI general deterrence described here is probabilistic in nature and incorporates the concept of control, as well. A probabilistic model recognizes uncertainty and attempts to incorporate components for handling the relevant stochastic processes. Computer simulation is of particular value in designing and exercising probabilistic models. The system model is a symbolic model which is described verbally, schematically, and mathematically.

DWI GENERAL DETERRENCE MODEL

The model developed for DWI general deterrence incorporates the perceived risk concepts discussed previously. The basic components and interconnections are shown in the top level flow diagram of Figure 3. Any general deterrence program would be made up of a combination of the following elements: law generation, media exposure, enforcement improvement, and adjudication improvement. As shown in Figure 3, general deterrence operates to feed back information by means of media exposure to the driver's decision process to increase the expected awareness of sanctions and probability of arrest.

The scenario for the system model is an urban community whose population is between 100,000 and 1,000,000 people. Traffic law enforcement is handled by a municipal police department, and the adjudication of DWI cases is handled by a municipal court. The community has its own public media resources: television station(s), radio station(s), and newspaper(s).

Trips are generated for the driver population as a function of driver groups and time. Each driver-trip enters into a DWI decision model to

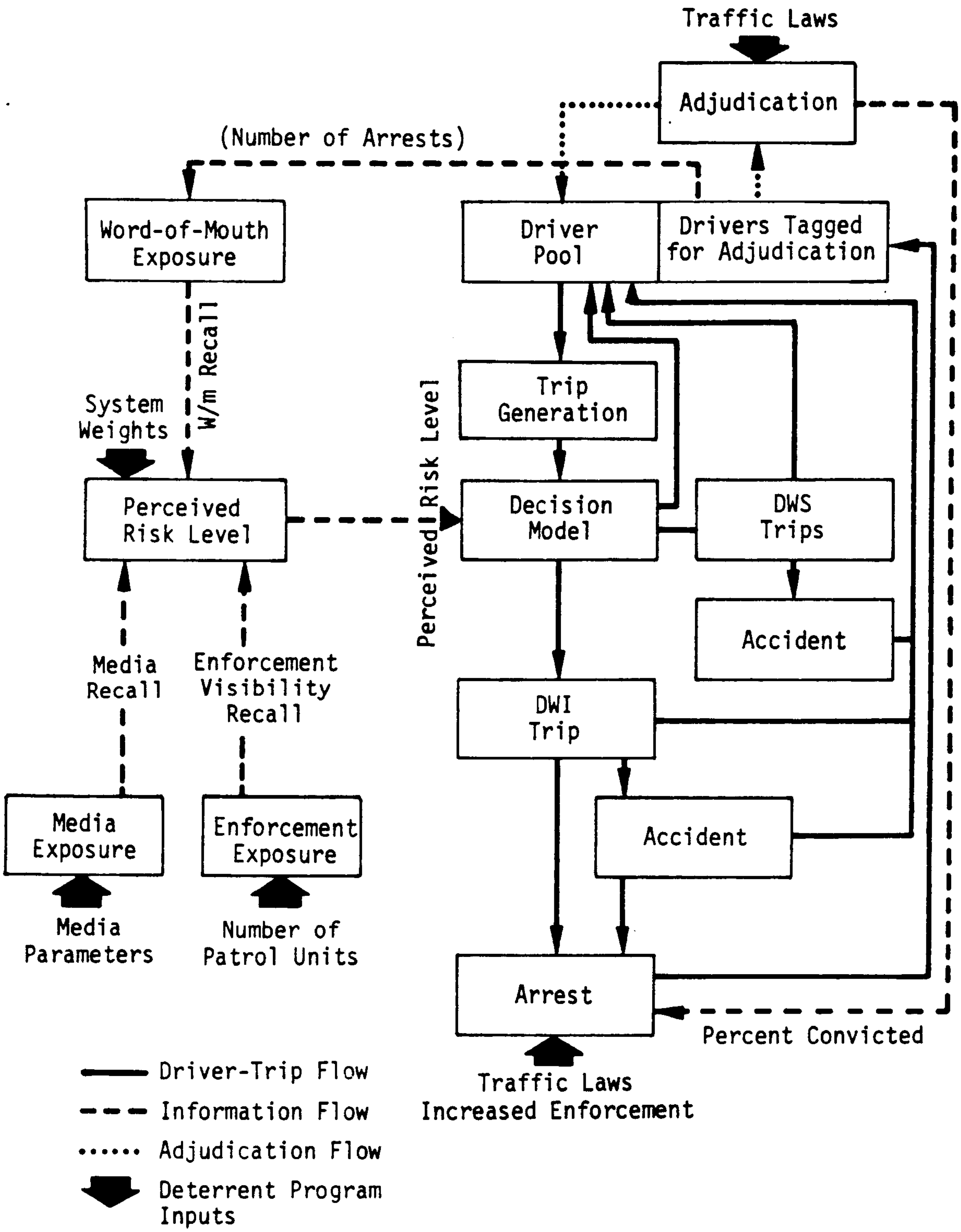


Figure 3. DWI general deterrent model top level flow diagram.

determine if the trip is taken while intoxicated or not intoxicated. Although trips will actually be taken at varying BAC levels, we have simplified the decision to a binary outcome for the model. DWI is defined as a BAC of 0.10 percent and above.

Trips resulting in accidents are generated with the accident risk factors that have been established for drivers at BAC's of 0.10 percent and above, and at BAC's below 0.10 percent. DWI trips resulting in arrests are predicted from enforcement laws, enforcement levels, and enforcement attitudes. A separate adjudication model delays arrested drivers in returning to the driver pool.

Information is fed back to the driver through media exposure, enforcement exposure, and word-of-mouth exposure to increase his perceived risk level and awareness of the sanction, which, in turn, enters the decision model to deter some drivers from driving while intoxicated on subsequent trips.

Since the system changes in time, the model employs a Markov chain which starts with a set of initial conditions and computes changes in these conditions over a given time period, ΔT. Therefore, the model starts with time period T_0, then $T_1 = T_0 + \Delta T$, $T_2 = T_1 + \Delta T$, etc. This process assumes that computations in any given time period are independent of previous and subsequent time periods.

The duration of the model's time cycle is determined from empirical data. For example, roadside data show that trip frequencies, trip purposes, and driver BAC levels vary as a function of time of day. Thus, the minimum time period is selected so that trip rate, trip purposes, and BAC levels are relative invariant within a time period. The three different system flows may have different time periods; driver-trip flows use half-day periods while adjudication flow and information flow use one-week periods. All three flows are synchronous to permit the examination of events and outcomes in chronological order.

DRIVER-TRIP COMPONENT OF THE MODEL

The focal point of the system model is the particular trips made by every driver. Given the number of drivers in a community and the number and purpose of trips taken by an average driver within a time period, the model generates trips.

Driver Pool

The driver pool consists of all drivers with valid licenses within the community differentiated into groups on the basis of their frequency of drinking and their awareness of DWI sanctions. The frequency of drinking groups consist of abstainers, light drinkers, moderate drinkers, and heavy drinkers. The sanction awareness groups consist of those drivers who are aware of the sanction and those who underestimate the sanction.

Trip Generation

The expected or average number of trips a driver takes within a time period and the purpose of each trip are obtained from origin-destination (OD) surveys of urban areas. Trip purposes include home-work, home-shop, home-other (visit friend, eat, drink, or recreation), work-other, and other-other. The driver pool and trip generation flow are shown in Figure 4. For every time cycle, trip purpose, and driver group, a number of trips will enter the trip decision routine.

DWI DECISION MODEL

From utility theory, a driver makes a DWI decision on the basis of the value of taking the trip DWI, the shape of his or her risk aversion curve, the expected probability of enforcement action, and the expected severity of the sanction. In defining these relationships, there is some empirical evidence on the actual risk of being arrested, and on driver awareness of sanctions. However, little empirical evidence currently exists about drivers' risk aversion characteristics and the extent to which they differ among various groups. In a few preliminary tests conducted by the project staff, risk aversion was found to be relatively constant; however, awareness of the sanction and perceived probability of apprehension were found to differ notably among individuals.

A functional flow diagram of the DWI decision model is shown in Figure 5. The decision model is based on utility theory. That is, for a given trip the driver compares the expected value of a DWI trip (U_T) to the perceived risk of the trip (Y_T). Whichever value is greater will determine the outcome of the decision. The perceived risk of the trip is defined as the product

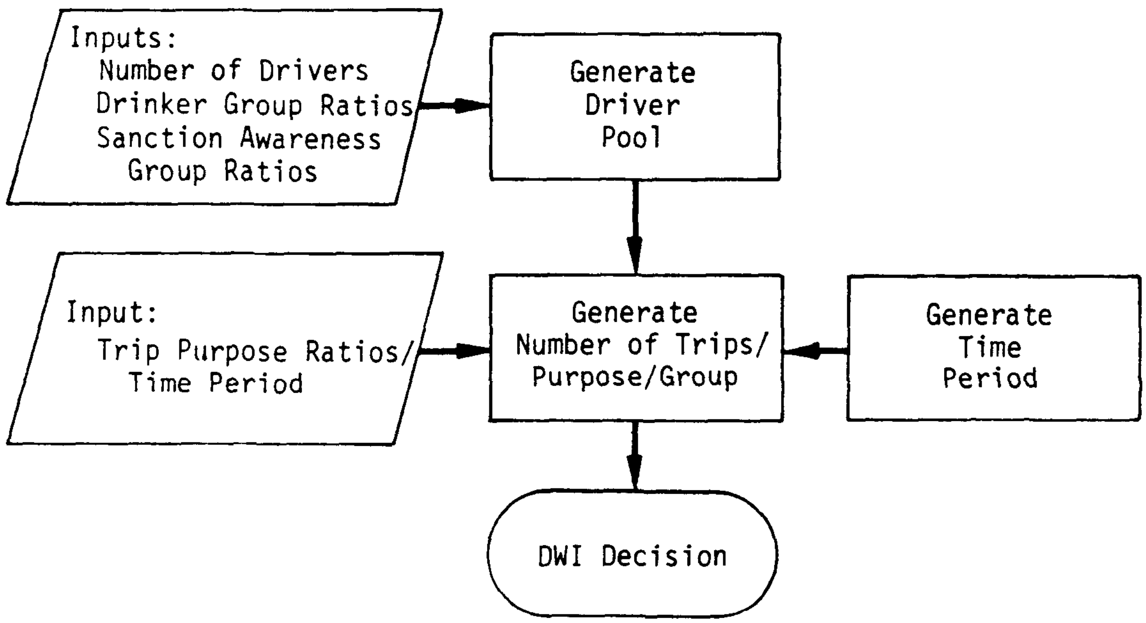


Figure 4. Driver-trip component of model.

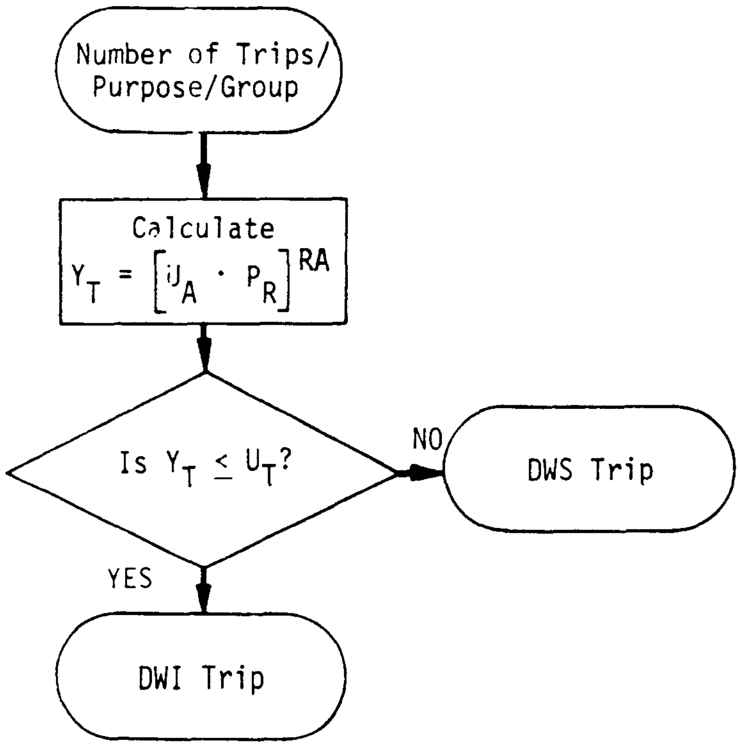


Figure 5. DWI decision routine.

of the expected penalty and the perceived enforcement rate and this product is raised by the risk aversion factor or:

$$Y_T = (U_A P_R)^{RA}, \qquad (1)$$

where Y_T = perceived risk of trip, U_A = expected penalty of the trip with an actual value of 1.0, P_R = perceived enforcement rate where $0 \leq P_R \leq 1$ and RA = the risk aversion factor with a value ≤ 1.0. When RA = 1, the above curve represents an equal payoff curve, and as RA goes to 0 the risk aversion increases.

The expected utility of a DWI trip (U_T) is a function of two variables: the trip purpose (U_P) and the value of drinking (U_D), as expressed in (2).

$$U_T = U_P \, U_D \qquad (2)$$

For each different trip purpose there is a different U_P. OD data collected from roadside breath tests show that the frequency of drinking varies with trip purpose (Wolfe *et al.*, 1974). This OD data is used to estimate the values of U_P. For example, trips for social purpose have a low value of U_P.

The value of drinking (U_D) varies as a function of groups within the driver population. For non-drinkers the value is, of course, 0, while at the other extreme, the value is near 1 for heavy drinkers.

Depending on the decision, the outcome of the trip is either a DWI trip or a driving while sober trip (DWS).

TRIP OUTCOMES

Trip outcomes determine whether a trip ends in an accident--fatality, injury, or property damage--or in a DWI arrest. Data from previous studies are used as the basis for stochastically generating outcomes.

Of particular note here is that the decision model can change a potential DWI trip into some other alternative; thus, the impact of a general deterrence program can be assessed directly, not only in terms of *reduction of DWI trips but also in terms of reduction in accidents. Consequently, this model eliminates the need to apply a separate Bayesian analysis to predict potential reduction in crashes.*

This section describes the trip outcomes for driving while sober and for driving while intoxicated, and presents flow diagrams for each.

Driving While Sober

If the decision outcome is DWS, four events may occur: fatal accident, injury accident, property damage accident, or safe trip. The number of accidents is determined from the expected probability of an accident while the driver is sober. The flow diagram is shown in Figure 6. For a safe trip the driver returns to the driver pool and is available to take another trip. For an injury or property damage accident he is delayed from returning to the driver pool on the basis of the time required to treat the injury or obtain another vehicle. If a fatal accident occurs the driver does not return to the pool.

Driving While Intoxicated

If the decision outcome is DWI there is a chance of being involved in an accident, arrested for DWI, or both. The number of accidents is determined from the expected probability of an accident while the driver is intoxicated. The flow diagram is shown in Figure 7. As before, the driver either returns to the driver pool or is delayed in case of accident or arrest.

Two different submodels are used for DWI arrest. One is conditional only on a DWI trip, while the other is conditional upon a traffic accident occurring during a DWI trip. The occurrence of a traffic accident serves as the detection portion of the DWI arrest model. After an arrest there is a delay to account for booking, posting of bail, and releasing the driver from custody. The driver then returns to the driver pool but remains "tagged" to permit later identification for adjudication.

DWI Arrest

The probability that a patrol unit (the combination of one or two police officers in a patrol vehicle) will arrest a DWI is the probability

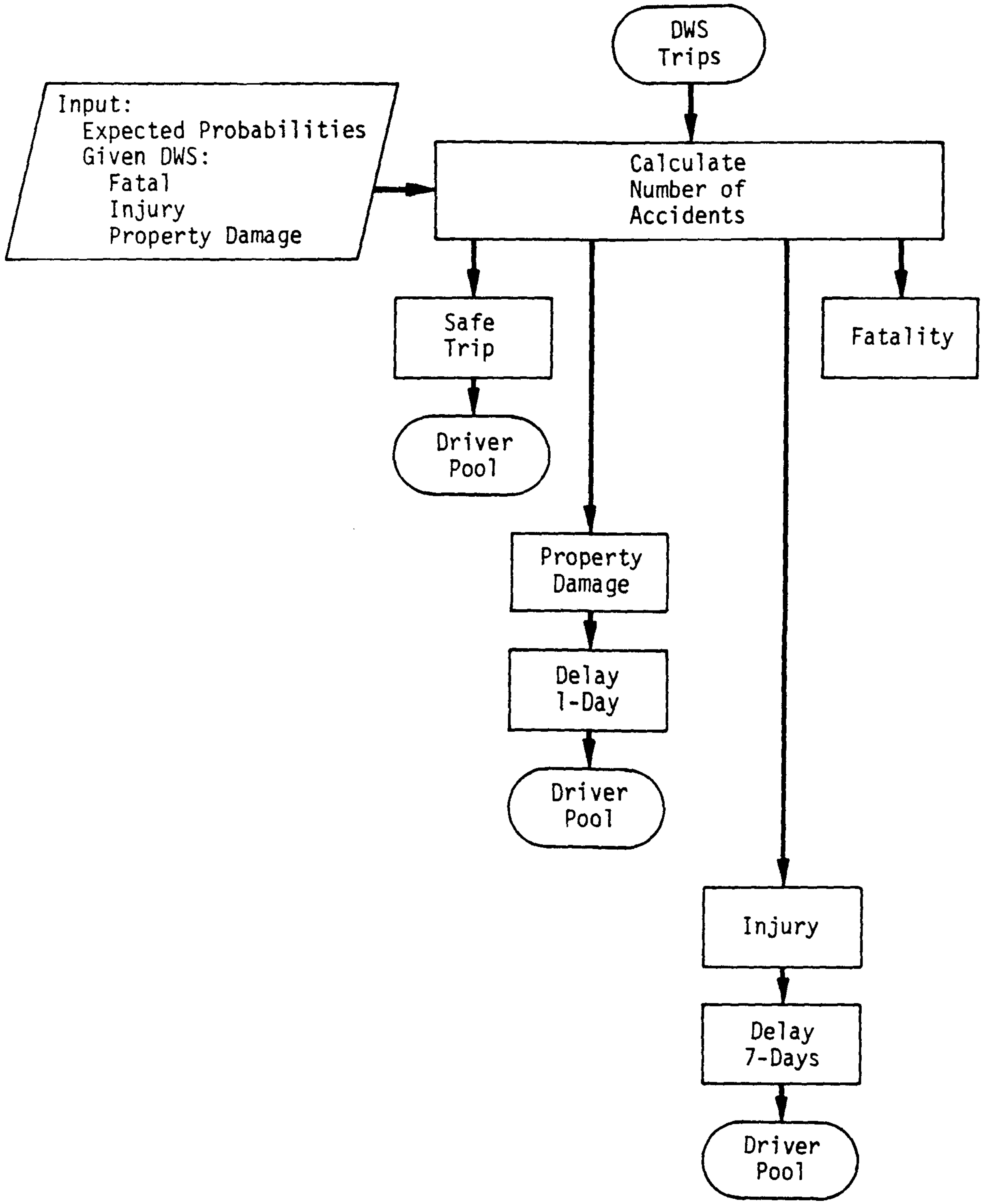


Figure 6. Driving while sober trip model.

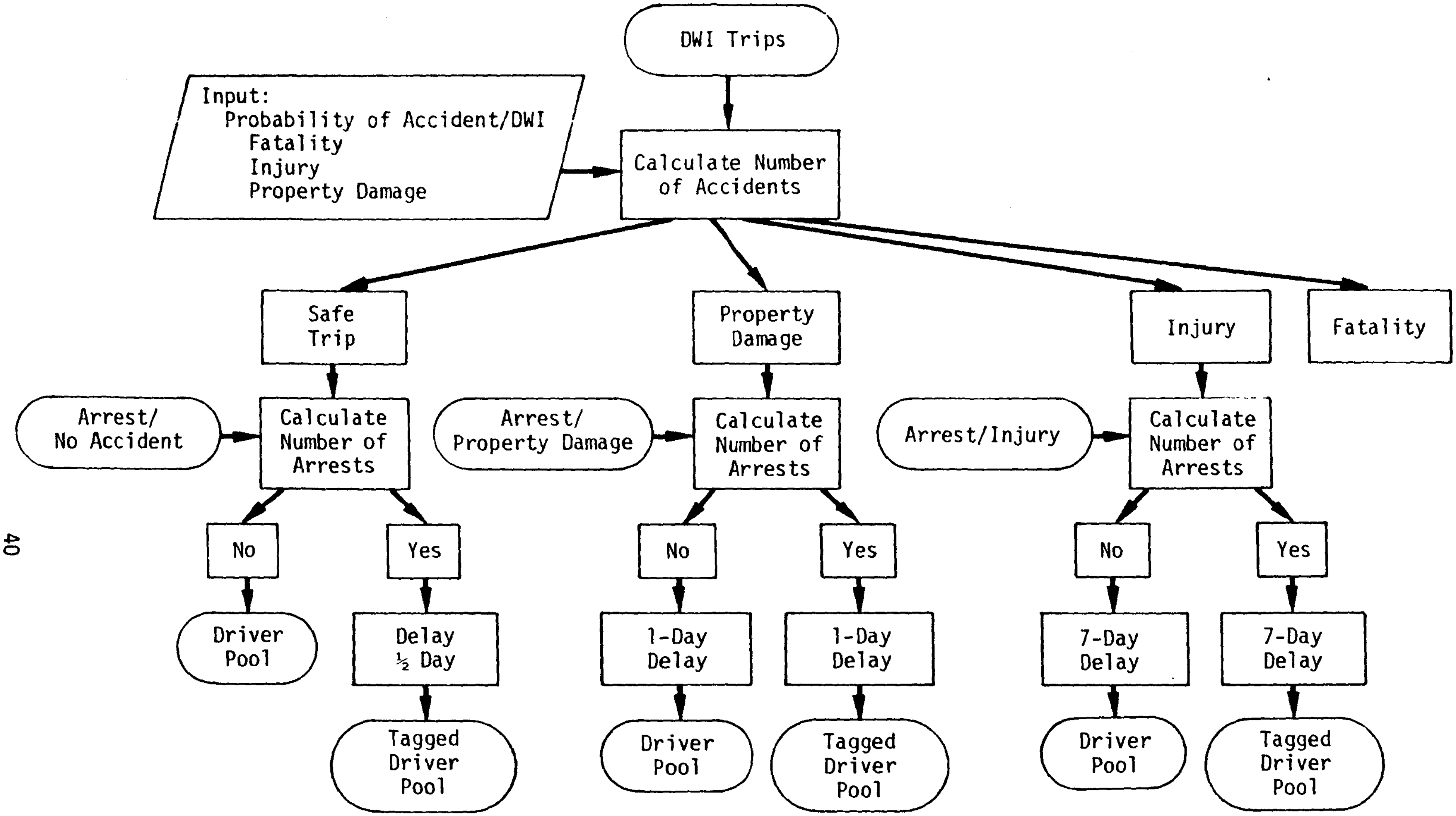


Figure 7. Driving while intoxicated trip model.

of three sequential events occurring: the observation, detection, and arrest of the detected DWI driver.

A simple model is used to determine the probability of any driver being observed by the police. It is the product of the number of patrol units, the percentage of time the units spend observing vehicles while on patrol, the number of observations a patrol unit can make per unit time, and the amount of time on patrol divided by the product of the total number of trips during the patrol period and the average trip duration. The expression is given by:

$$P_{OBS} = \frac{(E_U)(E_S)(K_T)(T)}{(ADT)(ATL)} \tag{3}$$

where:

E_U = number of patrol units working the jurisdiction during a time shift.

E_S = search efficiency and it is the percentage of preventive patrol per time shift. It is dependent upon the assigned duties of the patrol unit and attitudes towards the control of DWI's.

K_T = number of discrete observations per unit time.

T = total time patrol units are out on patrol.

ADT = average number of trips during a time period.

ATL = average trip length in minutes.

The model is based on the following assumptions: 1) all drivers have an equal potential of being observed, 2) all observations are independent and random, 3) a patrol unit observes one driver at a time, 4) when a patrol unit is on patrol it is observing drivers. The expression allows variation of several factors in enforcement, including the number of patrol units working a shift, the efficiency of the patrol in searching for DWI's, and the effect of a patrol unit going off its beat to investigate an accident or book a DWI.

Once a driver is observed by a patrol unit, the expected probability of arrest is dependent on three weighting functions or variables: the policeman's attitude and training, prearrest screening law, and the DWI backlog of the court system. The function is expressed by:

$$P_D = W_{ATT}\, W_{PS}\, W_{ADT}(\%\ \text{convict})\, P_{OBS} \tag{4}$$

where:

W_{ATT} = attitude towards a DWI arrest. According to previous surveys, police attitude is one of the main variables influencing the arrest of DWI's. No empirical data are available on this probability value.

W_{PS} = the weight for the prearrest screening law. If it exists, its value is one, if not, it will be the ratio of the number of drivers whose BAC is 0.15 or greater to the number of drivers whose BAC is 0.10 or greater. From roadside survey data the average BAC level of drivers who are at BAC's of 0.15 or greater is 0.175. This value agrees with the average BAC's of drivers arrested for DWI (NHTSA, 1972). This model assumes that police are not 100 percent confident that the drivers are intoxicated unless the driver's BAC is 0.15 or greater.

W_{ADT}(% convicted) = the weight for court overload. When the DWI court backlog builds up, cases are dismissed according to the statute of limitations. As the percent convicted decreases, this information is fed back to the arrest model and lowers the arrest rate.

DWI Arrest with an Accident

If a property damage or an injury accident occurs, the model assumes that the patrol unit has detected the DWI driver as a result of the accident, and the governing factor is whether or not there is enough evidence for a DWI arrest. If there is a prearrest screening law, the probability is that they are arrested. If not, the model assumes that the proportion of intoxicated drivers who are at 0.15 BAC or above are arrested.

DWI ADJUDICATION

The adjudication flow for the model requires the incorporation of only those elements which impact the information feedback component of the model.

Consequently, many judicial steps not relevant to the DWI general deterrence model have been omitted.

As suggested by the literature review, adjudication may have a negative effect: as DWI enforcement increases, courts become overloaded and inefficient in handling DWI cases. This information is fed back to enforcement, which may reduce the efficiency of enforcement, thereby reducing enforcement exposure and, ultimately, the perceived risk of DWI trips. A positive effect of adjudication comes from word-of-mouth exposure of drivers which increases their awareness of enforcement and sanctions, and ultimately the perceived risk and expected costs of DWI trips as well.

The DWI adjudication component of the model incorporates dismissal of DWI cases as a function of backlog and suspension of convicted drivers from the driver pool.

As shown in the DWI adjudication flow diagram in Figure 8, "tagged" drivers--i.e., those drivers arrested for DWI but still remaining in the driver pool, are scheduled for trial. When the trial date arrives these drivers are added to the court cases awaiting adjudication. The court system has a maximum number of cases that it can dispose of by normal proceedings. If a driver remains in the court trial queue over the statute of limitations, his case is dismissed and he returns to the driver pool. The remainder of the drivers are disposed of at a rate determined by the mean disposition time and the number of court workers. For this study, a court worker is defined as the personnel and facilities required to process a DWI case. The probability of conviction for the processed cases is a preset number. The convicted drivers are suspended from the driver pool, and the nonconvicted drivers return to the driver pool.

INFORMATION FEEDBACK

The DWI decision model responds to changes in the driver's perceived risk of enforcement and his awareness of sanctions. The system model assumes that these variables do not change unless the driver receives information feedback in one or more of the following three ways: word-of-mouth about those who have been arrested, visibility of police patrols during periods of high DWI activity, and exposure to public information campaigns on DWI enforcement and sanctions.

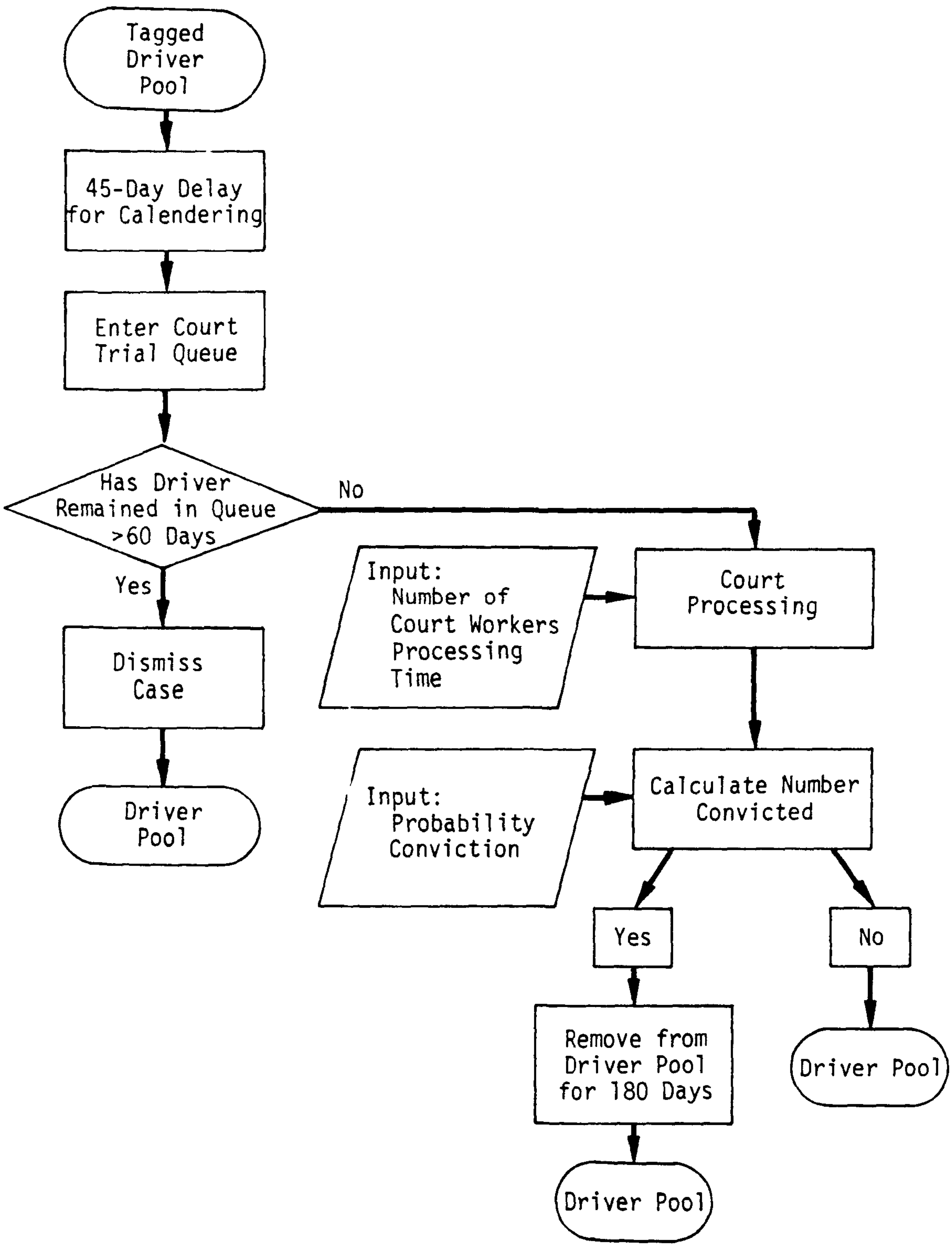


Figure 8. DWI Adjudication.

The model considers the effect of information exposure in terms of the driver's ability to recall the message. This ability to recall, termed exposure retention, is measured as percentage recalled. A change in the driver's perceived awareness of a sanction or perceived risk of arrest, then, is the product of exposure retention and the driver's receptiveness to the message.

Following psychological learning theory, retention of the message increases with the number of exposures but with diminishing returns. Also, as time passes, people forget the message, and retention decays with time in the absence of new exposures. A driver's receptiveness to the message content will be treated as a system parameter, but will be constant for each driver group during any one simulation run.

Exposure Recall

Exposure recall is adapted from the Media Planning Calculus Model developed by Little and Lodish (1969). Exposure of a driver to the information means that the driver has perceived the message. Exposure or nonexposure within a time frame (Z_t) of an individual to information is a random variable. Let

$$Z_t = \begin{cases} 1, & \text{if a driver is exposed} \\ 0, & \text{if not.} \end{cases} \tag{5}$$

The distribution of Z_t is determined by a media insertion, an enforcement exposure, or the presence or absence of an arrest. The number of exposures an individual retains in a time period is described by the difference equation

$$Y_t = Z_t + \alpha Y_{t-1} \tag{6}$$

where α is a memory constant or the fraction of Y_t retained from one time period to the next and $0 \leq \alpha < 1$.

Recall of the message increases with the number of exposures but with diminishing returns or

$$r = 1 - e^{-\beta Y_t}, \qquad (7)$$

where β is the learning effect time constant.

The above equations apply under the following assumptions: message recall is a correlate of impact, all drivers have the same potential for recall, and all combinations of exposures for a given information source have the same memory function. By knowing the number of exposures an individual has received, the above expressions allow us to calculate the recall fraction.

Perceived Enforcement Rate

The driver's perceived enforcement rate (P_R) changes as a function of information recall times the driver's receptiveness to the information or the perceived risk weight of the information source. The model is linear and the effects of the three information sources--word-of-mouth, enforcement visibility, and public media--may be accumulative and interact with each other.

The functional flow for the perceived enforcement rate information is shown in Figure 9. A Monte Carlo simulation is used to determine each of the three exposure recall routines. Word-of-mouth feedback depends on the number of DWI arrests and includes the number of drivers who have been arrested as well as a multiple of that number to reflect other individuals who have learned of the arrest. These additional drivers are selected randomly and are capable of receiving more than one word-of-mouth exposure. Enforcement visibility feedback reflects the effect of having patrol units on the street during periods of high DWI activity. The input is based on the DWI arrest section of the model and it uses the probability of a patrol unit observing a vehicle (P_{OBS}) from the DWI arrest submodel. Only the nighttime P_{OBS} is used. The public media feedback depends on the probability of exposure to the message and the message insertion rate into the media. For all three information sources the message learning rate and retention rate are separate and were treated as system variables.

The perceived enforcement weights for the three information sources and their potential interactions were treated as system variables and their effects on the overall system were treated by sensitivity analysis.

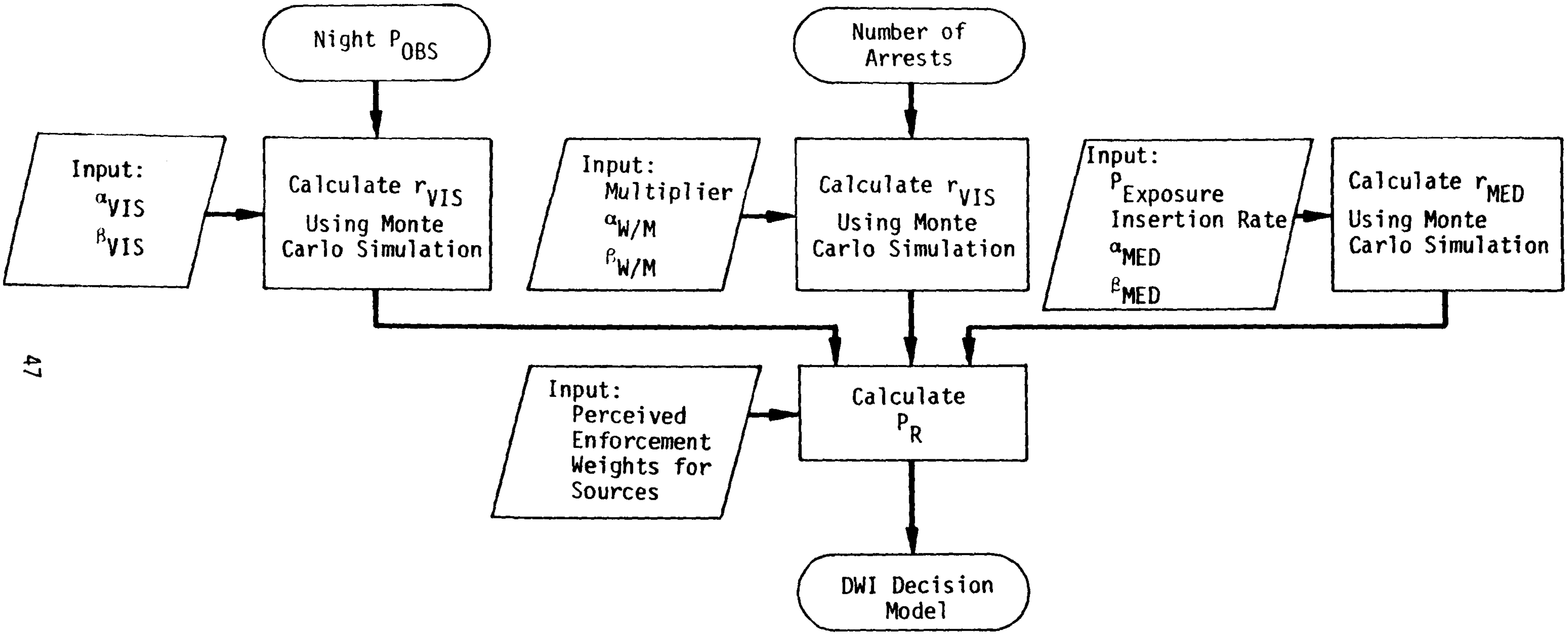


Figure 9. Perceived enforcement rate.

Sanction Awareness Routine

The perceived cost of the sanction (U_A) is a driver group characteristic which varies among groups. Once a driver knows the actual cost of a sanction (U_A') it is assumed that this knowledge remains with him and his sanction value is changed accordingly.

Figure 10 shows the functional flow for changing the perceived cost of the sanction. It assumes that if the driver receives any word-of-mouth feedback, the value of U_A is changed to U_A'. It also assumes that when the driver has retained a media message above a given level (K_A), the value of U_A is changed to U_A'. If every driver receives the message and his U_A has changed, then it is no longer a group variable.

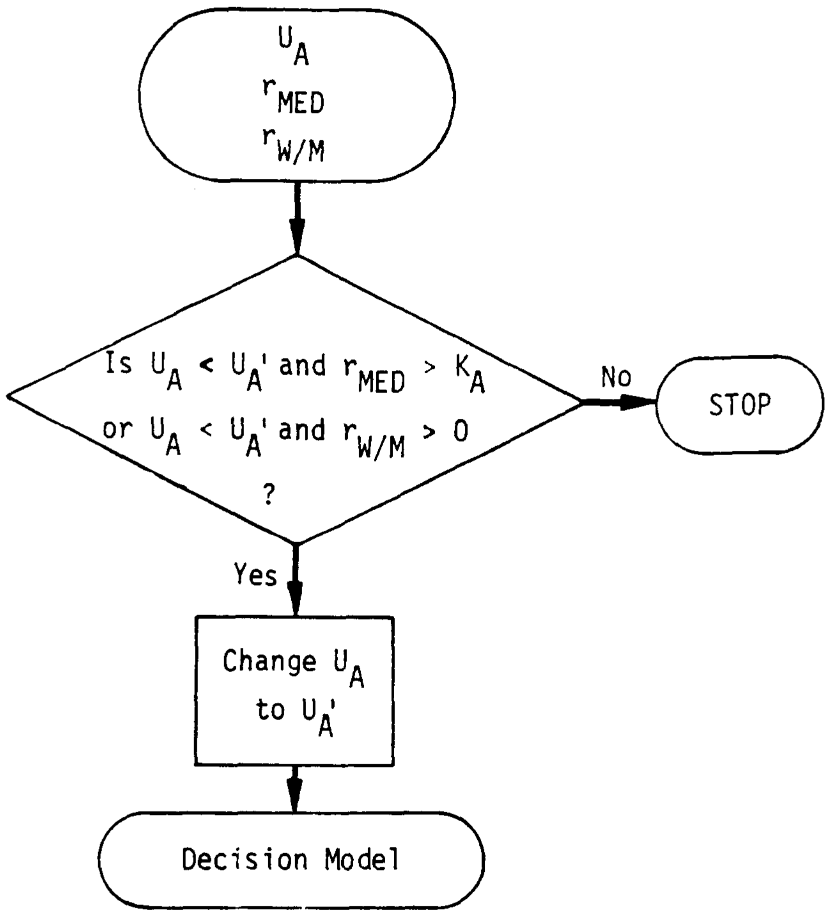


Figure 10. Sanction awareness.

COMPUTER-BASED SIMULATION

A computer-based simulation program was developed to exercise the DWI general deterrence model. The simulation permitted the dynamic manipulation of system variables which affect the number of DWI trips taken and distinguish among the potential of different countermeasure programs for reducing the number of alcohol-related accidents. The simulation program was designed to support the system analysis of DWI general deterrence reported here, and to be used as a tool in future research efforts. A primary benefit of the simulation program will be in its application to tests of the sensitivity of system parameters and to the identification of priorities for further research.

GENERAL SIMULATION DESCRIPTION

The computer-based program employed for the DWI general deterrence model is a fixed-time step simulation. That is, a simulation run is a series of cycles in which each cycle represents a fixed period of time, and system parameters remain constant within each cycle. However, parameter values change from one cycle to the next as a consequence of the dynamic feedback of results of preceding cycles. Finally, upon completion of the simulation, records of activities within the system and of system outputs are provided for examination.

An expected value, Poisson-flow process, is employed by the DWI general deterrence computer simulation program within each cycle. The process operates as follows. A given number of units (driver-trips, for example) enters a subsystem network serially and is assigned to alternative events according to a calculated probability. The Poisson process generator determines which unit is assigned to which event. For example, a driver-trip which has already resulted in a driver arrested for DWI is assigned either to the conviction or the acquittal event. Additional considerations are incorporated into the process to better reflect the real world. For example, units might incur time delays such as those involved in the adjudication process, or they might be stopped from exiting an event, for example, a driver experiencing a fatal accident.

SYSTEM FLOW NETWORKS

The computer simulation program incorporates the three networks of the DWI general deterrence model--the driver-trip network, the adjudication network, and the information feedback network. The different units which flow within these networks are respectively: driver-trips, arrested drivers, and drivers' perceived risk levels. The three network flows are interconnected. For example, the driver-trip network produces DWI arrests which enter both the information and adjudication networks. The adjudication network processes the DWI arrests and produces the ratio of convicted DWI drivers. This ratio, in turn, influences the arrest rate in the driver-trip network. The information network processes the arrest rate to influence the driver's perceived risk levels in the driver-trip network.

Each network has a different time step to best reflect the frequency of changes in the real world. The driver-trip network has a computation cycle of 12 hours; and the information and adjudication networks each have a cycle of seven days. Therefore, relative to performing and updating driver-trip computations, information and adjudication computations are performed and updated every 14th time that the driver trip cycle is performed and updated.

Driver-Trip Network

Within the driver-trip network, driver-trips can experience the various possible events which might take place, such as safe trip, DWI arrest, fatal accident, injury accident, and property-damage accident. The flow diagram for this network is provided in Figure 11, and amplified in Figures 12 and 13. The initial number of trips for a time step is a function of the conditions established for the simulation run. As shown in Figure 11, driver-trips become DWI trips, DWS trips, or non-trips as a function of the decision calculation. Figures 12 and 13 show the Poisson-flow event network for the DWS and DWI trips respectively.

The output of each type of event provides a Poisson input to the next event. These event types were designed to correspond to the stage types used in the Traffic Safety Demonstration Program Modeling System (DEMON) model (David, *et al.*, 1976). A brief description follows:

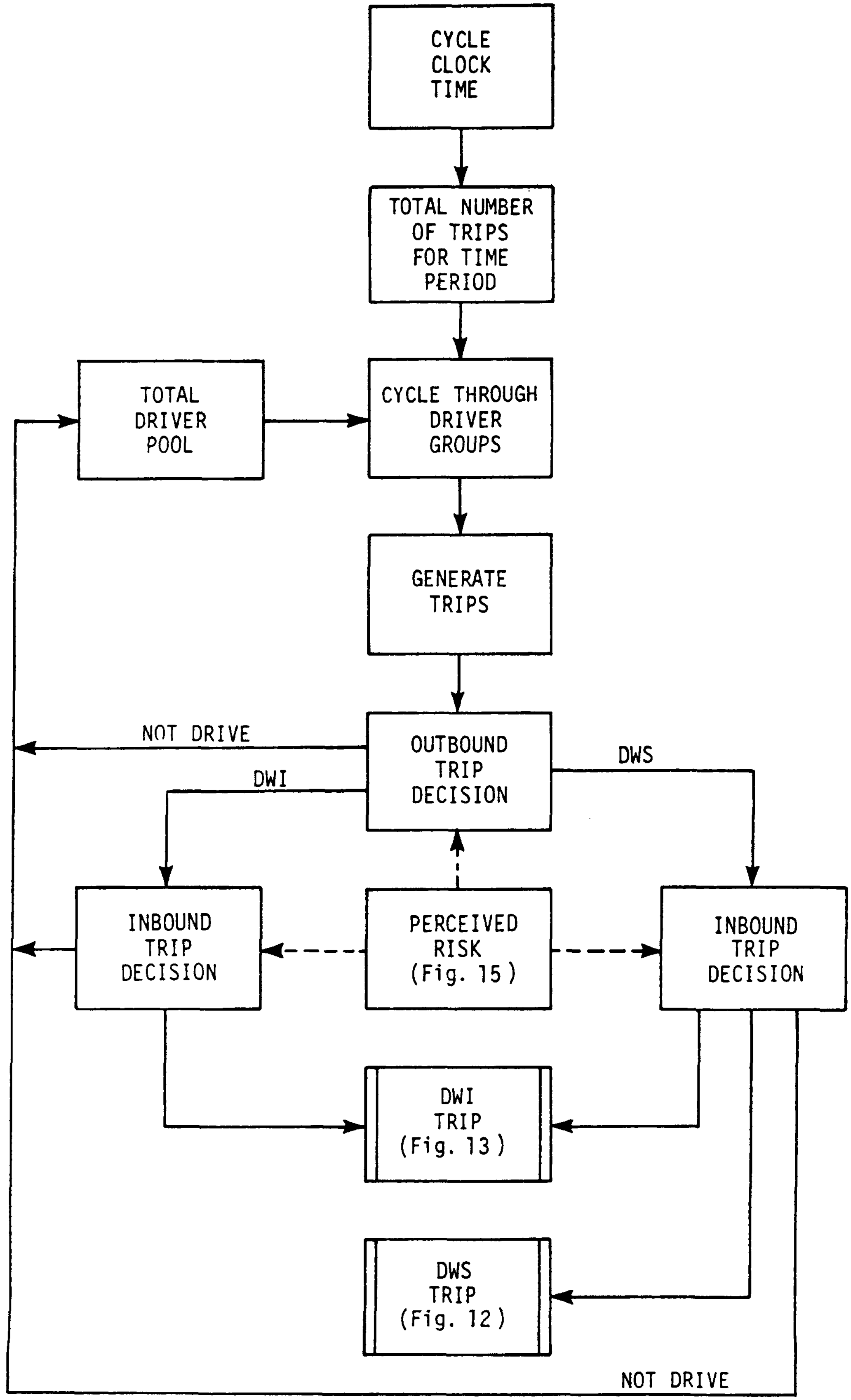


Figure 11. Driver-trip flow diagram.

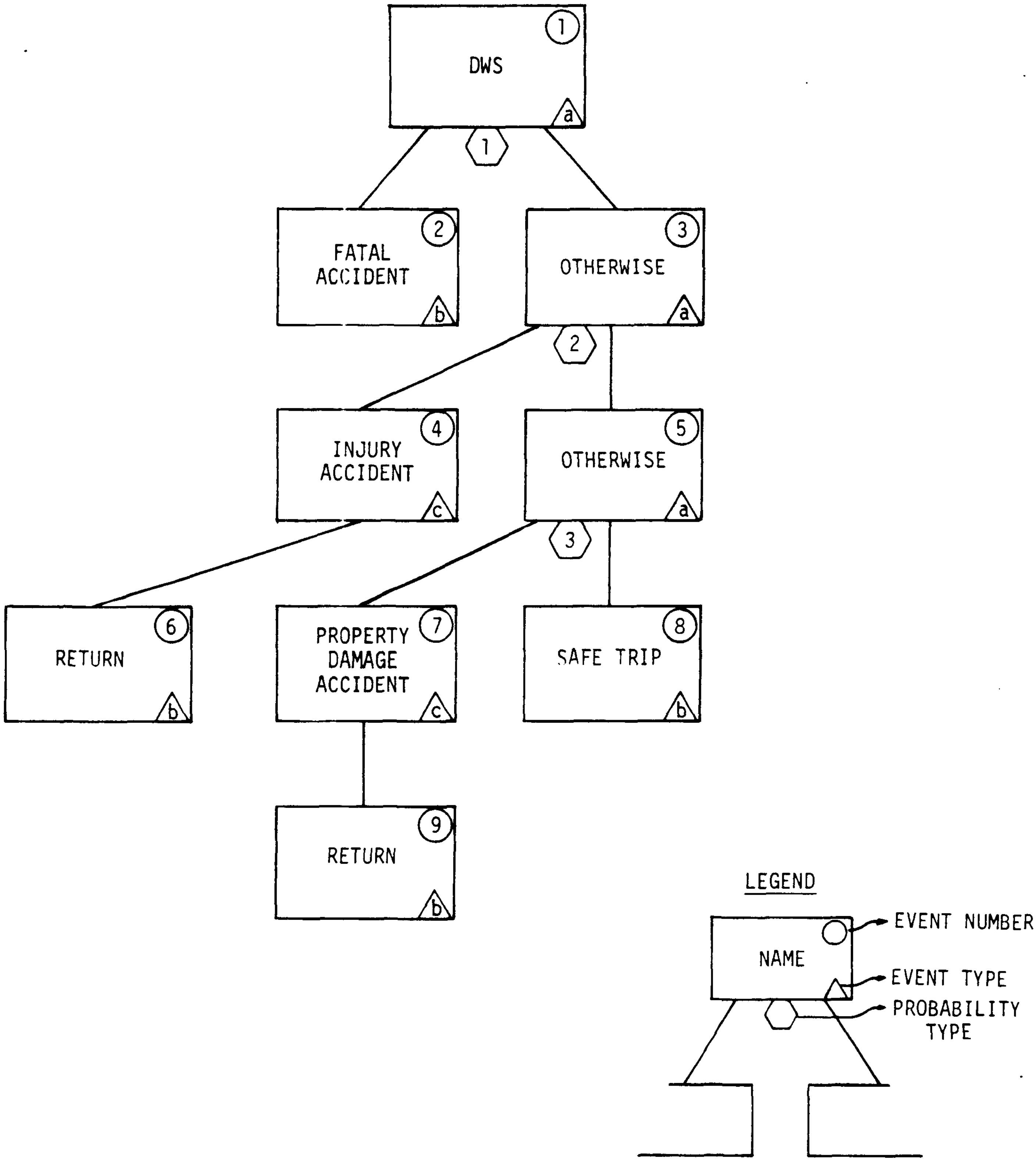


Figure 12. DWS trip Poisson-event network.

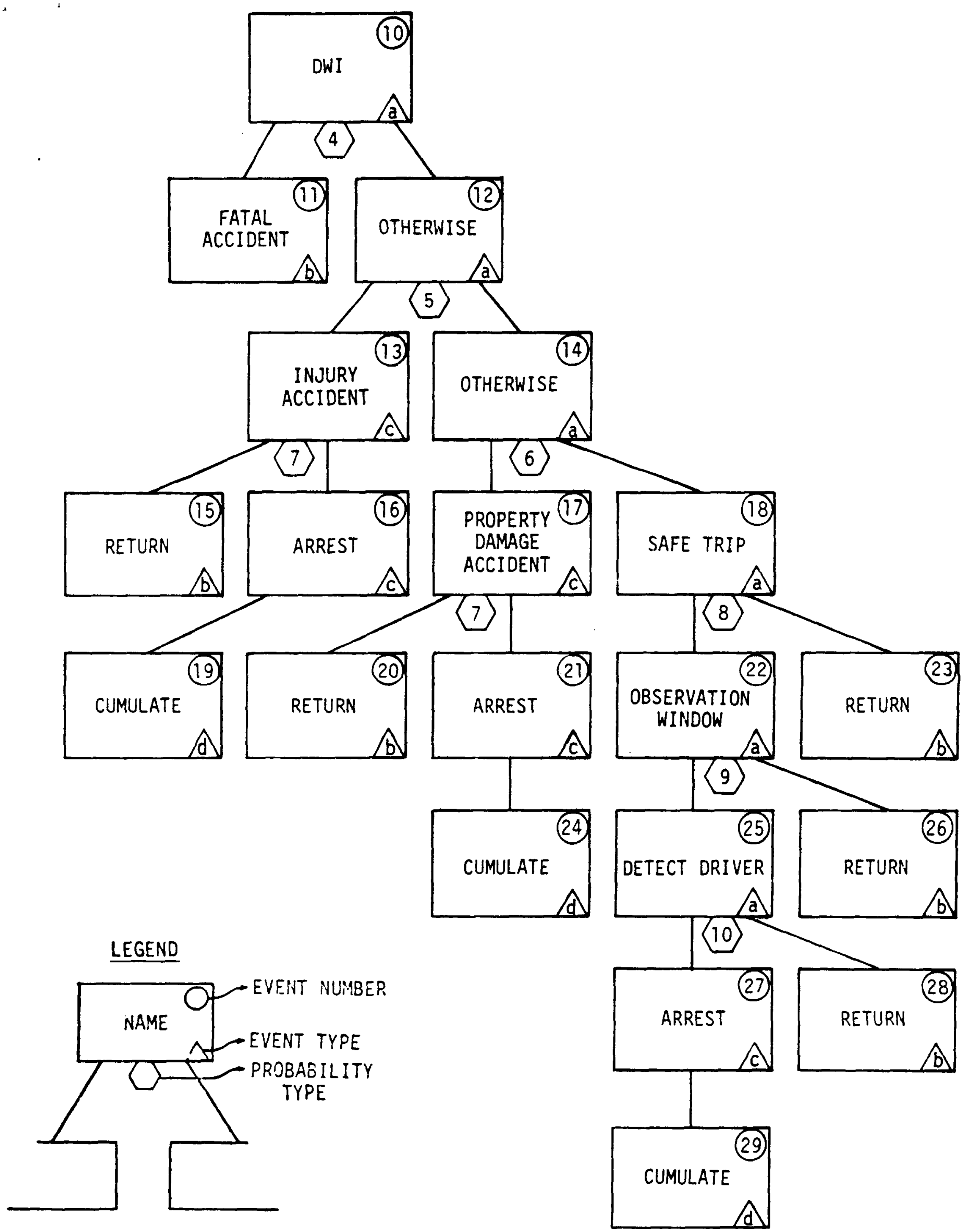


Figure 13. DWI trip Poisson-event network.

Type (a). This type is used at branching points in the network. No time delays are involved.

Type (b). This type is used to exit from the network at the end of a simulation time step. The number of exiting drivers is counted.

Type (c). In this event, the entering driver is held for a constant delay time, independent of the number of entering drivers, to delay the return of a driver to the driver pool after an accident or DWI conviction.

Type (d). This type is employed to hold drivers for subsequent processing. No time delays are involved; drivers are simply accumulated for a subsequent event, such as adjudication.

The probability types associated with an event identified in Table 1 have been described in the development of the system model.

Within any time step, the program calculates: 1) if there were a sufficient number of driver trips for the event to occur--if not, the number of trips is accumulated for succeeding time steps, 2) the number of driver-trips that have passed through the event and 3) the number of driver-trips being processed in the event and the associated time delay of those trips. The computation starts with the first event in the network and proceeds, in order, through the remaining events.

Adjudication Network

This network processes drivers who have been arrested for DWI. The arrest events, Events 15, 24, and 29, are shown in the DWI trip network of Figure 13.

The adjudication network contains two new event types.

Type (e). This type is used for an arrested driver who is calendared for trial, but remains part of the driver population. No time delay is involved, but cost might be accrued.

Type (f). This is a general queuing event which is used only for court disposition in the adjudication network. Court personnel are available to process drivers, one at a time, and each at the same processing rate. Drivers remain in the event until processing is completed.

TABLE 1

PROBABILITY TYPES FOR THE POISSON EVENT NETWORKS

NUMBER	TYPE
1	DWS Fatal Accident
2	DWS Injury Accident
3	DWS Property Damage Accident
4	DWI Fatal Accident
5	DWI Injury Accident
6	DWI Property Damage Accident
7	Arrest Given Accident
8	Driver in Patrol Unit's Search Window
9	Detection Given Driver in Patrol Unit's Search Window
10	Arrest Given Detection
11	Conviction

Arrested drivers are accumulated for adjudication processing (Event Type (d)) and then, on the 14th driver-trip cycle, the accumulated drivers enter the adjudication network. This network is illustrated in Figure 14.

Drivers enter into the calendaring event where they receive a "tag" for adjudication, but remain part of the driving population. Upon conviction, the drivers are suspended from the driver pool for a fixed time period. Drivers return to the driver pool with their "tags" removed after the suspension delay, or directly without delay if not convicted.

Information Feedback Network

The information network calculates the perceived enforcement rate and sanction awareness and provides perceived risk values for the DWI decision. These values are a function of the drivers' exposure to three different information sources--word-of-mouth, enforcement visibility, and public information. As discussed earlier, message recall is calculated and transformed into perceived enforcement rate. The information network is illustrated by the flow diagram shown in Figure 15.

The information values are calculated every 24-hour period (every other driver-trip time step) for each source. The number of exposed drivers is determined by a Monte Carlo method employing a discrete event simulator with a uniform distribution. The recall fraction is calculated from the number of exposures the driver receives. This fraction, together with the driver's receptivity to the message, is employed to calculate perceived enforcement rate and sanction awareness to determine the perceived risk value.

COMPUTER PROGRAM FLOW CHARTS

Five major computer routines--DETER, EXFLOW, RECALL, CALFLOW, and PROBCAL--were developed to perform the required calculations and processing for the computer simulation program. The interrelationships among these routines are described briefly in this section, and graphic representations of the operations performed by each are included to provide an overall understanding of the operations required to execute the simulation and of the sequence in which they are performed. The calculations involved were discussed earlier in the description of the system model.

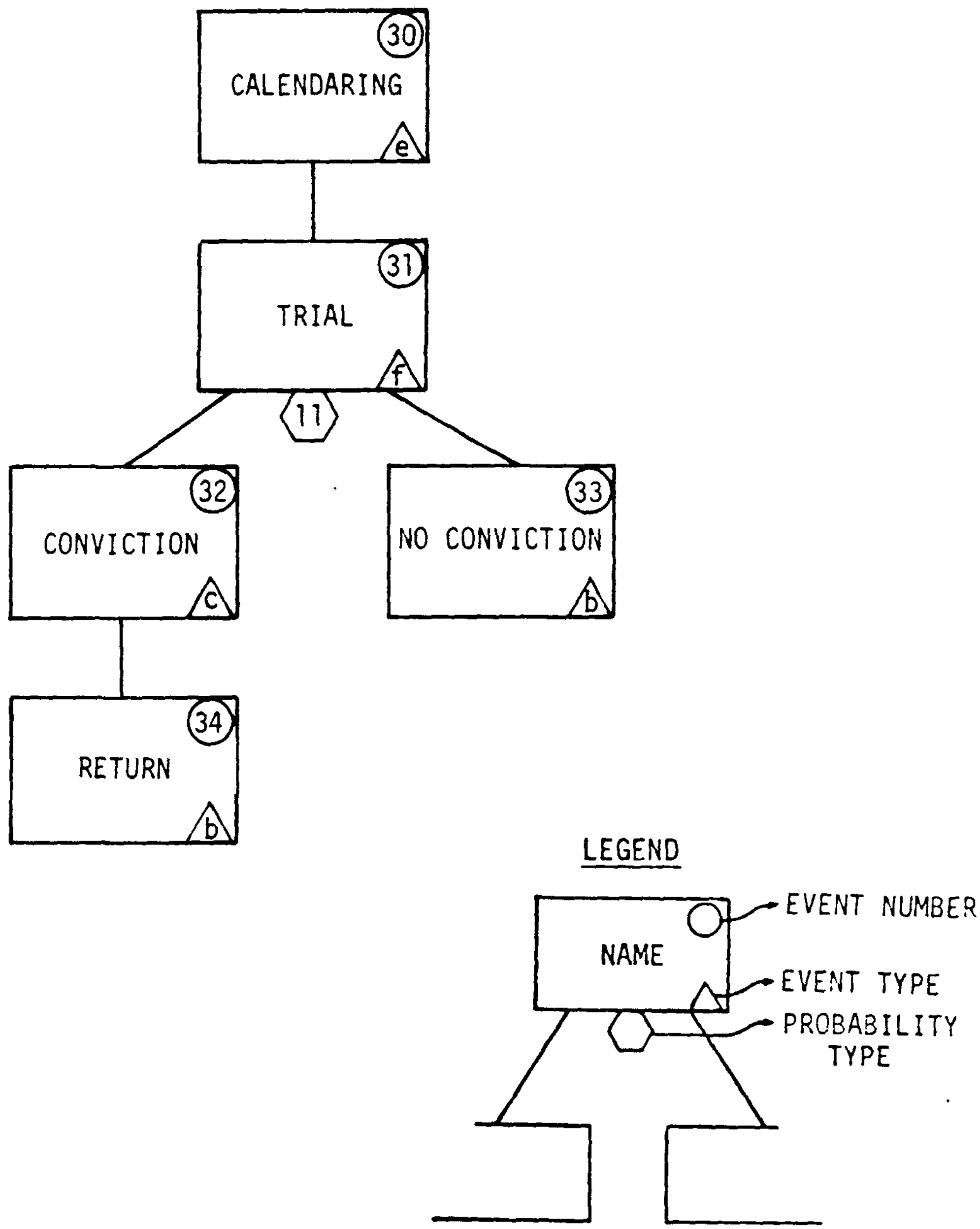


Figure 14. Adjudication Poisson-event network.

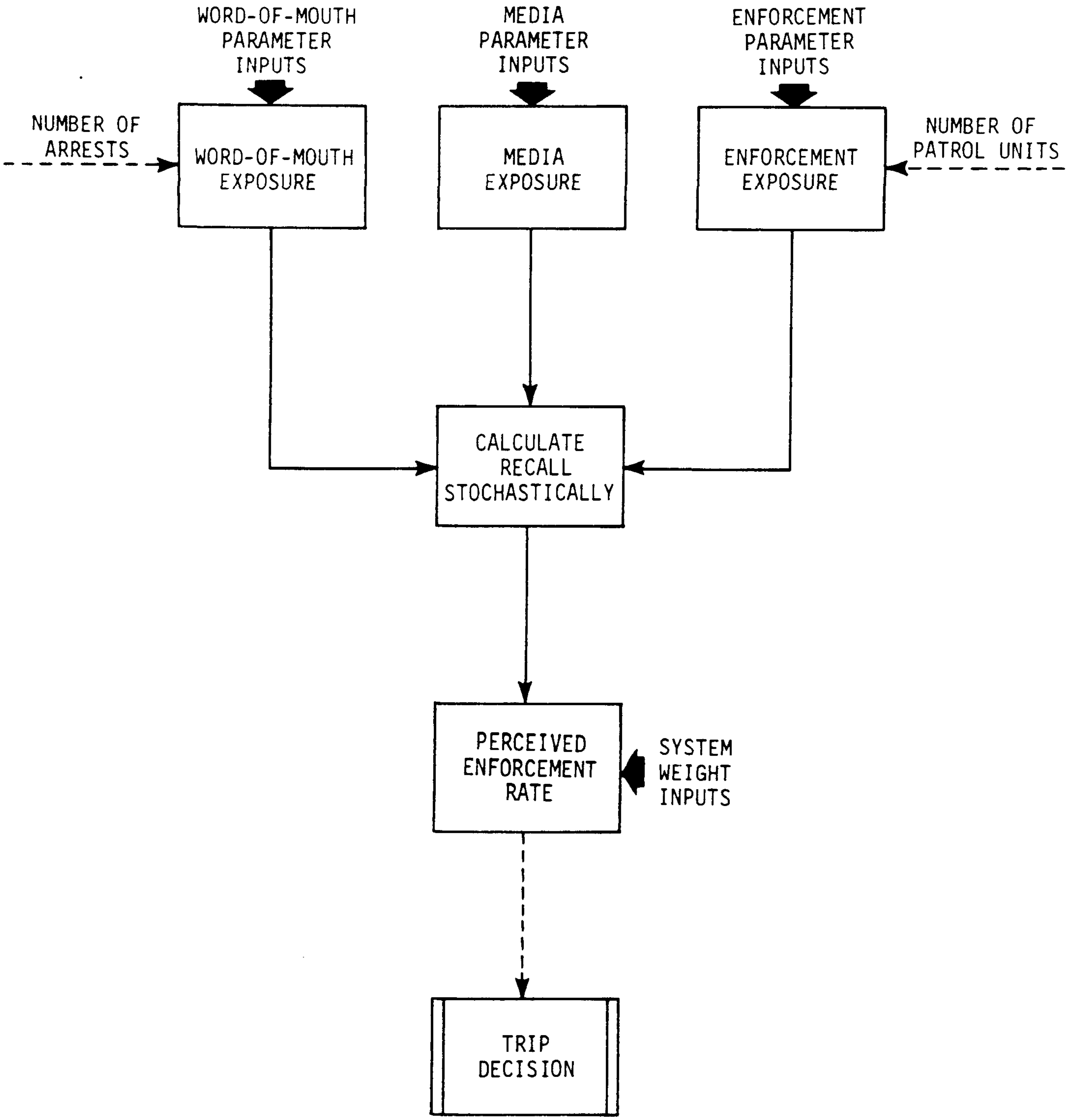


Figure 15. Information flow diagram.

The main program, DETER, shown in Figure 16, reads all the inputs necessary for a single simulation run, maps the inputs from a user-oriented input structure into the appropriate internal array, calls the EXFLOW routine to execute the simulation run, and prints the system outputs at the completion of the run.

The sequence of operations employed by EXFLOW to execute the simulation is illustrated in Figure 17 and consists of the following steps:

1. EXFLOW initiates run conditions and starts the simulation clock to generate and count half-day cycles.

2. EXFLOW determines whether or not the perceived risk values need to be updated. If so, calls the RECALL routine (Figure 18).

3. RECALL cycles through the three information sources--word-of-mouth, enforcement visibility, and public information--and determines driver exposure.

4. RECALL calculates the recall fraction on the basis of previously retained exposure and any new exposures, and applies system weights to calculate the new perceived risk levels. Control of the program returns to EXFLOW.

5. EXFLOW cycles through the driver groups, trip purposes, and trip segments to calculate trip risk and trip utility values (Figure 19).

6. These two values are used in the decision computation to determine whether the trips are DWS or DWI, and through combination with trip distribution inputs, EXFLOW calculates the number of DWS and DWI trips.

7. EXFLOW continues to control the flow of trips through both the DWS and DWI event networks. CALFLOW is executed for each event in each network.

8. If branching is required, CALFLOW calls the routine PROBCAL to (Figure 20) calculate the appropriate probabilities in accordance with the flow (Figures 20 and 21).

9. CALFLOW also makes the following calculations for each event:

- Number of driver trips being processed
- Time delays and costs accrued by driver trips that have passed through.

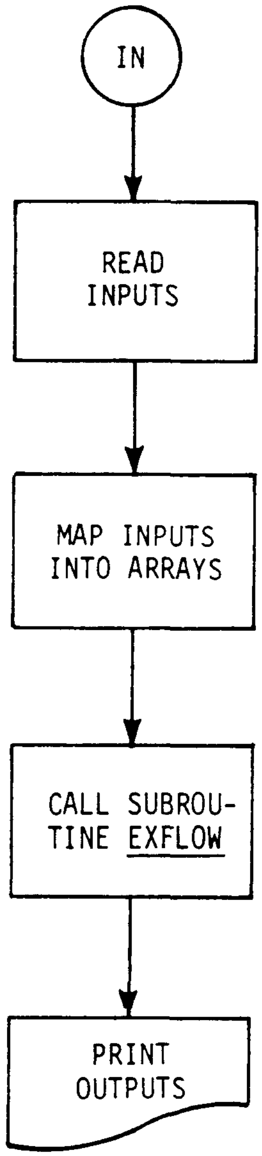


Figure 16. Program DETER flow chart.

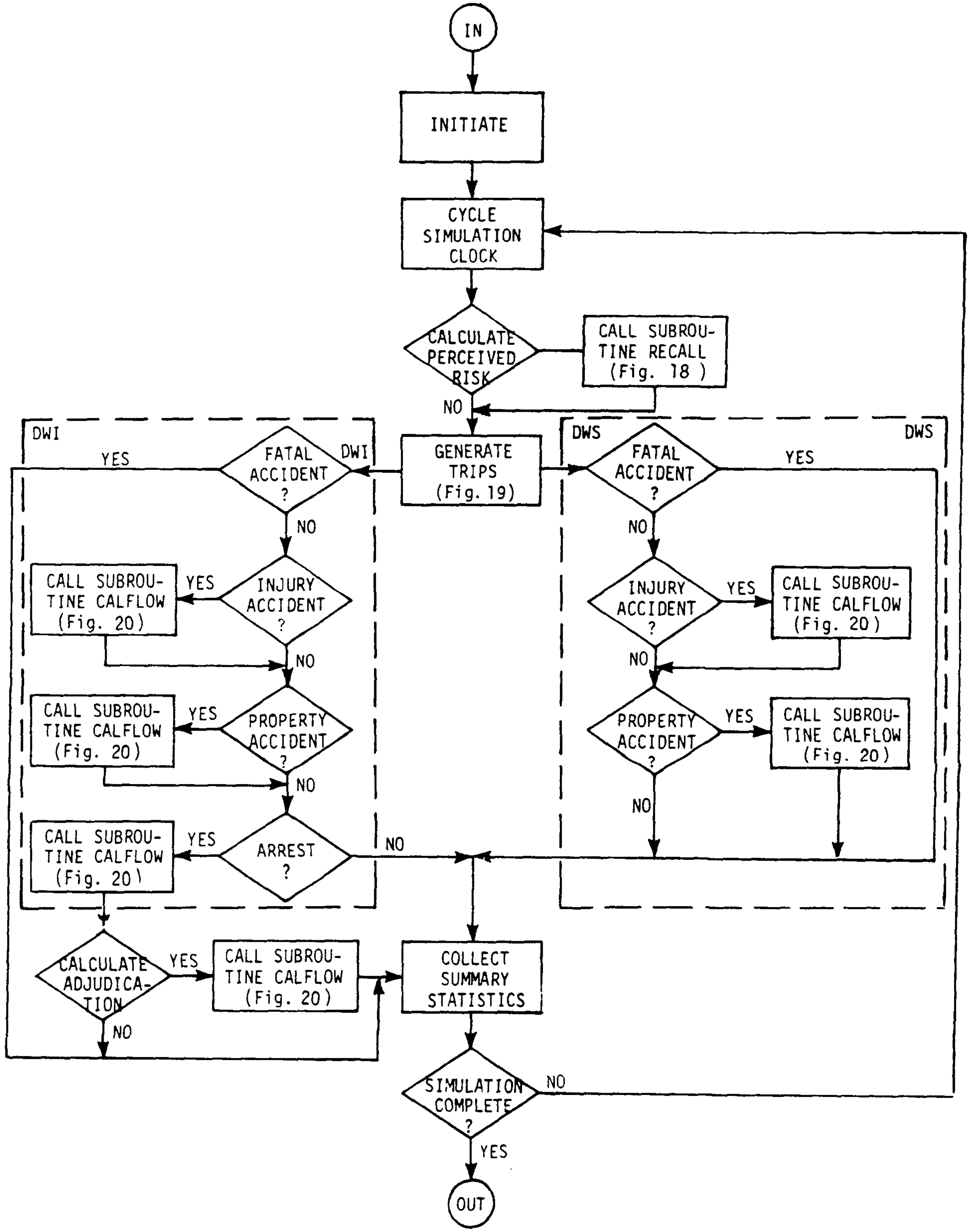


Figure 17. Subroutine EXFLOW flow chart.

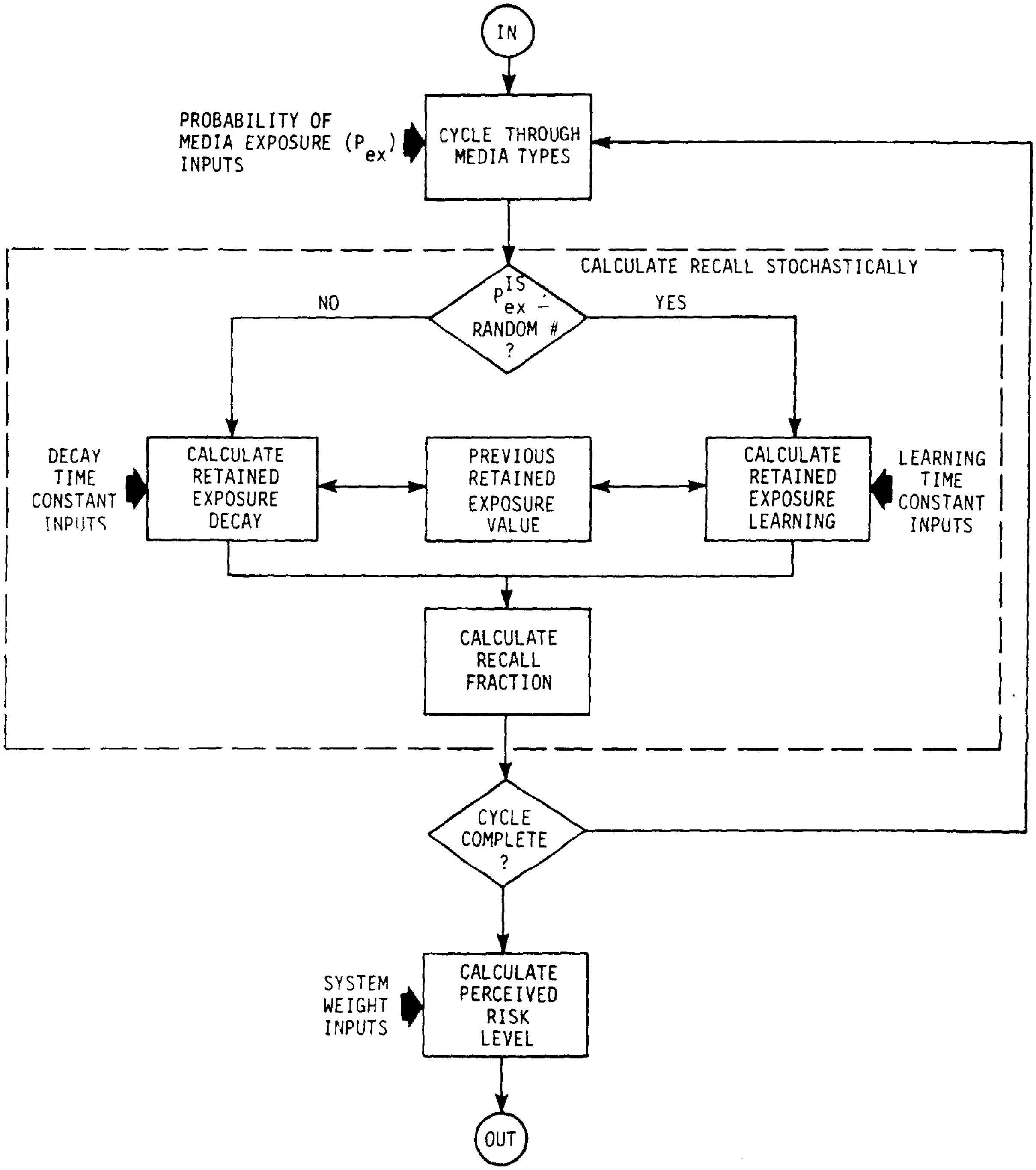


Figure 18. Function subroutine RECALL flow chart.

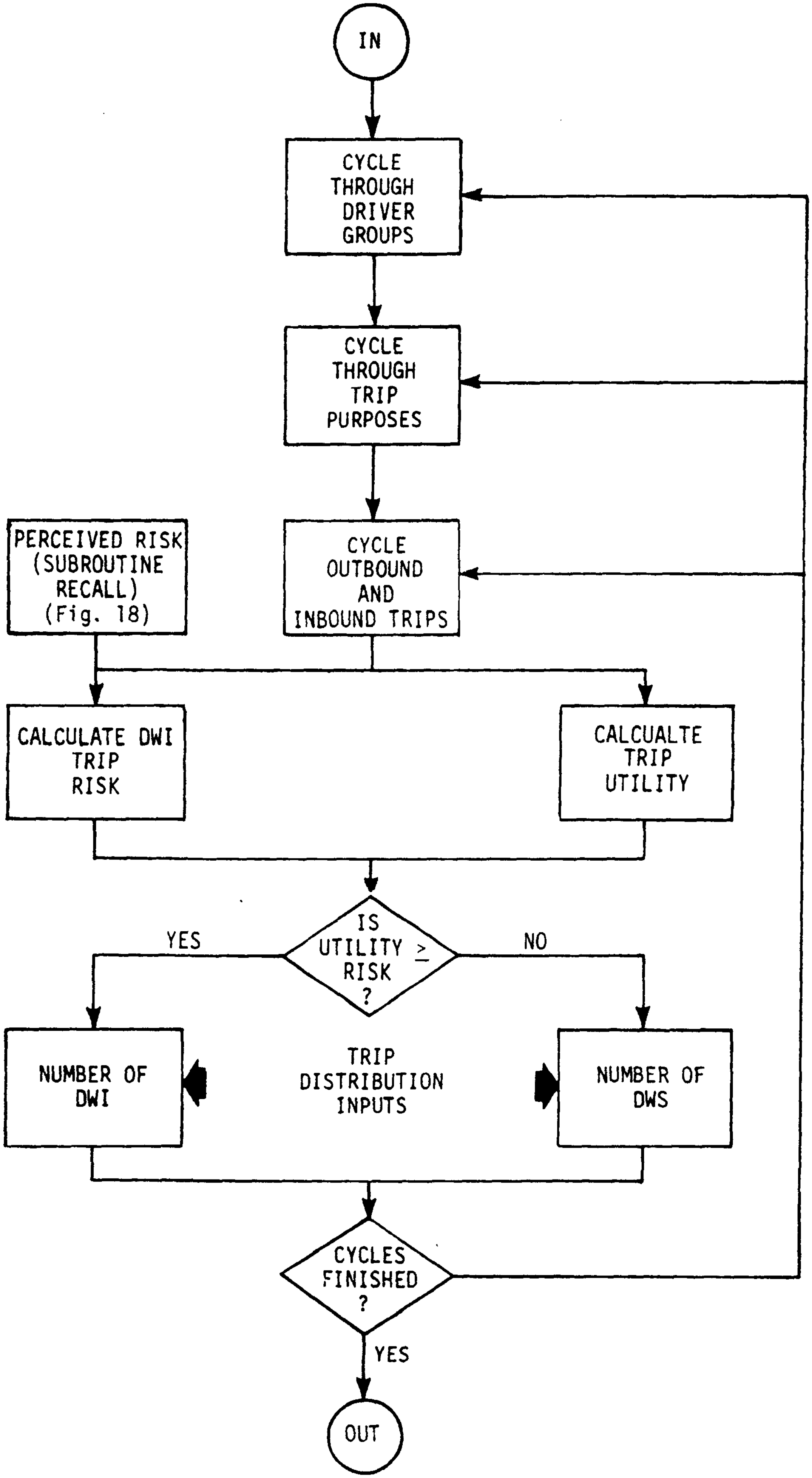


Figure 19. Trip generation of EXFLOW flow chart.

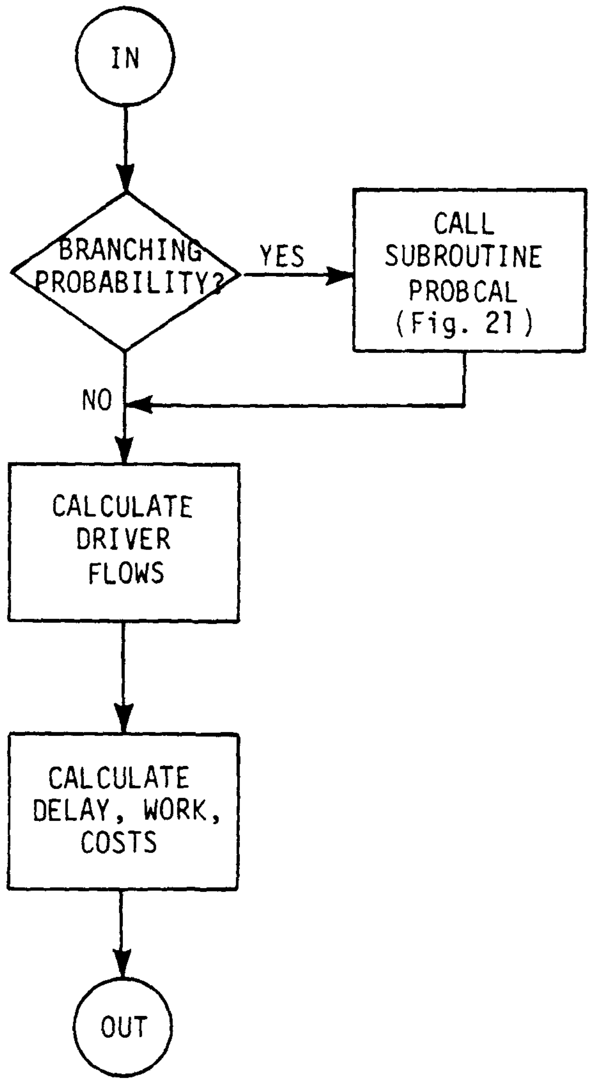


Figure 20. Subroutine CALFLOW flow chart.

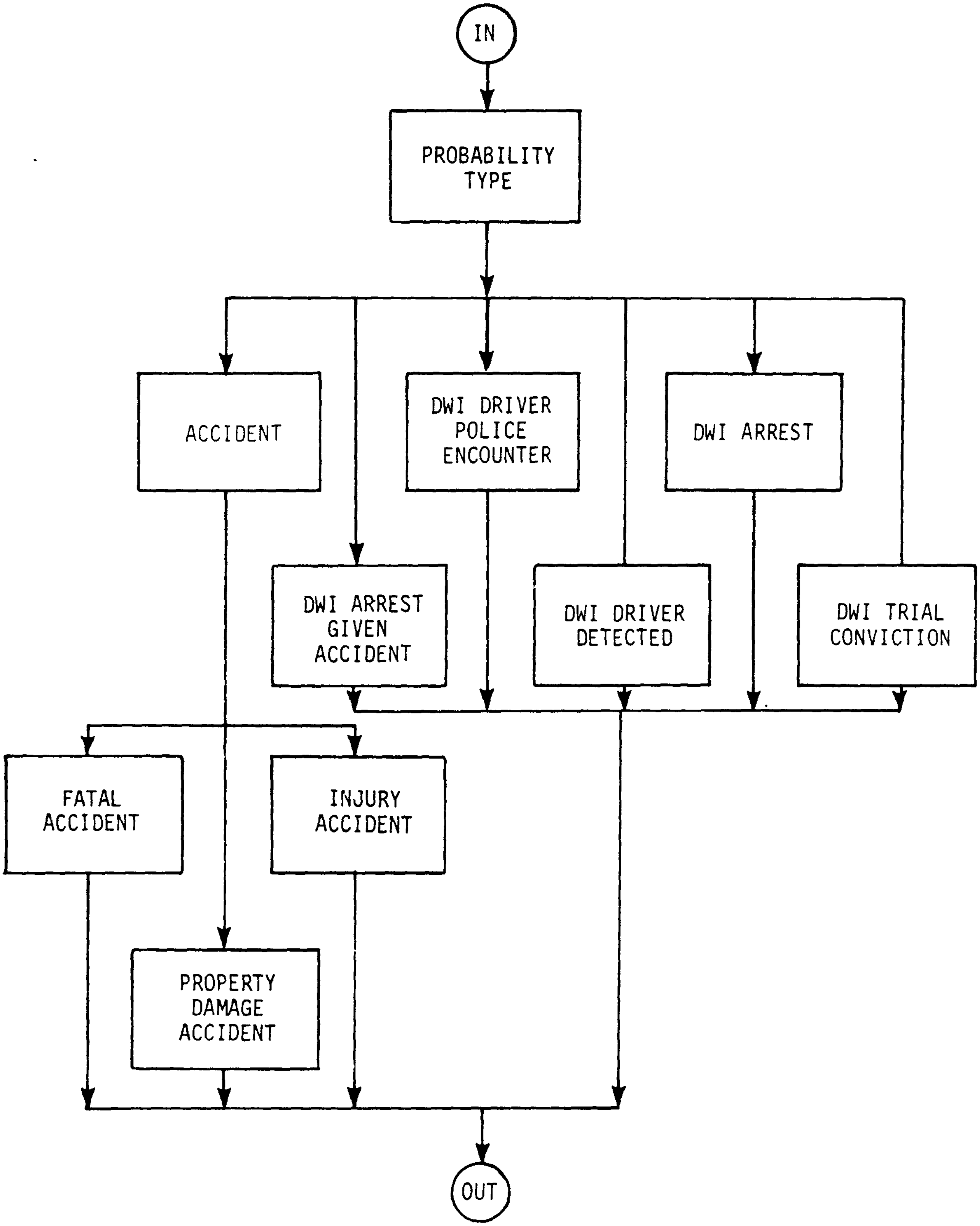


Figure 21. Subroutine PROBCAL flow chart.

10. Control returns to EXFLOW which determines whether adjudication calculations are required and, if so, calls CALFLOW to perform them.

11. Upon completion of all network flows, EXFLOW collects the summary statistics and recycles the program until the simulation is complete.

SIMULATION EXPERIMENTS

Experiments were conducted using the computer-based simulation program just described to evaluate the potential effects of different countermeasures on the DWI trip rate. Three approaches were used: programs that increase the perceived enforcement rate of a driver, programs that increase enforcement visibility and rate, and programs that present public information on enforcement and sanctions. Relative comparisons can be made between the programs and potentially effective programs can be identified.

The general approach to the simulation experiments incorporated the following steps:

1. Perceived enforcement weights for the baseline, word-of-mouth feedback, and enforcement visibility were estimated and calibrated using roadside breath test survey data.

2. Year-to-year variances in the simulation performance measures were determined by a Monte Carlo simulation. These variances were used to establish the confidence limits for analyzing the results of countermeasure program changes and to determine whether these program changes would produce significant results.

3. Countermeasure programs that affect the perceived enforcement weights (baseline, word-of-mouth feedback, and enforcement visibility feedback) were evaluated by varying these weights in parameter sensitivity experiments. The maximum effect any one of these weights have on the system was determined by performing experiments with the weights pushed to their upper limits, i.e., so high that a driver exposed to that information source alone refrains from driving intoxicated because his perceived risk value becomes much greater than the utility value of drinking and driving.

4. Enforcement, adjudication, and public information parameters were changed in experiments to reflect countermeasure programs that increase enforcement and media exposure to information about enforcement. The experiments evaluated the impact of these changes on the overall system.

5. The results of the experiments were evaluated to identify those variables that have a potential for significantly decreasing the DWI trip rate. The results were then compared to the results of real world countermeasure programs to determine whether the simulation program could have accurately predicted the outcomes of these real world programs.

EXPERIMENTAL SETUP AND DATA OUTPUT

The data input format for the simulation experiments is shown in Table 2. This includes the driver-trip parameters, the DWI decision parameters, the trip outcome parameters, and stage parameters for the network flow model. Other data inputs include the time period of the simulated experiment and changes in system parameters which represent the implementation of countermeasure programs.

The summary data available as simulation outputs include:

- Weekly time series plots
  - DWI rate
  - Night DWI rate
  - Number of accidents
  - Number of DWI arrests
  - Court backlog of DWI cases
- Monthly and yearly accumulative summaries
  - DWI rate
  - Night DWI rate
  - DWI fatal accidents
  - DWI injury accidents
  - DWI property damage accidents
  - Total fatal accidents
  - Total injury accidents
  - Total property damage accidents
  - DWI enforcement rate
  - DWI conviction rate

The enforcement rate in this case is the number of arrests per DWI trip. This differs from the enforcement rates quoted in the literature which are

TABLE 2

DATA INPUT FORMAT
(Example)

****DRIVER AND TRIP PARAMETERS****

TRIP PURPOSE	NUMBER OF TRIPS: WEEKDAY DAY	NUMBER OF TRIPS: WEEKDAY NIGHT	NUMBER OF TRIPS: WEEKEND DAY	NUMBER OF TRIPS: WEEKEND NIGHT	TRIP PURPOSE UTILITY: WEEKDAY DAY	TRIP PURPOSE UTILITY: WEEKDAY NIGHT	TRIP PURPOSE UTILITY: WEEKEND DAY	TRIP PURPOSE UTILITY: WEEKEND NIGHT
HOME-WORK	41374	7248	15837	5279	.176859	.189241	.176980	.189327
HOME-SHOP	30200	12382	42760	7391	.176882	.190019	.176920	.189964
HOME-OTHER	67346	28992	96869	44871	.187548	.221639	.187562	.221622
OTHER	94828	19328	38272	12933	.191853	.247199	.191834	.247236

DRIVER GROUP	DRINKING UTILITY DISTRIBUTIONS: DAY MINIMUM	DAY MODE	DAY MAXIMUM	NIGHT MINIMUM	NIGHT MODE	NIGHT MAXIMUM	FRACTION OF ADULT POPULATION
HEAVY 1	.200	.600	1.000	.400	.900	1.000	.045
HEAVY 2	.200	.600	1.000	.400	.900	1.000	.045
MODERATE 1	0.000	.300	.600	0.000	.500	1.000	.090
MODERATE 2	0.000	.300	.600	0.000	.500	1.000	.090
LIGHT 1	0.000	.100	.300	0.000	.100	.600	.155
LIGHT 2	0.000	.100	.300	0.000	.100	.600	.155
ABSTAIN 1	0.000	0.000	0.000	0.000	0.000	0.000	.210
ABSTAIN 2	0.000	0.000	0.000	0.000	0.000	0.000	.210

**** DWI DECISION PARAMETERS ***

DRIVER GROUP	SANCTION AWARENESS	RISK AVERSION
HEAVY 1	.700	.200
HEAVY 2	1.000	.200
MODERATE 1	.700	.200
MODERATE 2	1.000	.200
LIGHT 1	.700	.200
LIGHT 2	1.000	.200
ABSTAIN 1	.700	.200
ABSTAIN 2	1.000	.200

```
MEMORY RETENTION CONSTANT - MEDIA =      .850
                            VERBAL =      .975
                            VISIBLE =      .500
LEARNING EFFECT TIME CONSTANT =      .500
PERCEIVED RISK WEIGHTS
              BASELINE =      .0002
              MEDIA    =     0.0000
              VERBAL   =      .0005
              VISIBLE  =      .0002
WORD OF MOUTH RECALL THRESHOLD =     0.0000
PROBABILITY OF BEING EXPOSED PER MEDIA EXPOSURE =   0.000000
WORD OF MOUTH MULTIPLIER =  10
```

TABLE 2 (Cont.)

DATA INPUT FORMAT
(Example)

****TRIP OUTCOME PARAMETERS ****

TIME PERIOD	DWI OBSERVATION PROBABILITY
WK DAY	.014400
WK NITE	.015400
WKEND DAY	.013500
WKEND NITE	.014800

PREARREST SCREENING LAW WEIGHT = .255
WEIGHT FOR PATROLMAN ATTITUDE = .050
PROBABILITY OF DWI CONVICTION = .700

ACCIDENT TYPE	ACCIDENT PROBABILITY	
	BAC≤0.1	BAC>0.1
FATAL	2.20000E-07	7.39000E-06
INJURY	1.07900E-05	7.93300E-05
PROP. DAM.	1.43880E-04	3.70910E-04

ARREST PROB. GIVEN INJURY ACCIDENT = .515
ARREST PROB. GIVEN PROPERTY DAMAGE = .510

TABLE 2 (Cont.)

DATA INPUT FORMAT
(Example)

STAGE NAME	STAGE NUMBER	NEXT STAGE	NEXT STAGE	REQUIRED TREATMENT TIME	AVG. UNIT PROCESSING TIME	NUMBER OF WORKERS
DWS INJURY ACCIDENT	4	6	0	0.000	0.000	0
DWS NO INJURY ACCIDENT	5	7	8	0.000	0.000	0
RETURN TO POOL FROM STAGE 4	6	0	0	7.000	0.000	0
DWS PROPERTY DAMAGE ACC	7	9	0	0.000	0.000	0
RETURN TO POOL FROM STAGE 5	8	0	0	0.000	0.000	0
RETURN TO POOL FROM STAGE 7	9	0	0	1.000	0.000	0
DWI TRIP	10	11	12	0.000	0.000	0
DWI FATAL ACCIDENT	11	0	0	0.000	0.000	0
DWI NO FATAL ACCIDENT	12	13	14	0.000	0.000	0
DWI INJURY ACCIDENT	13	15	16	0.000	0.000	0
DWI NO INJURY ACCIDENT	14	17	18	0.000	0.000	0
RETURN TO POOL FROM STAGE 13	15	0	0	7.000	0.000	0
DWI ARREST/INJURY ACCIDENT	16	19	0	0.000	.500	0
DWI PROPERTY DAMAGE ACCIDENT	17	20	21	0.000	0.000	0
DWI SAFE TRIP	18	22	23	0.000	0.000	0
RETURN-TAGGED-FROM STAGE 16	19	0	0	7.000	0.000	0
RETURN TO POOL FROM STAGE 17	20	0	0	7.000	0.000	0
DWI ARREST/PROPERTY DAM ACC	21	24	0	0.000	.500	0
DWI IN PATROLMANS WINDOW	22	25	26	0.000	0.000	0
DWI NOT IN PATROLMANS WINDOW	23	0	0	0.000	0.000	0
RETURN-TAGGED-FROM STAGE 21	24	0	0	1.000	0.000	0
DWI DRIVER DETECTED	25	27	28	0.000	0.000	0
DWI DRIVER NOT DETECTED	26	0	0	0.000	0.000	0
DWI DRIVER ARRESTED	27	29	0	0.000	.500	0
DWI DRIVER NOT ARRESTED	28	6	0	0.000	0.000	0
RETURN-TAGGED-FROM STAGE 27	29	0	0	.500	0.000	0
CALENDARING	30	31	0	45.000	.025	0
TRIAL	31	32	33	.500	.500	4
DWI CONVICTION	32	0	0	180.000	0.000	0
NO DWI CONVICTION	33	0	0	0.000	0.000	0

the number of arrests per year per registered driver. The performance measures were selected under the assumption that the same performance measure would be recorded in the real world situation. The primary performance measure is the total DWI rate; any changes in this rate will be reflected in the number of fatal and injury accidents. Changes in enforcement rate reflect an increase in efficiency of arrests and an increase in costs for enforcement and adjudication.

DEVELOPMENT OF SIMULATION PARAMETER VALUES

An initial step in simulation is to select parameter values. This selection requires a simulation scenario to determine the number of drivers, the number of daily trips, the purpose and length of the trip, the characteristics of the enforcement agency, the number of court workers, and the number of public information messages. Table 3 lists these parameters and the data sources used to develop the values.

For certain other parameters, however, no real world values were available. One of the problems with a systems analysis of DWI general deterrence conducted at this time is the lack of knowledge available on the driver's decision function, the utility value of drinking and driving, and the perceived risks involved. The analysis used a decision utility model where the decision process can be defined by four variables: the drinking-driving utility value, the perceived risk of enforcement, the sanction awareness, and the risk aversion characteristic of the driver. Previous research has not, directly or indirectly, obtained empirical measurements of these variables. Therefore, the systems analysis assumed values for these variables on the basis of known approximate relationships--that is, the proportion of DWI trips for a given trip purpose and the proportion of DWI trips at different times of day. What is not known are the actual values of these variables and the extent of individual and temporal variations of these values. To develop the system model, the following assumptions were made:

- Utility value distributions were assigned to driver groups so that the proportion of DWI trips per driver group agreed with the results of roadside breath test surveys. The trip purpose utility values were selected by calibration experiments using parameter adjustment techniques so that the proportion of DWI trips within a trip purpose category agreed with roadside data.

TABLE 3

SIMULATION PARAMETER VALUES AND DATA SOURCES

PARAMETER	DERIVATION	DATA SOURCE
DWI Trip Rate		
24-Hour Rate	Roadside breath test surveys	Borkenstein et al., 1964 Perrine et al., 1971 Farris et al., 1976
Night Rate	" " "	NHTSA, 1972 Wolfe et al., 1974
Accident Rate	Nationwide survey	National Safety Council, 1975
Alcohol Accident Probabilities		
Fatalities	Epidemiological surveys	Nielson, 1969 Filkins et al., 1970 Perrine, et al., 1971
Injuries	" " "	Borkenstein et al., 1964 Farris, et al., 1976
Property Damage	" " "	Borkenstein et al., 1964
DWI Arrest Rates	Number arrests per driver in ASAP communities	NHTSA, 1972
Origin-Destination Data		
Trip Purpose Ratios	Origin-destination surveys of urban areas	Tittlemore et al., 1972 CALTRANS, 1977
Average Trip Length	" " "	
Average Number of Trips per Driver	" " "	
Police Enforcement Patrols	Survey data on number of patrols per number of drivers	Smith et al., 1969

TABLE 3 (Cont.)

SIMULATION PARAMETER VALUES AND DATA SOURCES

PARAMETER	DERIVATION	DATA SOURCE
Adjudication Data		
Average Court Processing Time	Evaluation of ASAP adjudication activities	NHTSA, 1974b
Percent Convictions Number of Drivers Processed	" " "	
Drinking Frequency Group	Nationwide survey for NIAAA	Harris and Associates, 1974
Proportion of Drivers Aware of Sanctions	Surveys of driver groups	Little, 1968 NHTSA, 1972 Borkenstein et al., 1971
Self-Reported Drinking Frequency and Incidence of DWI	Roadside breath tests surveys	Borkenstein et al., 1964 Wolfe et al., 1974
Incidence of DWI per Trip Purpose	Roadside breath test survey	Wolfe et al., 1974

- The baseline value of the perceived enforcement rate was defined as the same as the actual rate which was developed in the arrest model.

- The model divides drivers into two sanction awareness groups: aware and unaware, using two different discrete sanction awareness values. Actually, drivers who are aware of the sanction would have a discrete value, but those unaware would be expected to have a distribution of values.

- All drivers within the population were arbitrarily assigned a risk aversion characteristic. No data exists on the risk aversion characteristic, and its value might show a large amount of individual and temporal variation.

The other parameters that did not have an adequate data base were the learning and memory recall time constants for the information feedback models. The learning time constant was assumed to be the same for all information sources. The memory recall was assumed to be long for word-of-mouth feedback, short for enforcement visibility feedback, and intermediate for public information feedback.

The detailed development of the values for simulation parameters and the data sources are presented in the Appendix to this report.

BASELINE PERCEIVED ENFORCEMENT WEIGHTS AND CALIBRATION EXPERIMENTS

The relationship between the perceived risk utility values and the drink-drive utility values is shown in the simulated decision risk curves in Figure 22. Two curves are presented representing two sanction awareness groups: one group that is fully aware of the sanction and the other group that gives the value of the sanction only seven-tenths of its actual value. The maximum trip purpose utility value (night-time, other-other trip) is shown on the vertical axis. If the perceived risk utility value is greater than this trip purpose value, the driver will not take a DWI trip.

The baseline perceived enforcement rate value, 0.0002, is shown on the horizontal axis. The total perceived enforcement weight for word-of-mouth feedback at saturation is estimated to be five times the baseline value, 0.001, or for one exposure, 0.0051. These points are shown on the horizontal axis in Figure 22. The effect of these perceived enforcement rate values on a driver may be demonstrated by the following analysis.

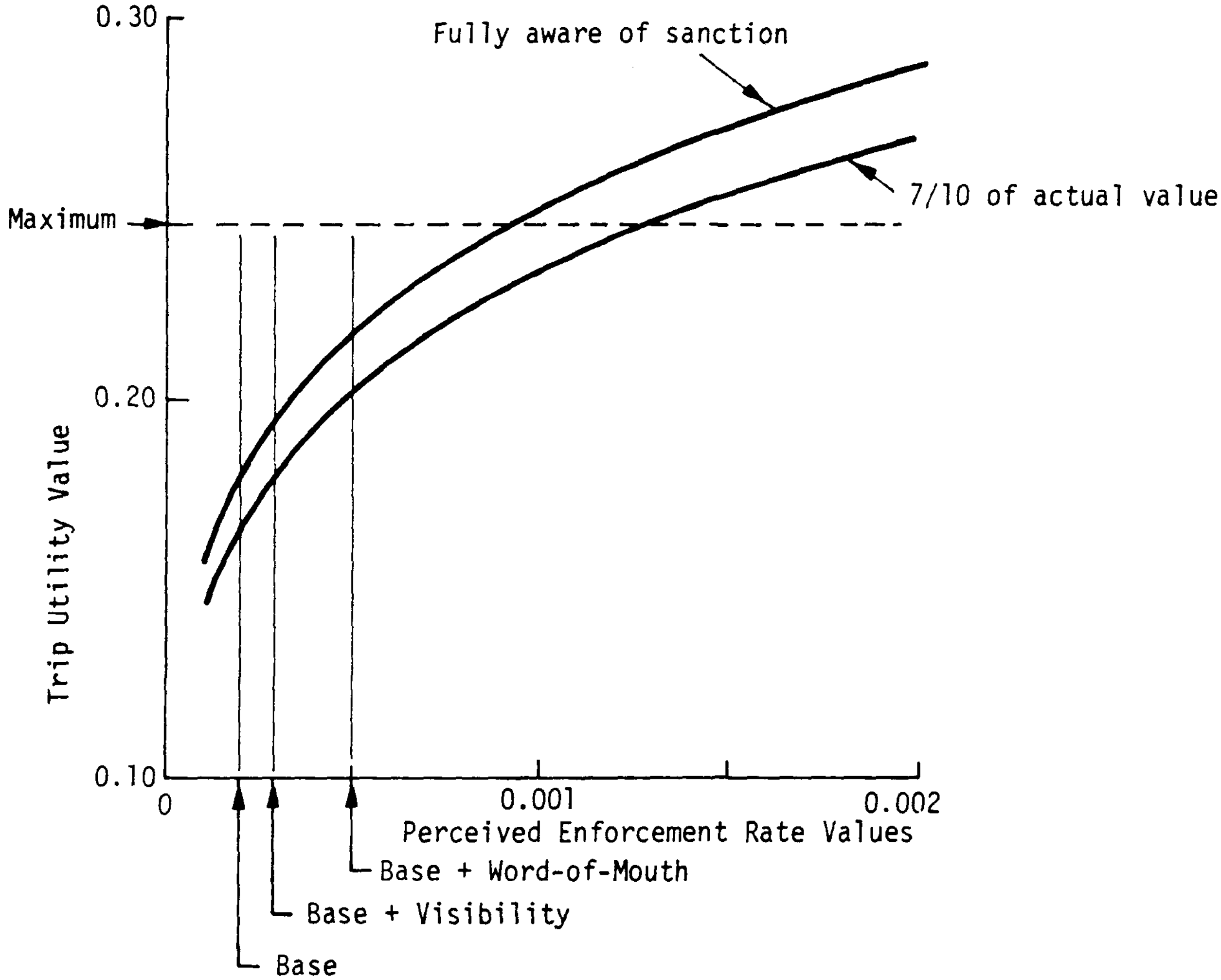


Figure 22. DWI decision curve for simulation model.

Normally, a heavy drinker will take 6.96 percent of his daily trips intoxicated. If he is exposed to a night patrol one time, he will only take 3.87 percent of his trips intoxicated. On the other hand, if he is arrested for DWI, he will only take 0.88 percent of his trips intoxicated. These baseline values were developed using the drinking groups utility curves shown in the Appendix and the DWI decision model. These values are optimistic since studies of real-world driver's recidivism rates do not show that arrest is a strong permanent deterrent.

The utility values for trip purpose were adjusted in the calibration experiments so that the DWI trip rates were the same as those of the roadside breath test surveys. The trip purpose utility values selected for the simulation, as shown in Figure 22, resulted in a 24-hour DWI trip rate of 1.9 percent and a nighttime DWI trip rate of 6.2 percent. These rates are close to the rates obtained from roadside breath test surveys presented in the Appendix.

BASELINE SIMULATION EXPERIMENTS AND CONFIDENCE LIMITS

The data inputs and parameter values developed during the calibration run were used as parameter values representing a baseline condition--i.e., a typical alcohol and highway safety problem for an urban area with 100,000 drivers. The baseline simulation experiment used an expected value model for generating the occurrence of accidents and arrests on the basis of the number of DWI and sober trips. Therefore, the simulation experiment will always produce the average number of DWI trips and accidents and there will be no variance about these average values.

The real world situation would have year-to-year variance of these values due to unaccounted fluctuations in the data. This year-to-year fluctuation of the data was simulated by using a random walk or Monte Carlo simulation which used the expected values of DWI trips, accident rates, and total number of trips to specify the parameter values of the Poisson distributions used in the Monte Carlo simulation.

A one-year baseline experiment was performed using the expected value model and a five-year baseline experiment was performed using the Monte Carlo model. The cumulative yearly summaries of these two experiments are presented in Table 4. The average variance and 95 percent confidence limit across five years are presented for the Monte Carlo experiment. The average values for the Monte Carlo experiment are close to the values from the expected value experiment.

Figures 23 and 24 show the weekly time series plots for the expected value and the Monte Carlo experiments. The differences between the two plots are the fluctuations in the weekly data. The Monte Carlo data more closely represent real world data.

The main difference between these two experimental approaches is that the variance in the Monte Carlo simulation covers up small differences in the expected values. Therefore, for any program to show a significant change in DWI trips and alcohol-related accidents within a year, its expected values would have to be outside the 95 percent confidence intervals presented in Table 4.

The remainder of the simulation runs use only the expected value model so that small differences in performance measures due to program changes will not be covered up by the random nature of the DWI trips and the accidents. The significance of a program change can be determined by comparing the expected value to the confidence limit.

SELECTION OF EXPERIMENTAL VARIABLES

Countermeasure programs which change the sensitivity of perceived enforcement rate were simulated by varying the perceived enforcement weights. Countermeasure programs which increased exposure to one of the feedback paths were simulated by increasing those system variables that affected exposure--i.e., increases in enforcement, changes in enforcement laws, and increases in public information messages. The general approach was to change one variable at a time. If the system was found to be sensitive to a variable--i.e., if a variable significantly affected the DWI trip rate and the number of alcohol-related accidents, that variable was combined with other variables found to be sensitive in order to evaluate their cumulative effect. The following sections describe the methodology and the selection of experiments for range of perceived risk values, legal and enforcement changes,

TABLE 4

BASELINE EXPERIMENTS USING EXPECTED VALUE AND MONTE CARLO MODELS

ONE-YEAR SUMMARIES FOR A JURISDICTION WITH A DRIVER POPULATION OF 100,000

	TOTAL DWI RATE	NIGHT DWI RATE	DWI IN FATAL PERCENT	DWI IN INJURY	PERCENT CHANGE IN FATALS (BASE)	ENFORCEMENT RATE	CONVICTION RATE
Expected Value Model							
	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
Monte Carlo Model							
	0.01854	0.06096	45.0	11.8	100	0.000428	0.688
	0.01920	0.06225	33.3	12.7	108	0.000465	0.656
	0.01936	0.06255	39.0	12.4	113	0.000429	0.686
	0.01919	0.06221	40.5	11.6	111	0.000397	0.682
	0.01897	0.06172	45.7	11.6	100	0.000433	0.769
Average	0.01905	0.06349	40.7	12.0	105	0.000464	0.708
Standard Deviation	0.00032	0.00312	5.0	0.5	7.6	0.000107	0.048
95% Confidence Interval	0.0184-0.0197	0.0572-0.0697	30.6-50.7	11.0-13.0	90.1-120	0.000250-0.000678	0.611-0.805

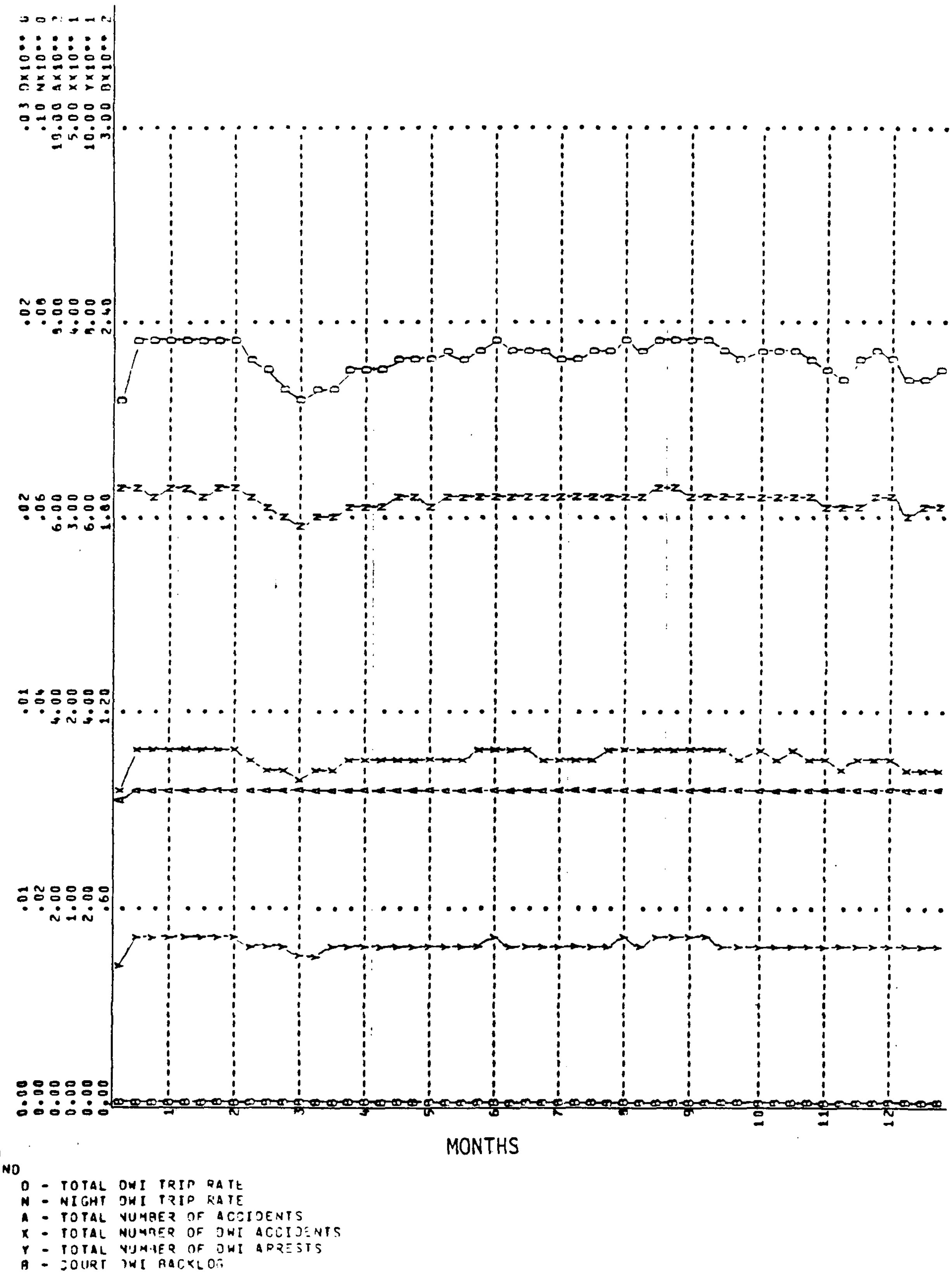
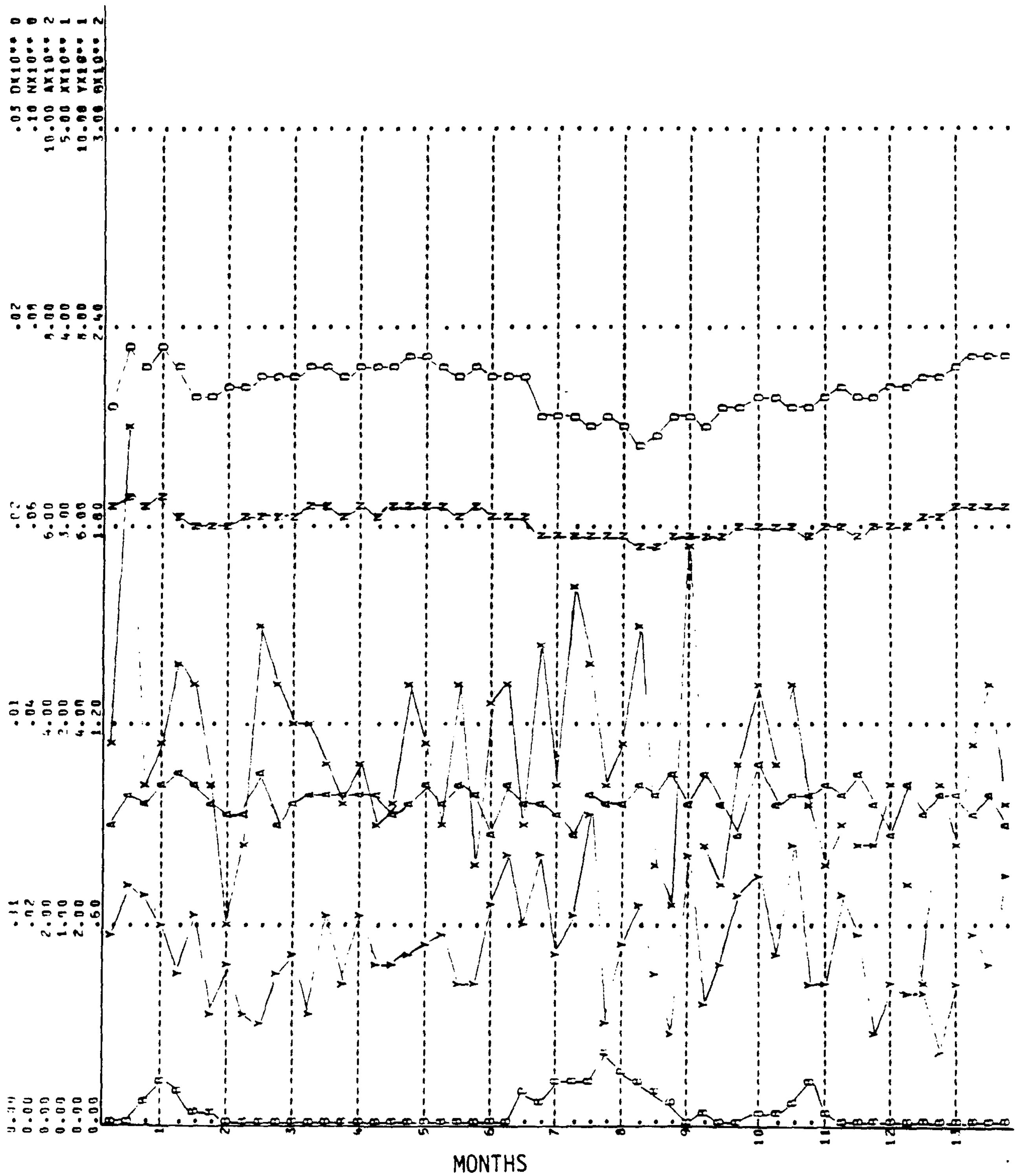


Figure 23. Weekly time series of expected value simulation of base case.



LEGEND
D - TOTAL DWI TRIP RATE
N - NIGHT DWI TRIP RATE
A - TOTAL NUMBER OF ACCIDENTS
X - TOTAL NUMBER OF DWI ACCIDENTS
Y - TOTAL NUMBER OF DWI ARRESTS
B - COURT DWI BACKLOG

Figure 24. Weekly time series Monte Carlo simulation of base case.

public information, and interaction between public information and enforcement.

Range of Perceived Enforcement Rate Experiments

The range of values for three weights--baseline, word-of-mouth, and enforcement visibility--was selected by evaluating the decision model curve presented in Figure 22. If the baseline weight was increased to 0.0013 it would eliminate all the DWI trips. The word-of-mouth and visibility perceived risk weights depend on the number of exposures and the time elapsed since the last exposure. A perceived enforcement rate of 0.0028 is required to prevent a driver from driving intoxicated after receiving one exposure. The values selected for the experiments range from the baseline weight to an order of magnitude higher, which covers the maximum potential effect of these parameters. The exact values used in the experiments are shown in Figure 25.

There was no media exposure during these experiments. The effect of changing the media perceived risk weight was evaluated by analyzing changes in the baseline weight based on the assumption that the media campaign saturates the community--i.e., it fully exposes all drivers within the community.

Legal and Enforcement Program Experiments

Legal and enforcement changes in the jurisdiction have several effects: they will increase the arrest rate and, if the number of violators remains constant, the number arrested; they may increase the visibility of enforcement; and they may increase the workload of the enforcement agencies and the courts within the jurisdiction. The increase in arrest rate and patrol visibility are products of an enforcement program, while the increase in workload of the enforcement agency and the court are costs of a program.

Programs that increase the arrest rate without increasing enforcement visibility are changes in traffic law including a prearrest screening law, a lower BAC limit for DWI law, and a driving while impaired law. Changes in enforcement training and in police attitudes towards arresting intoxicated drivers can also affect the arrest rate. These program changes do not require additional personnel for the detection and arrest of drivers, but they do require additional personnel for the processing of arrested drivers.

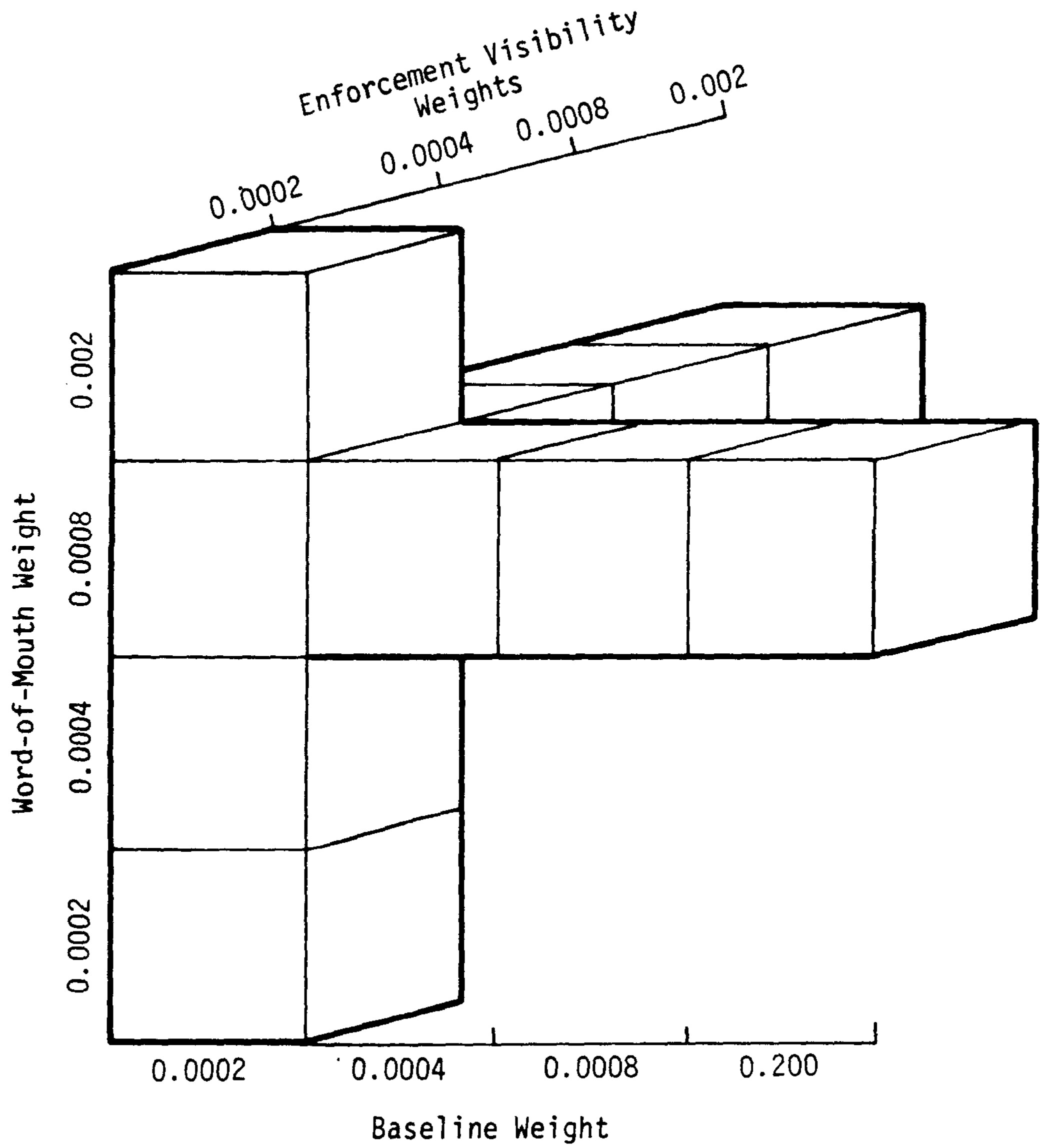


Figure 25. Design of perceived enforcement weight experiments.

Programs that increase enforcement visibility as well as the arrest rate include increasing the number of patrol units, changing patrol deployment methods, and increasing the efficiency of arrest procedures. Increasing the number of patrols increases the enforcement costs, and all three methods increase the enforcement and court workloads for the processing of arrested drivers.

Two programs were selected for the simulation experiments to provide representative examples of the different enforcement countermeasures in a jurisdiction:

- Implementation of a prearrest screening law
- Increase in the number of night patrols.

The prearrest screening law increases the arrest rate but not enforcement visibility. The increase in number of night patrols increases enforcement visibility during high DWI hours and also increases the arrest rate. These two programs cover the potential effects the other enforcement countermeasures would have on the overall system.

The simulation experiments were set up to provide a one-month baseline period as a control. At the beginning of the second month the new enforcement program was initiated, and the program was continued for 12 months. Preliminary experiments were performed to determine whether longer run periods were necessary because of slow changes in the dynamics of the system. However, the dynamics of the system stabilized in less than one month so that runs longer than a year were not required.

A series of experiments with varying parameters was performed on these two programs. These experiments used the perceived risk weights of the baseline experiments unless noted otherwise.

Prearrest Screening

Three runs were performed:

1. Prearrest screening was implemented

2. In addition to prearrest screening, two court servers were added to handle the increased number of DWI arrests

3. In addition to prearrest screening, the perceived enforcement weight for word-of-mouth feedback was increased to its maximum value for one exposure.

Increase in Number of Night Patrol Units

Four runs were performed:

1. The number of night patrol units was increased by a factor of two

2. The number of night patrol units was increased by a factor of four

3. The number of night patrol units was increased by a factor of two and the number of court servers was increased by a factor of one and a half

4. The number of night patrol units was increased by a factor of two and the perceived enforcement weight for enforcement visibility feedback was increased to its maximum value for one exposure.

Public Information Program Experiments

The amount of exposure to public information depends on the number of media insertions, the percentage of the population that is exposed to any one insertion, and the exposure decay rate. These experiments used only one value for the perceived risk weight for media feedback, 0.0002. Therefore, if a driver was fully saturated with the media message, his perceived enforcement weight is double his baseline weight. The experimental design used three exposure values, three insertion rates, and two memory decay rates. The design and values are shown in Figure 26.

Experiments with Interaction Between Public Information and Enforcement Programs

If a public information program has an effect only in combination with other information sources--i.e., the media perceived enforcement weight is zero, but the media/word-of-mouth and media/enforcement visibility interactions are greater than zero--the maximum effect can be no

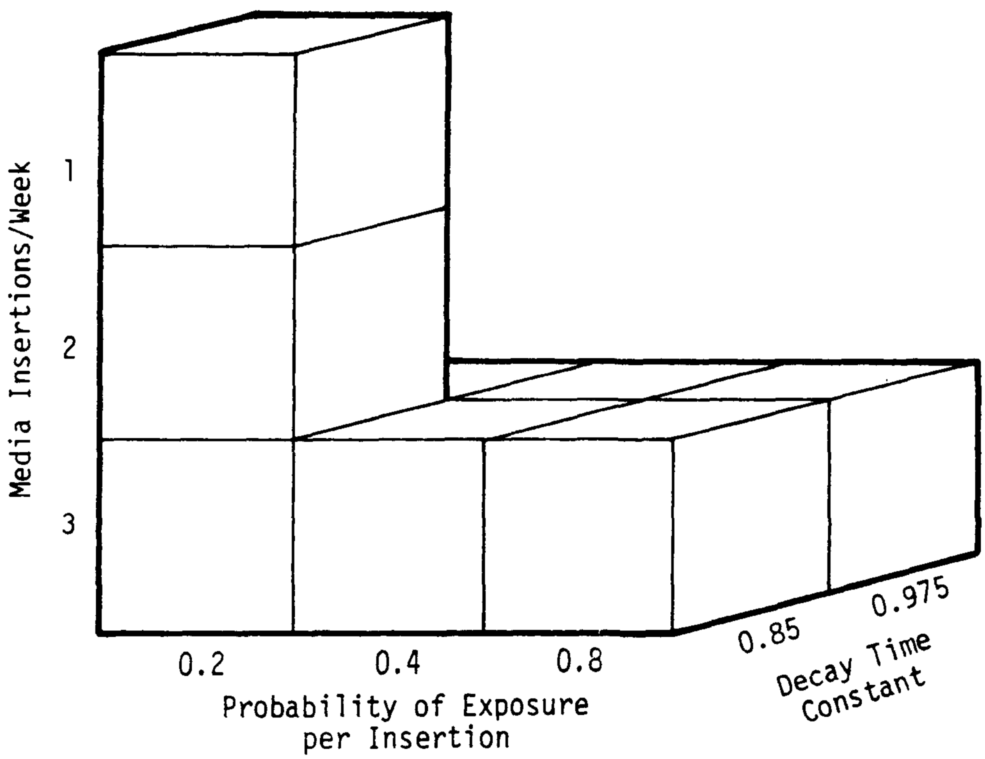


Figure 26. Design for public information exposure experiments.

greater than that attributable to the other information sources alone, and the experiments on the enforcement programs can be used to show the effects on the system. However, an additional series of experiments was conducted to evaluate the cumulative effect of a public information program which has an effect alone and is further enhanced when received in combination with enforcement feedback. The experiments listed in Table 5 were conducted to evaluate the effects of these combinations. The values for the interaction perceived enforcement weights were selected so that if a driver received only one exposure to the combination of information sources, it would deter him from driving while intoxicated.

EXPERIMENTAL RESULTS

The following sections present the results obtained from experiments conducted in the areas just discussed: range of perceived values, legal and enforcement programs, public information, and interaction between public information and enforcement.

Range of Perceived Enforcement Rates

The experimental results obtained from changing the perceived enforcement weights are shown in Table 6. Doubling the baseline perceived enforcement weights reduces the DWI trip rate by two-thirds while increasing it by a factor of four eliminates almost all of the DWI trips and alcohol-related accidents. The actual enforcement rate remains the same, even though the number of drivers arrested is drastically reduced.

The word-of-mouth perceived enforcement weight has to increase to its maximum value before it produces a change in the DWI rate and even then it would not significantly change accident statistics. The enforcement visibility perceived enforcement weight is more sensitive than the word-of-mouth. At its maximum value it produces a 14 percent reduction in the DWI rate. This, however, would not significantly reduce accident frequency on a year-to-year basis.

The results of the perceived enforcement weight experiments are summarized in Figure 27 which compares the DWI rates with the perceived enforcement weights. The baseline curve shows the potential effectiveness

TABLE 5

EXPERIMENTS WITH INTERACTION BETWEEN PUBLIC INFORMATION AND ENFORCEMENT PROGRAMS

(Perceived risk enforcement weights for baseline, word-of-mouth, and enforcement visibility same as baseline experiment)

EXPERIMENT NUMBER	PUBLIC INFORMATION PROGRAM	ENFORCEMENT PROGRAM	MEDIA/WORD-OF-MOUTH PERCEIVED ENFORCEMENT WEIGHT	MEDIA/ENFORCEMENT VISIBILITY PERCEIVED ENFORCEMENT WEIGHT
1	Media Perceived Enforcement Weight = 0.0002 Exposure Probability = 0.4/Insertion Exposure Rate = 2 Insertions/week	Baseline	0	0
2	" "	Baseline	0 to 0.004	0
3	" "	Baseline	0	0 to 0.004
4	" "	Baseline	0 to 0.004	0 to 0.004
5	" "	Prearrest Screening	0 to 0.004	0 to 0.004
6	" "	Twice the Number of Night Patrol	0 to 0.004	0 to 0.004
7	Media Perceived Enforcement Weight = 0 Exposure Probability = 0.4/Insertion Exposure Rate = 2 Insertions/week	Twice the Number of Night Patrol	0 to 0.004	0 to 0.004

TABLE 6

PERCEIVED ENFORCEMENT WEIGHTS EXPERIMENTS

ONE-YEAR SUMMARIES FOR A JURISDICTION WITH A DRIVER POPULATION OF 100,000

	TOTAL DWI RATE	NIGHT DWI RATE	DWI IN FATAL PERCENT	DWI IN INJURY	PERCENT CHANGE IN FATALS (BASE)	ENFORCEMENT RATE	CONVICTION RATE
Baseline							
0.0002 (Base)	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
0.0004	0.00688	0.02923	17.9	4.7	75.7	0.000431	0.688
0.0008	0.00121	0.00513	0	0.8	62.2	0.000431	0.688
0.002	0	0	0	0	62.2	---	---
Word-of-Mouth							
0.0002	0.01951	0.06293	40.5	12.7	100	0.000428	0.688
0.0004	0.01939	0.06269	40.5	12.6	100	0.000428	0.688
0.0008 (Base)	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
0.002	0.01859	0.06106	38.9	12.1	97.3	0.000428	0.688
Enforcement Visibility							
0.0002 (Base)	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
0.0004	0.01884	0.06154	37.8	12.3	100	0.000428	0.688
0.0008	0.01824	0.06035	38.9	11.9	97.3	0.000428	0.688
0.002	0.01645	0.05662	34.3	10.9	94.6	0.000428	0.688

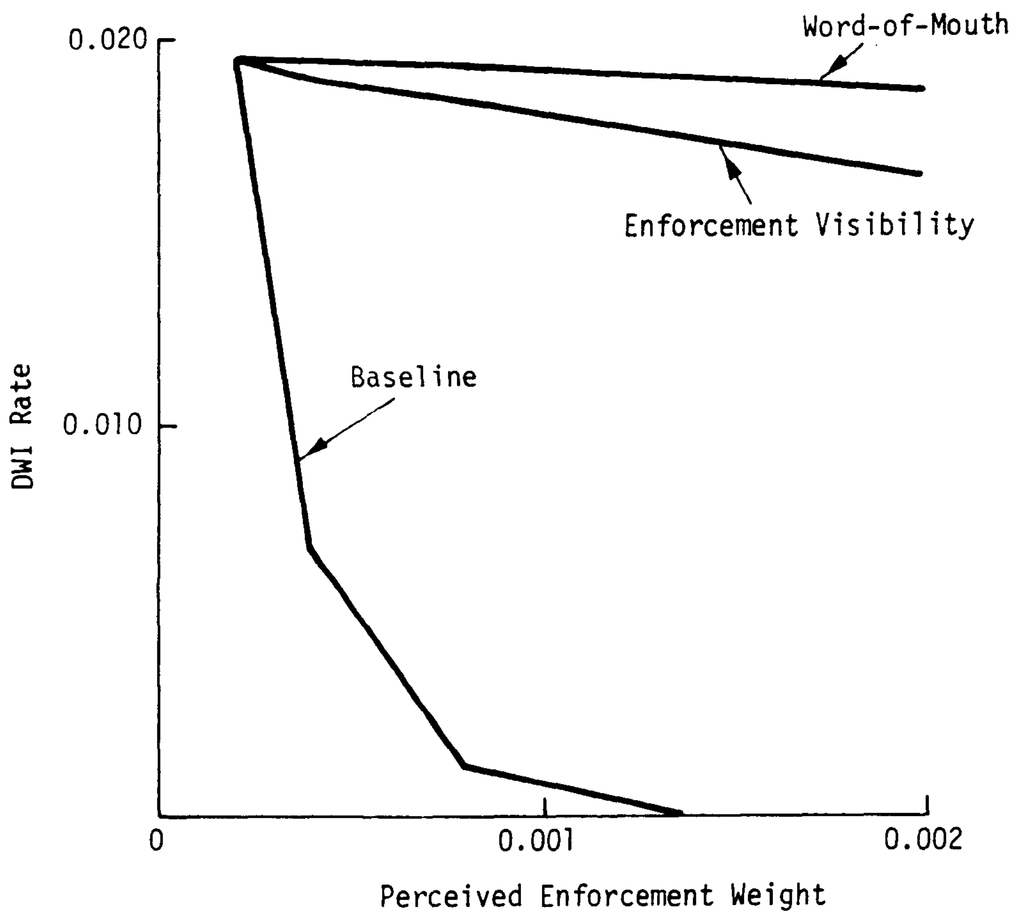


Figure 27. Perceived enforcement weights sensitivity analysis.

of a deterrent program if every driver's perceived enforcement weight is changed. The word-of-mouth and enforcement visibility curves show that even if exposure to these sources of information prevents the drivers from driving intoxicated, accident frequency will not be significantly reduced. This lack of sensitivity is due to the low probability of exposure and the even lower probability of multiple exposures.

Legal and Enforcement Programs

The following sections summarize the results of the two enforcement programs: prearrest screening and increase in night patrol.

Prearrest Screening

As shown in Table 7, the results indicate that implementation of prearrest screening alone produces only a small change in the DWI rate which would result in nonsignificant changes in accident statistics. Enforcement is doubled, but the ratio of convictions to arrests is reduced drastically due to the increase in court workload. By adding two court workers to the adjudication system in the second experiment, the conviction rate increases and the enforcement rate also increases, showing the influence of conviction probability on police attitudes. By increasing the perceived risk value for word-of-mouth feedback to its maximum value, prearrest screening produces only a 7½ percent decrease in the DWI trip rate, which would not result in significant differences in accident frequencies.

The dynamic characteristics of prearrest screening are shown in the time series plots in Figure 28. Prearrest screening is implemented in the fifth week. A sharp increase in arrest rate occurs which stabilizes by the eighth week. Meanwhile, the court backlog increases and starts to affect the arrest rate by the tenth week. The arrest rate stabilizes again by the fourteenth week at which time the court backlog is saturated. By the end of the third month, all variables have reaches stability.

Increased Night Patrols

The first two experiments with increased night patrols (Table 8) show small decreases in the DWI rate, an increase in the enforcement rate,

TABLE 7

PREARREST SCREENING LAW ENFORCEMENT PROGRAM

ONE-YEAR SUMMARIES FOR A JURISDICTION WITH A DRIVER POPULATION OF 100,000

	TOTAL DWI RATE	NIGHT DWI RATE	DWI IN FATAL PERCENT	DWI IN INJURY	PERCENT CHANGE IN FATALS (BASE)	ENFORCEMENT RATE	CONVICTION RATE
Base	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
Prearrest Screen Law	0.01870	0.06142	37.8	12.3	100	0.000958	0.381
Prearrest Screen Law + 2 Court Workers	0.01864	0.06110	37.8	12.3	100	0.001170	0.620
Prearrest Screen Law + $P_{W/M}$* = 0.002	0.01765	0.05908	36.1	11.6	97.2	0.000969	0.401

*$P_{W/M}$ is the Word-of-Mouth Perceived Enforcement Weight.

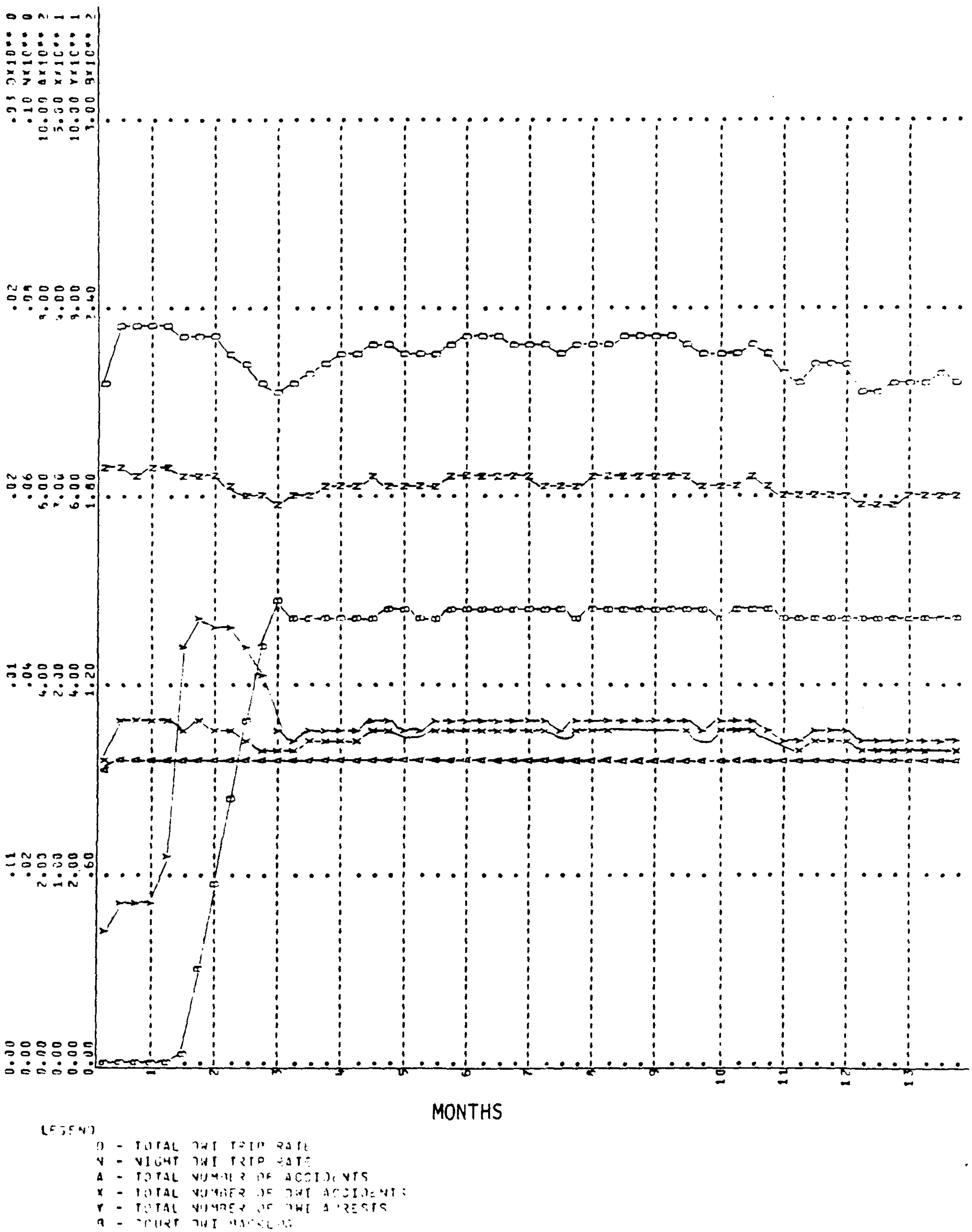


Figure 28. Time series of prearrest screening simulation.

TABLE 8

INCREASE IN NIGHT PATROLS ENFORCEMENT PROGRAM

ONE-YEAR SUMMARIES FOR A JURISDICTION WITH A DRIVER POPULATION OF 100,000

	TOTAL DWI RATE	NIGHT DWI RATE	DWI IN FATAL PERCENT	DWI IN INJURY	PERCENT CHANGE IN FATALS (BASE)	ENFORCEMENT RATE	CONVICTION RATE
Base	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
2 X Night Patrol	0.01861	0.06104	37.8	12.2	100	0.000576	0.639
4 X Night Patrol	0.01792	0.05970	36.1	11.8	97.3	0.000761	0.502
2 X Night Patrol + 1.5 X Court Workers	0.01861	0.06104	37.8	12.2	100	0.000576	0.698
2 X Night Patrol + $P_{VIS} = 0.002$	0.01407	0.05109	30.3	9.4	89.1	0.000593	0.700
4 X Night Patrol + $P_{VIS} = 0.002$	0.01079	0.04220	25.8	7.3	83.7	0.000960	0.602

and a corresponding decrease in the conviction rate due to the buildup of court backlog. The third experiment shows that adding court servers reduces the backlog and increases the conviction rate to its average value. The fourth experiment shows that if the enforcement visibility perceived risk weight is increased to its maximum value, the DWI rate is decreased by 25 percent, which would produce significant changes in the accident frequencies.

A time-series plot of increasing the night patrol by a factor of two and increasing the enforcement visibility perceived enforcement weight to its maximum value is shown in Figure 29 for comparison. This figure shows the dynamic characteristics of an effective deterrent program. Even though the DWI arrest rate increases, the actual number of arrests remains constant since there is a decrease in the DWI trip rate. This effectively keeps the court workload at a constant value and the conviction rate at its average value.

Public Information Program Experiments

The results of the public information exposure experiments are presented in Table 9. If every driver is saturated with the message, the results for the 0.0004 baseline perceived enforcement weight experiment shown in Table 5 can be used for comparison to these exposure experiments. This comparison shows that for the high exposure value and the long decay time, the DWI rate approaches its minimum expected value. However, with a reasonable decay time the effects are approximately one-half the maximum expected effects. The results of experiments varying the insertion rate and probability of exposure show that the insertion rate is inversely correlated to the probability of exposure and that these variables are interchangeable.

Interaction Between Public Information and Enforcement

If public information alone has an effect, the results just described apply. However, if the driver is exposed to more than one information source and his perceived risk is increased to a greater degree than that received from one information source alone, the first four experiments in Table 10 apply. If, in addition, enforcement is increased through prearrest screening or additional night patrol, the results of the fifth and sixth experiments

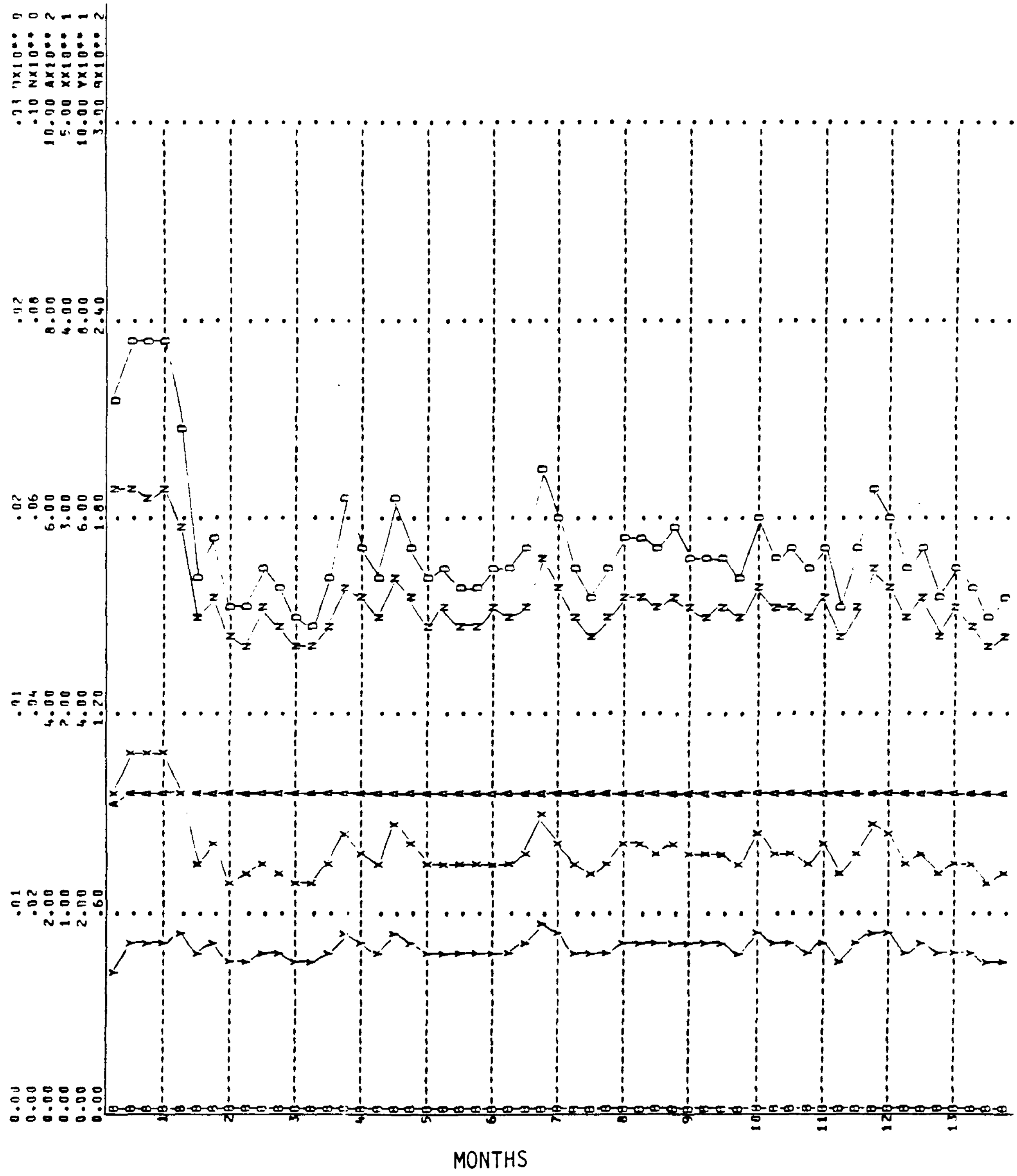


Figure 29. Time series of additional night patrol simulation with PR_{VIS} = .002.

TABLE 9

MEDIA EXPOSURE - PROBABILITY OF EXPOSURE PER
MESSAGE RECALL TIME CONSTANT AND INSERTION RATE

ONE-YEAR SUMMARIES FOR A JURISDICTION WITH A DRIVER POPULATION OF 100,000

	TOTAL DWI RATE	NIGHT DWI RATE	DWI IN FATAL PERCENT	DWI IN INJURY	PERCENT CHANGE IN FATALS (BASE)	ENFORCEMENT RATE	CONVICTION RATE
Base	0.01916	0.06221	37.8	12.5	100	0.000428	0.688
α = 0.850, 1/wk.							
P = 0.2	0.01745	0.05863	36.1	11.5	97.3	0.000428	0.688
0.4	0.01579	0.05519	35.3	10.5	91.9	0.000428	0.688
0.8	0.01330	0.04927	30.3	9.0	89.2	0.000428	0.688
α = 0.975, 1/wk.							
P = 0.2	0.01259	0.04721	28.1	8.5	86.5	0.000428	0.688
0.4	0.00990	0.03969	23.3	6.7	81.0	0.000428	0.688
0.8	0.00785	0.02397	21.4	5.5	75.7	0.000428	0.688
α = 0.850, P = 0.2							
1/wk.	0.01745	0.05868	36.1	11.5	97.3	0.000428	0.688
2/wk.	0.01568	0.05496	35.3	10.4	91.9	0.000428	0.688
4/wk.	0.01332	0.04931	30.3	9.0	89.2	0.000428	0.688

TABLE 10

INTERACTION OF PUBLIC INFORMATION WITH OTHER SOURCES

ONE-YEAR SUMMARIES FOR A JURISDICTION WITH A DRIVER POPULATION OF 100,000

	TOTAL DWI RATE	NIGHT DWI RATE	DWI IN FATAL PERCENT	DWI IN INJURY	PERCENT CHANGE IN FATALS (BASE)	ENFORCEMENT RATE	CONVICTION RATE
1) P = 0.4, 2/wk.	0.01341	0.04951	30.3	9.0	89.2	0.000429	0.706
2) (1) + $P_{Med-W/M}$ = .004	0.01317	0.04889	31.3	8.9	86.5	0.000429	0.706
3) (1) + $P_{Med-Vis}$ = .004	0.01243	0.04687	28.1	8.4	86.5	0.000429	0.706
4) (1) + $P_{Med-W/M}$ = .004 + $P_{Med-Vis}$ = .004	0.01222	0.04627	28.1	8.4	86.5	0.000429	0.707
5) (4) + Prearrest Screen Law	0.01168	0.04478	29.0	7.9	83.8	0.001063	0.550
6) (4) + 2 X Night Patrol	0.01110	0.04310	25.8	7.5	83.8	0.000605	0.703
7) P_{Med} = 0, P = 0.4, 2/wk. + $P_{Med-W/M}$ = .004 + $P_{Med-Vis}$ = .004 + 2 X Night Patrol	0.01482	0.05287	32.3	9.9	81.6	0.000591	0.700

apply. The addition of the media/word-of-mouth and the media/enforcement visibility perceived enforcement weights does not produce significant changes in DWI trip rate or accident statistics. Increased enforcement, along with these interaction terms, increases the differences but still does not significantly reduce accident statistics. The last experiment in Table 9 shows the results of a public information program with the perceived enforcement weight at zero, the enforcement visibility increased, and the media/word-of-mouth and the media/enforcement visibility perceived enforcement weights at their maximum values. This experiment resulted in a 23 precent reduction in the DWI trip rate from the base case and a 17 percent reduction in fatal accidents.

CONCLUSIONS AND RESEARCH RECOMMENDATIONS

The system analysis identified factors which influence driving while intoxicated, produced a systems model of DWI general deterrence, examined the sensitivity of system parameters relative to DWI trips and accidents, and assessed countermeasure approaches. Results were of two types: those which led to conclusions about the nature of DWI general deterrence and the relative potential of alternative countermeasures; and those which identified gaps in existing knowledge and suggested the need and direction for further research. The conclusions and recommendations of the project are presented in this section of the report.

CONCLUSIONS

1. Any Significant Reduction of DWI Trips or Related Accidents Must Necessarily be Affected Through General Rather than Special Deterrence.

Because available enforcement and adjudication resources are limited and attenuated when spread over the motorist population, special deterrence alone can have only a relatively small impact. The size of the potential impact resulting from DWI enforcement actions and the application of sanctions is reflected by the very low probabilities involved. For example, the combined probability of detection, arrest and conviction of a person driving while intoxicated is about 0.00035 per DWI trip.

2. DWI General Deterrence Depends Critically Upon Drivers' Perceived Risk of DWI Trips and on the Risk Aversion Characteristics of Potential Drinking Drivers.

Within the framework of utility theory, taking a DWI trip is a decision trade-off between the expected utility and the perceived risk of the trip. Deterrence, therefore, depends upon the perceived risk of the trip which, in turn, is influenced by the expected probability of being arrested and convicted, and by the expected severity of any imposed sanctions. For most people, the functional relationship between utility and risk is characterized as risk aversion--that is, people tend to avoid severe risks with the expectation of a severe sanction, small changes in expected probability of arrest will lead to large changes in DWI trip decision outcomes.

3. Relatively Small Changes in Perceived Enforcement are Likely to Produce Large Changes in Number of DWI Trips or Related Accidents.

Results of simulation experiments showed that relatively small changes in perceived enforcement led to relatively large changes in the number of DWI trips taken and in the number of alcohol-related casualties from accidents. However, information feedback on enforcement was required to change the perceived risk of drivers. Three different information feedback sources were evaluated in the experiments: word-of-mouth feedback to other drivers from drivers who were arrested, visual observation of enforcement activity, and public information through the news media and special public safety campaigns. For any information feedback source, two primary variables influence the extent of deterrence: the ability of the information to change the drivers' perceived risk and the amount of exposure of drivers to the information.

4. Word-of-Mouth Feedback from Apprehended or Sanctioned Drivers is Not Likely to Result in Any Significant Reduction in DWI Trips or Related Accidents.

The simulation experiments showed that enforcement programs which provided only word-of-mouth feedback did not significantly reduce numbers of DWI trips or alcohol-related casualties. The effect was minimal, even when assumptions about the extent and effectiveness of word-of-mouth feedback were carried to extremes.

5. Increased Visibility of Enforcement May Reduce DWI Trips or Related Accidents Only When Combined With Factors That Increase Perceived Enforcement When the Drivers are Exposed.

Results of simulation experiments indicated that enforcement programs which increase the visibility of the enforcement activity during times of high DWI activity might have a potential effect upon the number of DWI arrests, but only when factors affecting the drivers' perceived enforcement are also present. It cannot be assumed that the drivers's perceived risk will change significantly simply by being exposed to police patrol. Examples of countermeasure programs which might significantly sustain an increase in driver's perceived risk when he is exposed to police patrol are legal measures which facilitate pre-arrest screening and precisely define DWI (per se laws).

The results of the simulation experiments on increased enforcement might explain the results of some ASAP programs (NHTSA, 1972). Those programs which relied on increased enforcement alone resulted in little change in yearly accident statistics. Even ASAP programs that had a high increase in DWI arrests showed no significant change in the fatal accident rate. In fact, the jurisdictions with the highest arrest rates actually showed increases rather than decreases in the fatal accident rate from the baseline years. The simulation would indicate the ASAP increased enforcement failed to have much effect on drivers' perceived risk.

6. The Greatest Potential for Reduced DWI Trips or Related Accidents is Through Wide-Spread Dissemination of Information Emanating from Effective and Consistent DWI Enforcement and Adjudication Action.

The results of the simulation experiments indicated that public information is potentially the most effective method of exposing drivers to information on the risk of drinking and driving. The system analysis and the simulation experiments showed that the effectiveness of public information programs depend on message content, extent of exposure, and rate of exposure. Furthermore, the experiments demonstrated that public information has to be provided continuously to maintain its deterrent effect.

To determine whether exposure to any public information program is effective will, of course, require an empirical evaluation of whether or not the content of the message will change a driver's perceived risk. The content of the message might be information designed to increase drivers' awareness of the enforcement activity and DWI sanctions, or it might be designed to provide information on legal enforcement or adjudication changes that increase the driver's probability of arrest--for example, an increased DWI enforcement program in the community or the enactment of a prearrest screening law.

The results from implementing the 1967 British Road Safety Act support this conclusion. The lowering of the BAC limit for drunk driving and the enactment of a pre-arrest screening law were well publicized in a public information campaign. The totality of these changes significantly increased the driving population's perceived risk weight and led to deterrence even before the new laws were enacted. The subsequent loss in effectiveness of the campaign can be explained by the reduction in perceived risk as a function of the reduced dissemination of public information and the realization, by drivers, that the likelihood of enforcement was actually not as great as originally expected.

RESEARCH RECOMMENDATIONS

The system analysis showed that additional empirical evidence on basic variables involved in decisions to drive while intoxicated is needed and that programs to increase public awareness of the risk of apprehension and sanction need to be developed and evaluated. Additional data are required about the driver's DWI decision function and risk aversion characteristics, the variables that change the perceived enforcement rate, and the countermeasure programs that can influence these variables. In addition, an integrated test and evaluation program is required to determine the effectiveness of a DWI general deterrence program within a jurisdiction. The following specific research requirements were identified from the system analysis and the simulation experiments.

Research on Decision Variables

The nature of the driver's drinking and driving decision process and the variables that influence this process need to be better understood. Data are required on the relationships among the perceived value of drinking and driving, the perceived risk of enforcement, the awareness of sanctions, and utility values that drivers place on driving while intoxicated. The following individual studies are needed:

- *Perceived Risk of Enforcement.* Factors that influence a driver's perceived enforcement rate need to be identified and research conducted to determine the degree to which any factor is able to change it. Evidence is also needed to determine the extent to which perceived enforcement rates vary among drivers and the extent to which perceived enforcement rates are temporarily stable. Factors that might change perceived enforcement rates are legal changes, changes in enforcement procedures, and public information disseminated on enforcement and sanctions. In addition, data are needed on awareness of changes in enforcement, on changes in perceived risk, and on changes in BAC levels as a function of exposure to the various information sources.

- *Sanction Awareness.* Research is required to develop data on the proportion of people who are aware of existing DWI sanctions. Roadside surveys or other methods are required to measure sanction awareness and to test the extent of DWI deterrence as a function of expected sanction severity. (The degree to which the severity of sanction affects DWI trip rate is part of a current study being performed by NHTSA).

- *Utility of DWI.* The relative value a driver places on driving while intoxicated and the variables that influence this value need to be calculated. Empirical data are required to evaluate the effects of driver characteristics, such as type of drinker, age, social conformity, trip purpose, and environmental circumstance on DWI utility. Laboratory or field studies are also needed to determine whether these utility values are stable both in time and with respect to driver groups.

- *Nature and Degree of Risk Aversion.* Laboratory or field experimentation within the context of decision making are required to determine the risk aversion characteristics of potential drinking drivers. Little is known of the shape of the risk aversion curve, the extent of individual differences in risk aversion, factors which might influence or modify risk aversion characteristics of potential drinking drivers, or the extent to which risk aversion is correlated with other driver characteristics such as type of drinker, age group, or social behavior.

Research on Countermeasure Feasibility and Implementation

Research on the type described above can provide the basis for potential improvements in the effectiveness of DWI general deterrence. However, additional studies are required to determine the feasibility of implementing various components of general deterrence programs. Development and evaluation studies based on variables that affect drivers' perceived enforcement and on potentially effective information feedback paths would be required. Examples of needed research are summarized briefly in the following paragraphs.

- *Visibility of DWI Enforcement.* Enforcement procedures that increase the probability of driver exposure need to be identified. Studies could be conducted in two steps: 1) collect objective data on the probability that any driver will be exposed to a patrol unit, and 2) conduct roadside interviews to determine the number of drivers who perceive the enforcement activity.

■ *Public Information Messages.* Messages are needed that are effective in increasing the perceived risk of drivers. Efforts are needed to develop both message content and to select media sources. Message effectiveness research is also needed to correlate message exposure to measures of perceived risk.

■ *Message Exposure Techniques.* Using selected message content and media sources, research is needed to develop curves of retention as a function of exposure. Insertion rates of messages need to be varied while the proportion of the exposed population and its ability to recall the message are measured.

Research on Overall Effectiveness

Valid estimates of the effectiveness of DWI general deterrence might be obtained by integrating a program within a number of randomly selected jurisdictions and comparing the resultant DWI trip rates and accident rates with those of a number of randomly selected control jurisdictions. Of course, data collection and sampling would have to be identical for all jurisdictions. The type of data obtained would include traffic counts, roadside surveys of perceived risk, trip purpose, and driver characteristics, and measured driver BAC levels. These data will be employed to assess changes in perceived risk and in DWI trip rate as a function of trip purpose and driver characteristics. In addition, data will be collected on the number of accidents within the jurisdiction including the number of fatalities and if available, the number of DWI fatalities.

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APPENDIX

DEVELOPMENT OF PARAMETER VALUES FOR COMPUTER-BASED SIMULATION

The parameter values selected for simulation are based on expected values from real-world data sources. The expected probabilities of DWI, DWI arrests, DWI accidents, and sober accidents are obtained from nationwide surveys which collected roadside data, arrest reports, and accident investigations. The expected values of trips, trip length, trip purpose, patrol units in a jurisdiction, and the number of court servers are obtained from origination-destination, enforcement agency, and court system surveys.

DWI RATES

The results of roadside surveys were used to determine the proportion of drivers at a given BAC level. Figure A-1 shows the proportion of drivers above a given BAC level. The data points represent individual studies, while the curves are the median value of the various studies. The curves were used to calibrate the simulation runs to determine the number of DWI trips an average driver takes during a year, and the proportion of intoxicated drivers who are at or above a 0.15 BAC.

ACCIDENT RATES

The estimated precentages of drivers with BAC's at or above 0.10 who were fatally injured in accidents range from 44 to 55 percent (Neilson, 1969, Filkins, *et al.*, 1970, and Perrine, *et al.*, 1971). The actual percentage of drivers involved in fatal accidents may differ from this range since the epidemiological studies did not include surviving drivers of fatal accidents. For injury-procuding accidents the estimated percentages ranged from 10 to 13 percent (Borkenstein, *et al.*, 1964 and Farris, *et al.*, 1976), and for property damage accidents about 5 percent (Borkenstein, *et al.*, 1964).

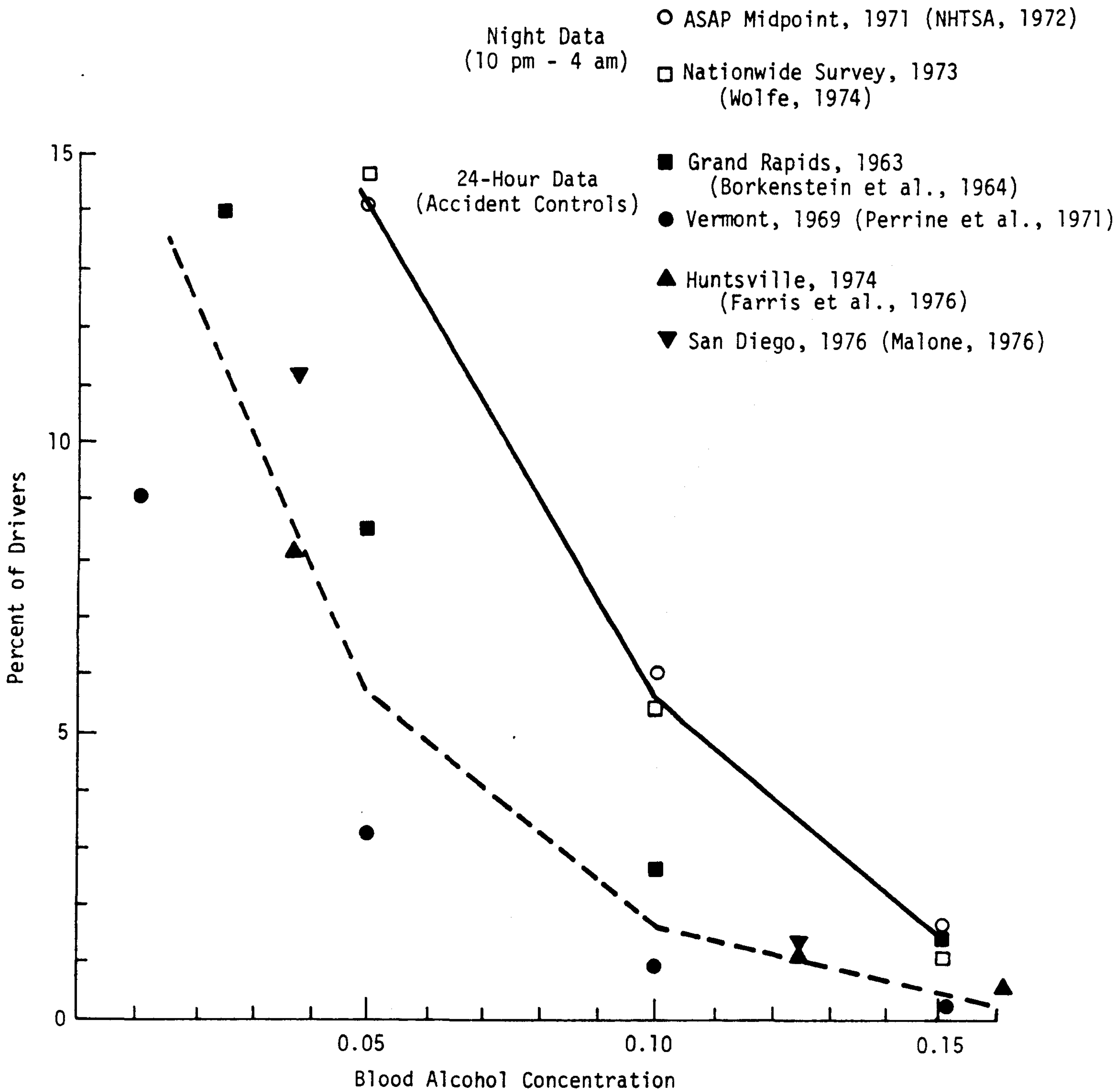

Figure A-1. Percentage of on-the-road drivers with BAC's equal to or greater than given levels.

The number of accidents involving intoxicated drivers in the United States during 1974 was estimated by using the ratios of 0.40 for fatalities, 0.13 for injury, and 0.05 for property damage accidents. National Safety Council (1975) accident statistics for 1974 were also used in the estimate. The values are presented in Table A-1.

The conditional probability of an accident occurring on a single trip given that the driver was intoxicated or sober was estimated by using the number of alcohol and non-alcohol related accidents presented in Table A-2 and the expected numbers of intoxicated and sober trips taken by drivers during 1974. The number of sober and intoxicated trips was estimated by using 3.11 as the estimated number of trips (Tittlemore, *et al.*, 1972), 125,100,000 as the number of drivers in the United States (National Safety Council, 1975) and 2 percent of the trips as the estimated proportion that are intoxicated (Figure A-1). Accident probability estimates are shown in Table A-2 and are used as expected probabilities in the model.

DWI ARREST RATES

The probability of an arrest given that the driver is at or above a 0.10 BAC level is estimated by dividing the number of arrests by the number of drivers within a jurisdiction times the average number of DWI trips per driver. This calculation uses enforcement data from the ASAP evaluation report (NHTSA, 1972). The arrest probabilities averaged across ASAP's communities and the highest and lowest values for individual ASAP communities are shown in Table A-3 and are comparable to Borkenstein's estimate (1975) that one out of every 2000 DWI drivers (0.0005) is arrested. Beital, *et al.* (1975) estimated that one out of every 200 drivers (0.0058) could be arrested if he comes within a patrolman's view and the patrolman is highly motivated. Beital's analysis used actual arrest data from six patrol officers in a specified patrol area, traffic count data at randomly selected times during the patrol, and a roadside breath test survey within the same patrol area. Bayesian analysis was used to calculate the a priori probability of arrests. The result is an order of magnitude higher than the average from the ASAP communities. The difference is caused by the fact that the derived value from the ASAP communities represents an average across the whole community while Beital, *et al.* represents only those drivers within the patrolman's view.

TABLE A-1

NUMBER OF DRIVERS INVOLVED IN ACCIDENTS IN THE UNITED STATES DURING 1974

	BAC < 0.10	BAC ≥ 0.10
Fatal	34,680	23,120
Injury	1,653,000	247,000
Property Damage	22,040,000	1,160,000
TOTAL	23,727,680	1,430,120

TABLE A-2

PROBABILITY THAT A DRIVER WILL BE INVOLVED IN AN ACCIDENT ON A SINGLE TRIP

	< 0.10 BAC	≥ 0.10 BAC
Fatal	0.00000022	0.00000739
Injury	0.00001079	0.00007899
Property Damage	0.00014388	0.00037091
COMBINED	0.00015489	0.00045729

TABLE A-3

ARREST PROBABILITIES OF ASAP COMMUNITIES

	BASELINE PERIOD	OPERATIONAL PERIOD
Average	0.0002	0.00044
High	0.0006	0.00148
Low	0	0.00012

SELECTION OF AN URBAN JURISDICTION

In selecting a jurisdiction, the first consideration was to determine whether the parameters would vary with the size or density of the population in the jurisdiction. An analysis of urban travel in eight standard metropolitan statistical areas (SMSA) was prepared for the Federal Highway Administration by Tittlemore, *et al.*, (1972). The study compared a cross section of urban areas and provided trip purposes by time of day, daily vehicle miles of travel, average daily trips, number of registered vehicles, and an average trip length in both minutes and miles for each trip purpose. Unfortunately, the analysis only included origin-destination (OD) surveys for weekdays.

A review of the data shows no consistent trend between trip purpose proportions and different urban areas. The number of registered vehicles, the average number of daily trips per registered vehicle, and the average trip lengths in both miles and time for each trip purpose are shown in Table A-4. The data show that the trip length in miles is linearly correlated with the number of registered vehicles and the trip duration in minutes is also correlated but to a lesser degree. The average number of daily trips appears to be uncorrelated with population size.

The California Department of Transportation provided a computer tabulation of OD surveys for two urban areas, Sacramento and Stockton (Caltrans, 1977). The data included trip frequency distributions as a function of the trip purpose and the time of day for both weekdays and weekends. The proportion of trips according to trip purpose is shown in Table A-5. The average number of daily trips per registered vehicle was 3.8 for Stockton, and 3.6 for Sacramento while the average number of daily trips per driver was 3.11 for Stockton and 2.93 for Sacramento. The ratio of the number of weekend to weekday trips was 0.906 for Sacramento and 0.841 for Stockton.

Since differences in population size would be compensated for by differences in enforcement and adjudication services, it was decided to use only one population size throughout the simulation runs. The nominal size of 100,000 drivers--equivalent to an urban area with a population of 250,000 people--was selected. The average number of daily trips per driver was selected at 3.02 for weekdays and 2.64 for weekends (3.02 X 0.874).

TABLE A-4

ORIGIN-DESTINATION DATA FOR EIGHT URBAN AREAS

URBAN AREA	REGISTERED VEHICLES (X 1000)	AVERAGE DAILY TRIPS PER REGISTERED VEHICLE	HOME BASE - WORK		HOME BASE - OTHER		NON-HOME BASE	
			MILES	MINUTES	MILES	MINUTES	MILES	MINUTES
Boston	1066	3.80	8.0	30	3.9	22	4.1	20
St. Louis	758	3.09	8.2	31	4.6	19	4.9	21
Seattle	520	3.41	7.6	26	4.2	18	4.2	16
Louisville	249	2.71	6.3	27	3.7	20	3.8	19
Oklahoma City	231	5.03	5.3	29	3.1	23	3.2	24
Stockton	66	3.81	4.2	17	2.6	13	2.5	13
Colorado Springs	68	4.57	4.3	16	2.9	14	2.5	13
Fall River	49	3.69	2.5	14	2.0	13	1.7	11
Average	376	3.76	5.8	24	3.4	18	3.4	17
Correlation Coefficient, r		0.28	0.87	0.76	0.78	0.61	0.80	0.55
Slope of Regression Line, b		-0.0006	0.005	0.014	0.002	0.007	0.002	0.007

TABLE A-5

PROPORTION OF TRIPS ACCORDING TO TRIP PURPOSE, TIME OF DAY, AND DAY OF WEEK

	Sacramento				Stockton			
	WEEKDAY		*WEEKEND*		*WEEKDAY*		*WEEKEND*	
	Day	*Night*	*Day*	*Night*	*Day*	*Night*	*Day*	*Night*
Home Base - Work	0.147	0.031	0.048	0.017	0.126	0.025	0.072	0.023
Home Base - Shop	0.105	0.039	0.161	0.024	0.094	0.042	0.163	0.032
Home Base - Other	0.211	0.096	0.389	0.165	0.232	0.096	0.344	0.175
Work - Other	0.083	0.007	0.013	0.003	0.117	0.010	0.018	0.009
Other - Other	0.222	0.058	0.137	0.042	0.205	0.052	0.121	0.048
	0.768	0.232	0.749	0.251	0.774	0.226	0.717	0.283
TOTAL		1.000		1.000		1.000		1.000

The values used for the proportion of trips were the mean of the Sacramento and Stockton studies. The number of drivers, the number of trips per driver, and the distribution according to trip purpose and time of day were used to calculate the number of trips taken within the jurisdiction.

ENFORCEMENT DATA

The DWI arrest model requires the estimation of the following parameters: the number of patrol units servicing the jurisdiction, the search efficiency of a patrol unit, the number of driver observations made by the patrol unit per unit time, the average trip duration, and the proportion of drivers who are at or above 0.15 BAC.

- *The Number of Patrol Units.* Data from a survey of police traffic services (Smith, *et al.*, 1969) were used to estimate the number of patrol units performing a traffic enforcement function. This survey showed a correlation between manpower allocations, average daily vehicle miles traveled, and traffic congestion. Table A-6 shows the relationship between the average daily vehicle miles traveled and the number of patrol units for county and city police. The average value, 0.177 patrol units per 10,000 miles of VMT, was used as the number of patrol units within a jurisdiction. The same survey estimates that the patrol unit is actively searching for DWI's is no more than 50 percent of patrol time. The other 50 percent is used in performing other traffic functions.

- *Time Required to Observe a Driver.* No data are available on the amount of time a patrol officer requires to detect a drunk driver. It is estimated that 10 to 15 eye fixations are required per vehicle for this discrimination. Using this number of fixations, the minimum time required by the patrol unit to observe one vehicle is between three and one-third and five seconds.

- *Average Trip Length.* The average trip lengths as a function of trip purpose were presented in Table A-4. These data combined with the average number of daily trips per driver and the proportions according to trip purpose are used to determine the total vehicle miles of travel for the jurisdiction and the total exposure time per time period. These values are used in the arrest model to determine the number of patrol units on duty in a time period and the total amount of time that vehicles are exposed during a time period.

- *Detection Probability.* No data are available to determine the probability that if a patrolman observes a DWI driver that he will also detect the driver. It is expected that this value will vary as a function of the patrolman's training, experience, and attitude. The value is estimated by calibrating the DWI arrest model against the enforcement rates shown in Table A-3. The value used in the model is 1 out of 20 drivers or 0.05.

TABLE A-6

TRAFFIC FORCE AND PERCENTAGE OF TIME ASSIGNED TO TRAFFIC ENFORCEMENT

JURISDICTION	NUMBER OF REGISTERED VEHICLES X 1,000	VMT X 10,000	PATROL UNITS	UNITS PER 10,000 VTM	PERCENT OF TIME ON PATROL
County					
1	278	588	103	0.175	0.74
2	671	973	175	0.179	0.88
City					
1	192	460	77	0.167	0.84
2	206	536	94	0.173	0.71
3	319	541	80	0.149	0.81
4	761	1041	230	0.220	0.86
AVERAGE				0.177	0.806

■ *Proportion of Driver Trips at High BAC Levels.* Of those drivers detected, the arrest model allows only the drivers at a BAC level of 0.15 or above to be arrested. In addition, if an intoxicated driver is involved in an accident and his BAC level is 0.15 or greater, he is arrested. The proportion of intoxicated drivers who are at or above a BAC of 0.15 is shown in Table A-7 for accident and control drivers in the Grand Rapids (Borkenstein, *et al.*, 1964) and the Essex Corporation (Farris, *et al.*, 1976) studies and for late night, weekend drivers in the Nationwide Breath Test survey (Wolfe, *et al.*, 1974). The controls of the epidemiological studies and the nationwide survey are in close agreement. The average of these figures will be used for the arrest probability in the absence of a prearrest screening law. The accident proportions will be used for the DWI arrest probability when an intoxicated driver is involved in an injury or property damage accident. The Essex Corporation figure will be used for the injury accidents, and the Grand Rapids figure will be used for the property damage accidents.

Insertion of the above derived values into the arrest model gives the expected probability of arrest for driving while intoxicated of 0.0002. This value is the same as the average value for the baseline year of the ASAP communities (Table A-3).

DWI ADJUDICATION DATA

The input data for the adjudication subsystem model include the conviction probability, the driver time delay for calendaring a trial, the trial time, and the court handling capacity. These data were obtained from a summary of court operations in the various ASAP programs (NHTSA, 1974). Table A-8 shows the number of cases processed, the average processing time, and the percentage of cases convicted for selected ASAP jurisdictions. Since the data show a variation in these values from one jurisdiction to another, the average values across these jurisdictions were selected for the simulation. The time delay for calendaring the trial--that is, the time from arrest to the trial date--was set at 45 days. The processing time per trial was set at one per day. The number of court workers was set at 4/100,000 drivers or a maximum processing rate of 0.010 per driver per year. The number of days a case was allowed to remain in the trial queue was a maximum of 60 days which is the statutory limitation time before the case is dismissed. For the cases processed, the conviction rate was set at 0.70.

TABLE A-7

PROPORTION OF INTOXICATED DRIVERS WHO ARE AT OR ABOVE A BAC OF 0.15

	CONTROL	ACCIDENT
Grand Rapids Study	0.25	0.51
Essex Corporation Study	0.235	0.615
Nationwide Breathtest Survey	0.280	

TABLE A-8

SUMMARY OF COURT PROCESSING FOR SELECTED ASAP'S

SITE	DRIVER POPULATION X 1,000	COURT PROCESSED PER DRIVER/ YEAR	AVERAGE PROCESSING TIME (DAYS)	PERCENT CONVICTED DWI OR RELATED
Cincinnati	509	0.0036	--	--
Denver	630	0.0069	--	--
Hennepin County	537	0.0125	--	61
Kansas City	284	0.0172	51	90
Los Angeles	--	--	51	--
New Hampshire	462	0.0111	22	90
Tampa	282	0.0103	--	--
Average		0.0103	41.3	70.3
Simulation Values		0.010	45	70

DRINKING FREQUENCY AND SANCTION AWARENESS GROUPS

The proportion of the drivers within a drinking frequency group may be obtained from nationwide surveys conducted for the National Institute of Alcohol Abuse and Alcoholism (Harris and Associates, 1974). The proportions and definitions of the groups are presented in Table A-9. Although individual jurisdictions may differ from the nationwide average, these proportions are used to represent a typical community.

Several survey studies have reported the proportion of respondents who could cite the correct legal sanction for DWI. The Hennepin County ASAP program (NHTSA, 1972) reported that 40 percent of the respondents in a household survey cited the correct sanction prior to the ASAP program, and 49 percent cited the correct sanction after the program was initiated. In a study by Borkenstein, *et. al.*, 1971, 30 percent of a group of students was aware of the sanction and 33 percent of a group of service club members was aware of the sanction. In a survey conducted by Little, 1968, 42 percent of a group of university students admitted to knowing the sanctions very well, and 60 percent cited the correct sanction. It is assumed that if a driver is unaware of the sanction, he will underestimate the penalty. However, no data were available from these surveys to confirm this assumption.

To determine the effect of sanction awareness, the simulation divides the driver population in half. One half will be aware of sanction and will be assigned a sanction awareness value equal to 1. The other half will have a sanction awareness value of less than 1.

SELECTION OF DRINKING GROUPS' UTILITY VALUES

A distribution of values was used for the drinking groups' utility values. The distribution takes into account other variables in the driver's utility values beside the frequency of drinking and the trip purpose. Discrete values are used for the trip purpose utility values. Therefore, the utility of any trip will be the discrete value for the trip purpose times the distirbution of utility values for a given drinking group. The distribution parameters were selected so that the proportion of drivers who drink and drive within a drinking group is the same as that reported in roadside surveys.

TABLE A-9

PROPORTION AND TYPE OF DRINKERS IN U.S. ADULT POPULATION

TYPE	PROPORTION
Abstainers and Infrequent Drinkers Less than 1 ounce a month (absolute alcohol)	0.42
Light Drinkers Less than 0.22 ounces a day	0.31
Moderate Drinkers Over 0.22 ounces but less than 1 a day	0.18
Heavy Drinkers Over 1 ounce a day	0.09

The relationship between self-reported drinking frequency and drivers with BAC's at or above 0.10 has been reported by Borkenstein *et al.*, 1964, and Wolfe, 1974. The two sets of data are shown in Table A-10. The Borkenstein data are for an accident control group, while Wolfe's data are for late-night weekend drivers. Triangular distributions based on these data were used for drinking utility values. The characteristics of the distribution could be selected by specifying the minimum, the mode, and the maximum values of the triangular distributions. Selection of these values for the four drinking groups is shown in Table A-11. Since the amount of drinking differs between daytime and nighttime periods, different distributions were used to represent the day and night utility values. To understand the relationship of these distributions in the decision model, the reversed cumulative distributions are shown for the six curves in Figure A-2. These curves may be interpreted in the following manner: if risk utility value is 0.18, and trip purpose utility value is 0.25, drivers whose utility value is 0.72 or greater will drive intoxicated. Using the data from Figure A-3, approximately 17 percent of the moderate drinkers, 68 percent of the heavy drinkers, and none of the light drinkers will drive intoxicated for this risk value and trip purpose utility value.

The relationship between DWI and trip purpose was reported in the 1973 nationwide breath test survey (Wolfe, 1974). The data are presented in Table A-12 and show the proportion of drivers at or above 0.10 BAC level categorized according to trip purpose. Unfortunately, these data are only for the weekend, night periods. It is known, however, that during the daytime the number of drivers above a BAC of 0.10 is less than at night.

Discrete utility values were selected for trip purpose. The proportions were adjusted so that the estimated number of day trips was an order of magnitude lower than the night trips and the proportions between weekdays and weekends were kept the same. The trip purpose utility values were adjusted to arrive at the proportion of trips per trip purpose given in Table A-12. Using these proportions and the estimated fraction of exposure time per trip purpose for the Stockton OD data (Caltrans, 1977), the proportion of DWI trips during a weekday 24-hour period would be 0.015 and for a weekday night period it would be 0.051. These proportions agree well with roadside survey data (Borkenstein, *et al.*, 1964 and Wolfe, 1974).

TABLE A-10

SELF-REPORTED DRINKING BEHAVIOR AND PROPORTION OF DRIVERS AT OR ABOVE 0.10 BAC

FREQUENCY OF INTOXICATION	PROPORTION OF DRIVERS	PROPORTION > 0.10 BAC
24-Hour Accident Control Group from Grand Rapids Study		
Never	0.59	0.0015
Yearly	0.22	0.011
Monthly	0.11	0.012
Weekly	0.08	0.023
Late Night-Weekend Driver from the National Breathtest Survey		
Abstainer	0.178	0
Very Light	0.384	0.033
Fairly Light	0.245	0.066
Moderate	0.183	0.099
Heavy	0.010	0.222

TABLE A-11

DRINKING UTILITY DISTRIBUTIONS

DRIVER GROUP	DRINKING UTILITY DISTRIBUTIONS						FRACTION OF ADULT POPULATION
	MINIMUM	DAY MODE	MAXIMUM	MINIMUM	NIGHT MODE	MAXIMUM	
HEAVY 1	.200	.600	1.000	.400	.900	1.000	.045
HEAVY 2	.200	.600	1.000	.400	.900	1.000	.045
MODERATE 1	0.000	.300	.600	0.000	.500	1.000	.090
MODERATE 2	0.000	.300	.600	0.000	.500	1.000	.090
LIGHT 1	0.000	.100	.300	0.000	.100	.600	.155
LIGHT 2	0.000	.100	.300	0.000	.100	.600	.155
ABSTAIN 1	0.000	0.000	0.000	0.000	0.000	0.000	.210
ABSTAIN 2	0.000	0.000	0.000	0.000	0.000	0.000	.210

TABLE A-12

PROPORTION OF DRIVERS AT OR ABOVE 0.10 BAC CATEGORIZED ACCORDING TO TRIP PURPOSE ON WEEKENDS, 2200 - 200 HOURS

TRIP PURPOSE	PROPORTION OF DRIVERS
Home Base - Work	0.020
Home Base - Social, Eat, Drink Ride Around	0.058
Home Base - Recreational	0.021
Non-Home Base	0.084

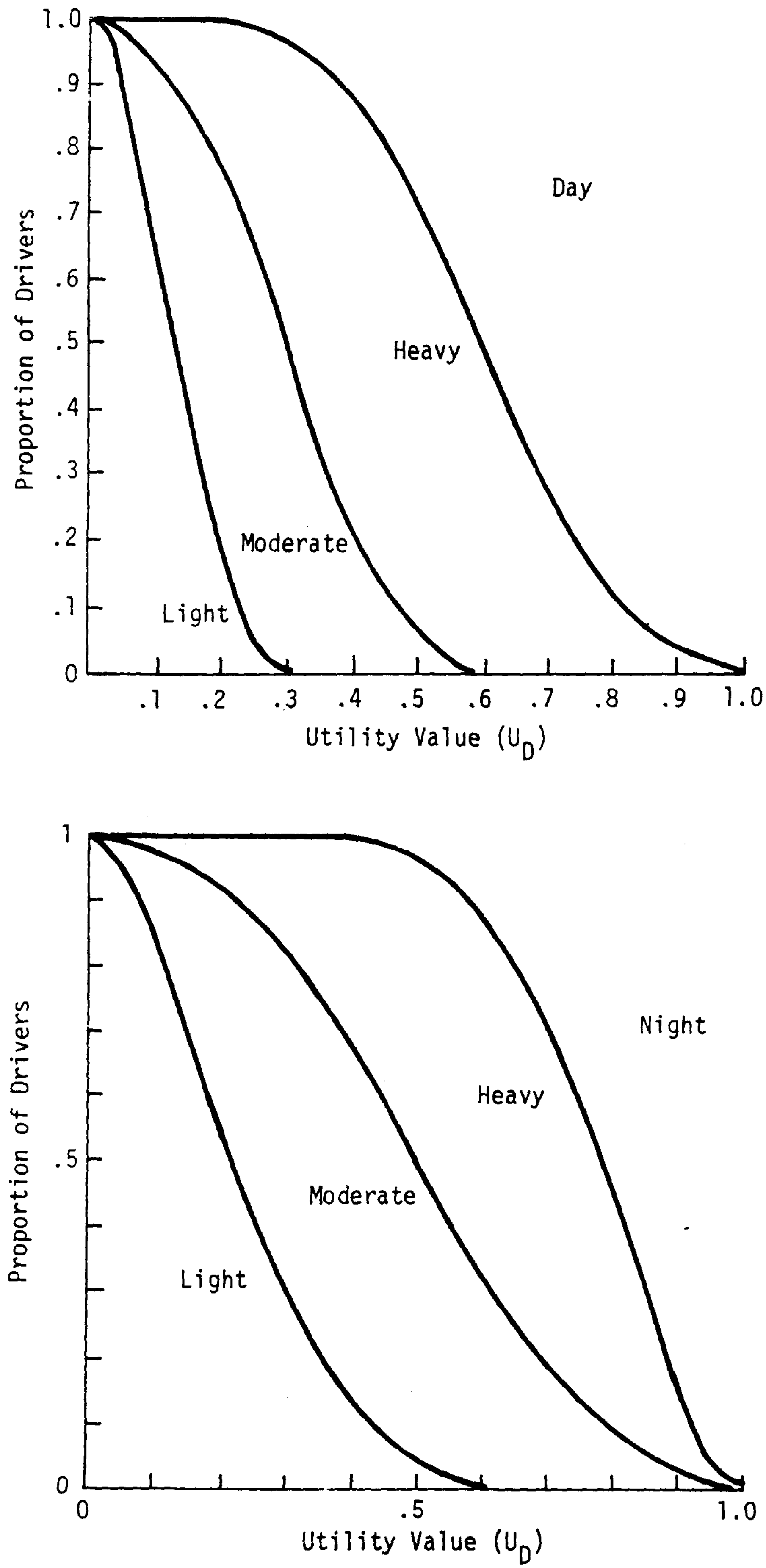

Figure A-2. Proportion of driver with utility values equal to or greater than the utility [illegible]

SELECTION OF EXPOSURE VARIABLES

Changes in the driver's perceived risk of enforcement occur by exposure to three types of information: word-of-mouth feedback from drivers arrested, visibility of patrol units, and public information messages. Each exposure type has two common parameters which affect message recall: the exponential learning rate and the retention time constant. The exponential learning rate was set at 0.5. The maximum learning rate versus exposures is shown in Figure A-3 provided there is no memory decay. The figure shows that five exposures are required to obtain a recall fraction of 0.9.

The effect of varying the retention time constant is shown in Figure A-4. For a retention constant of $\alpha = 0.5$, the decay is rapid without the driver receiving more exposures. For a retention constant of $\alpha = 0.99$, there is a very small amount of decay requiring approximately a year for a 10 percent reduction in recall. On a rational basis, the retention time constant will vary with the type of information: visibility will have a small time constant, since the effects should not last much longer than the actual time that the driver is exposed to a patrol unit. The word-of-mouth time constant is long, since the effect on a driver who has been arrested or has knowledge about a driver who is arrested is expected to last for a year or more. The retention time constant for a public information message should be intermediate, lasting for a month or more. Optimistic values were selected for the simulation runs. The visibility was selected at 0.5 wherein the effect will last from one to two weeks. The word-of-mouth retention time constant was selected at 0.975 where the effect will last from one to two years, and the media time constant was selected at 0.85 where the effect would last from one to two months.

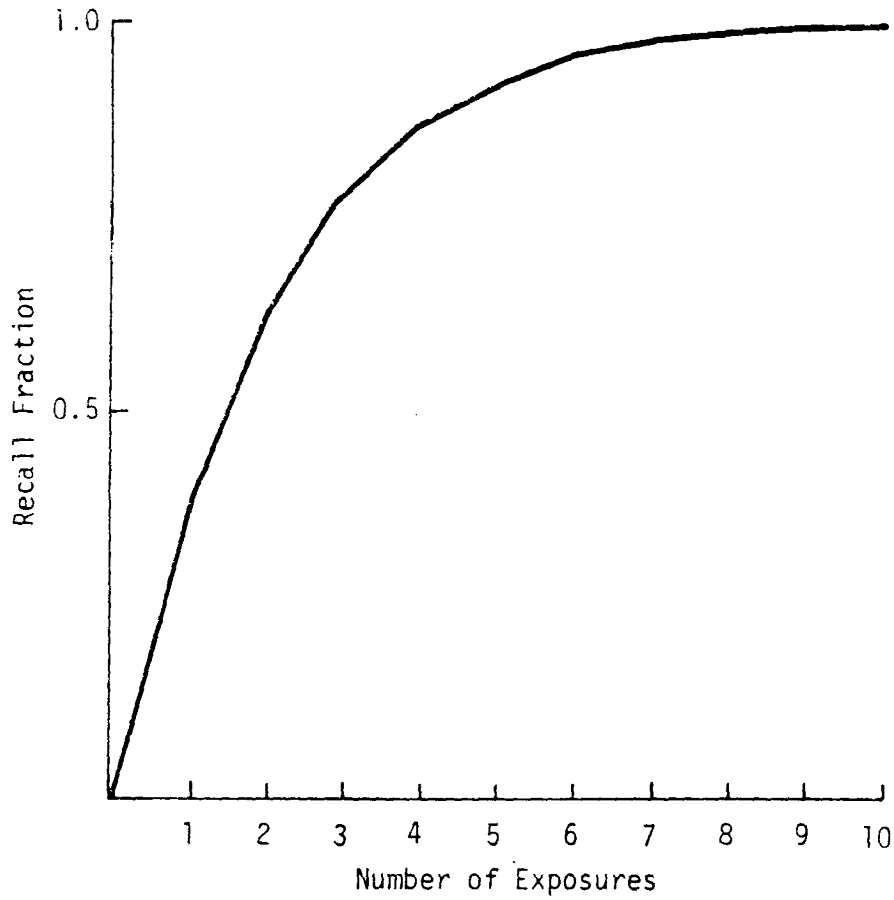

Figure A-3. Learning rate versus number of exposures.

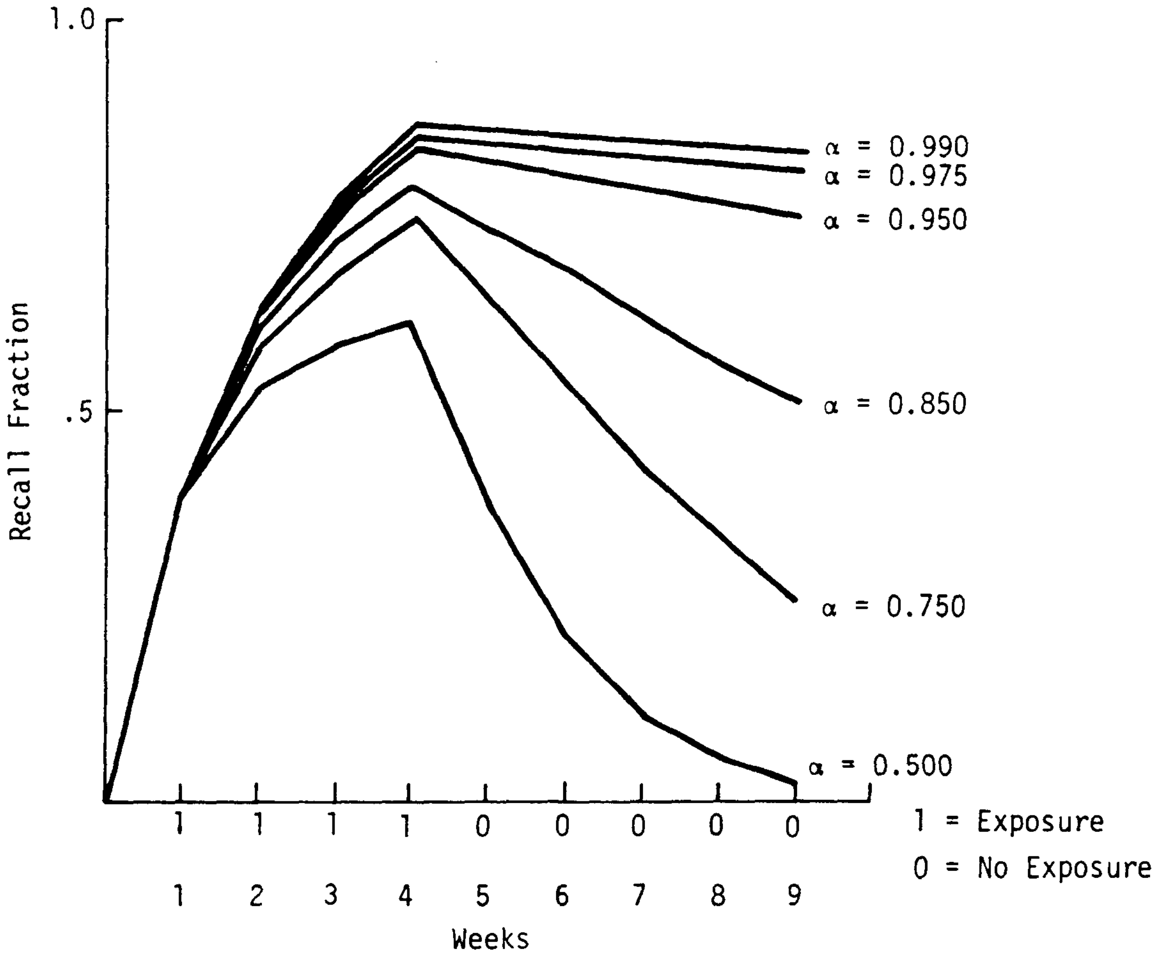

Figure A-4. Effect of retention time constant (α) on recall fraction.