Understanding Driver Performance Variability and Perception of Risk: Driver Hazard Perception Research Plan

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FOREWORD

This report identifies a proposed comprehensive research program for defining, measuring, and quantifying driver perception of hazards as it relates to highway design, operations, and safety standards. Six research projects were proposed: (1) multivariate analysis of a specific traffic situation, (2) traffic operational factors, (3) driver awareness of hazards/hazardous operating conditions, (4) unintended consequences of highway improvements, (5) social context, and (6) engineering or roadway changes to increase driver hazard perception.

These projects will provide input to human factors safety handbooks and will result in guidelines, tools, and models by which highway design can be developed and evaluated.

Copies of this report can be obtained through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, telephone: (703) 487-4650, fax: (703) 321-8547.

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16. Abstract

The objectives of this research project were to develop a comprehensive and clearly defined research program to define, measure, and quantify driver perception of hazards as it relates to highway design, operations, and safety standards. This was accomplished through a systematic research and development effort that defined six research projects. The Driver Hazard Perception Research Program broadly addresses how drivers perceive, interpret, and react to potential hazards on the road, and how this influences risk related vehicle control decisions about time, speed, and space. The results will provide input to human factors safety handbooks, such as the *Human Factors Highway Safety Handbook* for use by highway designers, and human performance driving models, such as the Driver Performance-Based Highway Design Module (DPB/HDM) that incorporates human factors data and driver behavior models. The sequence of projects provides: (1) a broad, empirically based understanding of the role of driver roadway hazard perception leading to driver action; (2) understanding of the safety consequences of these perceptions and actions; (3) identification of causal factors influencing driver hazard perception; and (4) proposed countermeasures to improve driver hazard perception for benefits in safety and traffic operations.

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CHAPTER 1

DRIVER HAZARD PERCEPTION INTRODUCTION

Project Objectives

The objectives of this proposed research program are to define, measure, and quantify driver perception of hazards as it relates to highway design, operations, and safety standards. This will be achieved by conducting six research and development efforts resulting in guidelines, tools, and models by which highway designs and operations can be developed, tested, and modified.

Scope

The Driver Hazard Perception Research Program broadly addresses how drivers perceive, interpret, and react to potential hazards on the road, and how this influences risk-related vehicle control decisions about time, speed, and space. The research will produce new design and operations practices and recommended safety countermeasure options. The results will provide input to safety handbooks, such as the *Human Factors Highway Safety Handbook* for use by highway designers, and human performance driving models, such as the Driver Performance-Based Highway Design Module (DPB/HDM) that incorporates human factors data and driver behavior models. The sequence of proposed projects will provide: (1) a broad, empirically based understanding of the role of driver roadway hazard perception leading to driver action; (2) understanding of the safety consequences of these perceptions and actions; (3) identification of causal factors influencing driver hazard perception; and (4) proposed countermeasures to improve driver hazard perception for benefits in safety and traffic operations.

Background

Traffic engineers can specify the design characteristics of the roadway and the operational procedures. They cannot directly control the behavior of the driver For this reason, design and operational practices must be consistent with the perceptions, capabilities, and actions of the driving public. Unfortunately, there are issues that complicate doing this, one of which is that driver behavior is not rigidly fixed, but is adaptive. Drivers are not simply "controlled" by roadway geometry, design elements, and traffic control devices. They bring their own perceptions and motivations to the driving task, and adapt their behavior to optimize their performance according to their own criteria. Hazard perception and evaluation is an important part of this process. Driver behavior will be modulated by risk to the degree the driver perceives and values the hazard. Furthermore, drivers are not passive elements when safety countermeasures are introduced, although they have often been implicitly treated this way. Evans[1] refers to this as the "engineering approach." It assumes that a driver's behavior remains

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[1]Evans, L. (1985). Human behavior feedback and traffic safety. *Human Factors, 27*(5), 555-576.

unchanged by some engineering change, so that the benefits of that change are fully determinable by engineering assumptions. In practice, driver behavior will often interact with design changes, reducing safety or other benefits. For example, improving a severe horizontal curve may lead to traffic traveling faster through the site, so that safety benefits are not those that would be expected if motorists merely continued to drive the roadway as they had done previously. Thus, the ability of drivers to perceive and evaluate hazards, and their adaptations to perceived risks, interact with highway design features and operational characteristics to determine the actual safety of a roadway.

There has been a substantial body of research on driver risk perception and risk taking, but it has largely been concerned with the characteristics of the individual driver, such as personality traits, life stresses, driving experience, and so forth. This work may be of theoretical interest and may help target drivers who may require particular training or other safety interventions. This literature is of virtually no use, however, in indicating how roadways might be better designed to match the manner in which the users of those roadways perceive and respond to potential hazards. The purpose of the proposed Driver Hazard Perception Research Program is to provide the empirical and modeling basis for highway design and operations practices and safety countermeasures that reflect the way drivers perceive roadway hazards.

Where there is a potential hazard on the road, this comes to influence driver behavior and roadway safety through an internal (and not necessarily conscious) sequence of perceiving the hazard, determining subjective risk, responding to that perceived risk in the context of the full driving task, and evaluating the appropriateness of the response. The portion of this process that the traffic engineer can most directly address is the perception of the hazard and, therefore, that is the focus of much of the proposed plan. However, for new measures to be effective, there must be a better understanding of the process by which hazard information gets translated into driver actions. The means by which a potential roadway hazard influences driver behavior, and ultimately safety outcomes, is not a simple, unitary process.

In reviewing the diverse literature on risk perception, it became apparent that hazard perception operated at various levels, and that this was only an initial stage in a process by which a driver acquires a sense of risk and makes decisions related to risky outcomes. Figure 1 represents a conceptual scheme that was developed to clarify the various aspects of driver hazard perception and how they relate to driver behavior and performance. This schema has proven useful for organizing thinking about driver hazard perception issues and the associated research needs.

Project Approach

The project objectives were accomplished through a research and development program that included the following tasks:

Literature Review - Identify driver perception of hazards related to highway design, operations, and safety standards and the methods and measures used to define and quantify driver hazard perception. The detailed findings of the literature review may be found in Dekker, Kotwal, and Lerner (1994).[2]

Identify Research Gaps - Identify research gaps and issues in human hazard perception and define a preliminary reseach program to address these findings.

Organize and Convene an Expert Panel - Convene a panel of nine experts in the fields of experimental psychology/human factors psychology and traffic engineering to review and comment on the literature review, gaps in the literature, and proposed research plan; to make recommendations, including experimental methodologies, to develop the draft research program; and to identify research priorities. (Appendix A presents the names and affiliations of the expert panel members.)

Develop a Draft Research Program - Develop a comprehensive and clearly defined research program to address driver hazard perception. Submit the draft to the expert panel for review and incorporate comments in the final research program.

Summary of Key Issues From the Literature Review

The existing literature in two distinct, though overlapping, areas—driver performance variability and driver perception of risk—was reviewed during the project and analyzed by project staff and the expert panel described above. Each of these areas is characterized by large and very diffuse literatures. Although there has been a great deal of research, it covers a very broad spectrum, and the depth of knowledge for many specific questions is disappointingly weak. Both areas also lack models, theories, or frames of reference with which to integrate the disparate research.

Research related to driver risk perception suffers from a range of methodological problems or limitations. Relatively little of the research has dealt specifically with risk *perception*, as opposed to risk taking. From a traffic engineering perspective, risk perception is particularly interesting because it potentially can be manipulated by the traffic engineer, whereas driver motivational and personality factors that contribute to risk taking are less tractable. Many of the research methods used in this literature are based on perceptions or judgments of static situations with no actual inherent risk, and the validity is often questionable. Spatial, temporal, and system aspects of risk perception have received little systematic research attention, but various theoretical (e.g., risk homeostasis) or analytical (e.g., accident migration) treatments have emphasized the potential importance of these aspects. Not only is there little agreement on how to measure subjective risk, there is not even much reasoned consideration of how to measure *actual* risk so that *mis*perception can be characterized.

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[2]Dekker, D.K., Kotwal, B.M., and Lerner, N.D. (1994). *Understanding Driver Performance Variability and Perception of Risk.* Federal Highway Administration. Report No. FHWA-RD-96-014.

Risk behaviors have provided fertile ground for theorists, and a range of classes of theories were discussed in this review. However, there is little agreement in the field regarding acceptance of any particular theoretical positions, and none of the theories appears particularly refined or predictive. One problem that neither current theory nor measurement practice seems to have addressed is how to predict and quantify the benefits or disadvantages that may come about through small changes in driver behavior. For example, if some change in the roadway (e.g., a wider "clear zone") results in some objectively improved safety situation (e.g., less opportunity to have a fixed-object collision), but also results in a small but sustained shift in some aspect of driver behavior (e.g., change in mean speed or change in eye-off-road time), the literature does not seem to provide tools to allow any meaningful estimates of net safety benefits.

A great deal of the empirical research on risk perception appears to have focused on driver factors: age, sex, personality factors, transient or impaired states, etc. Surprisingly little has focused on roadway factors: geometrics, traffic control devices, traffic variables, and roadway environment. Although there are scattered facts, there is no clear body of results to suggest how various traffic engineering elements influence risk perception and the ultimate behavioral and safety consequences.

In summary, despite their size, both the literature on driver risk behavior and the literature on driver performance variability suffer important limitations. There are weaknesses in methodology and theory. There are large areas of limited knowledge, and inadequate tools to integrate findings, draw implications, and suggest improvements. There are needs for significant efforts to improve methodology, empirical knowledge base, and models/theories. This is especially the case when relating risk perception or performance variability to aspects of highway design and operations, since much of the existing work has been oriented toward driver factors and related countermeasures (training, licensing etc.), rather than roadway factors.

Proposed Human Factors Safety Research Program

As stated above, the project objectives have been accomplished through a systematic research and development effort that defines six interrelated research projects that will result in guidelines, tools, and models by which highway design can be developed, tested, and modified. These research efforts are interrelated and will draw on each other for data and information. An overview of the six projects is presented in Figure 2 (the projects are arbitrarily numbered to simplify discussion of their relationship). The results of these projects will contribute to enhanced designs of the highway system to meet the needs and limitations of the drivers. A summary of the individual projects and their respective products follows below. Chapter 2 presents the details of the specific projects on driver hazard perception.

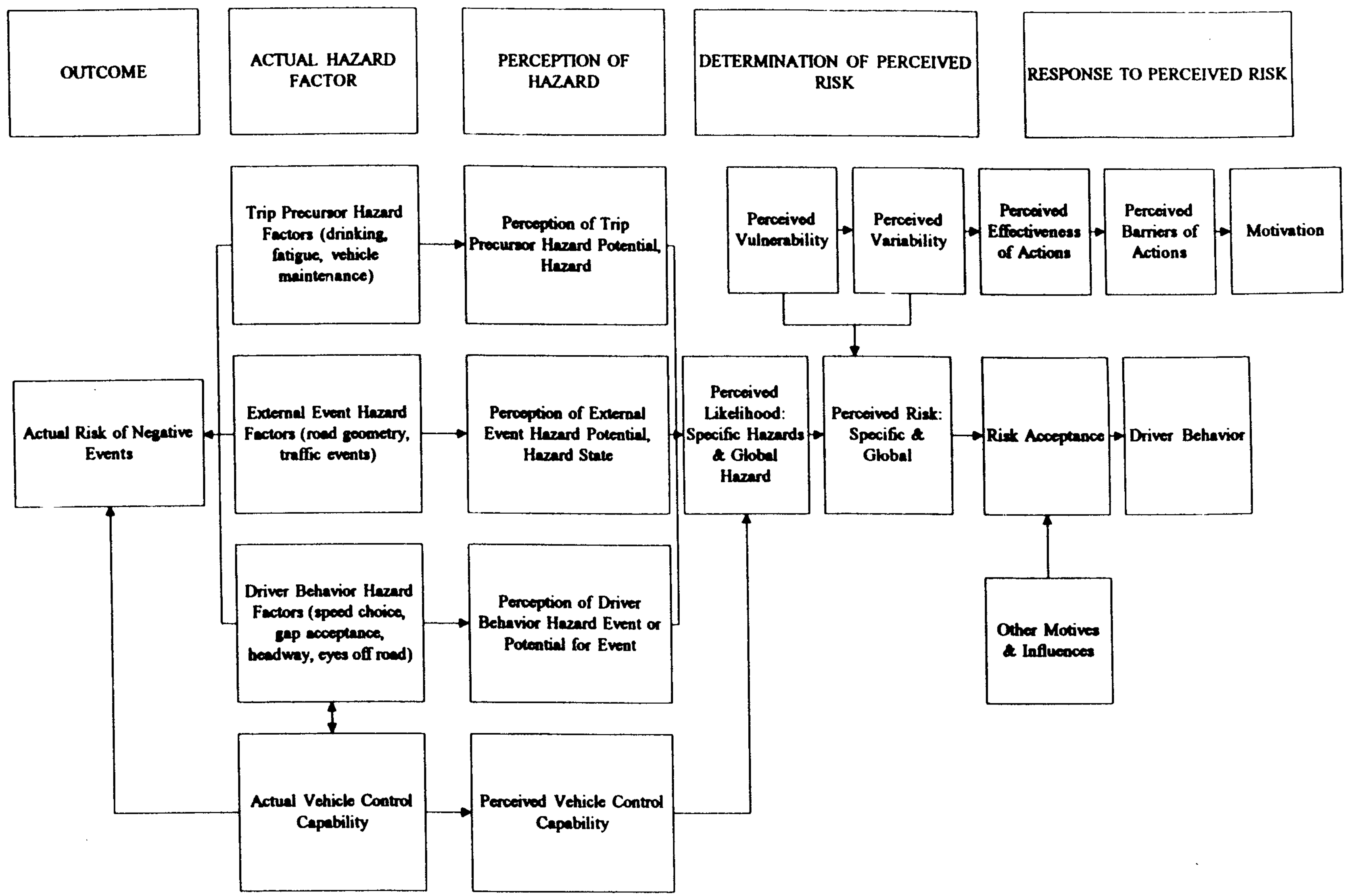

Figure 1. Conceptual scheme for driver risk.

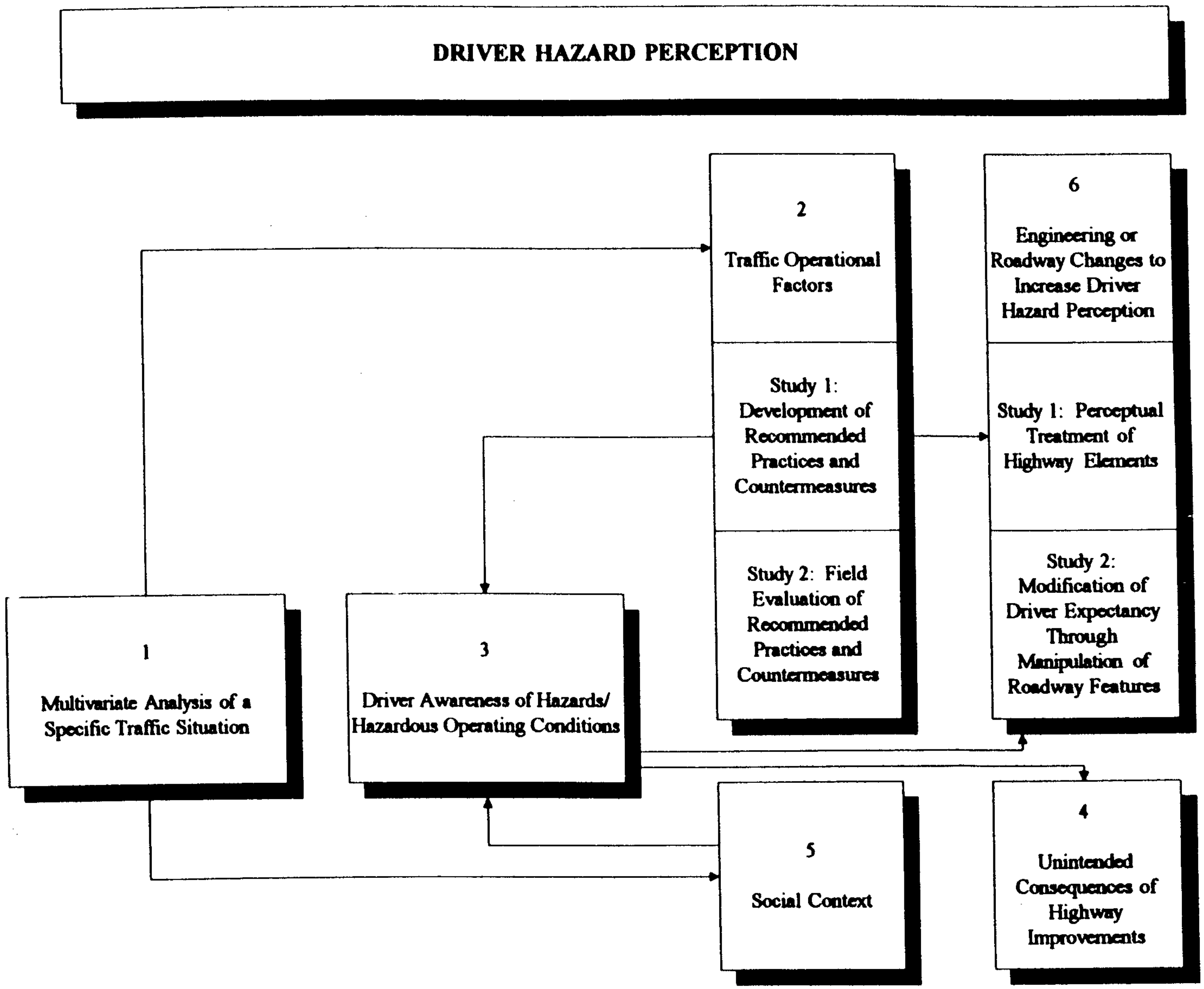

Figure 2. Human factors highway safety research program.

Project #1: Multivariate Analysis of a Specific Traffic Situation. This project will identify a specific driving situation, such as a left turn at an unprotected intersection, where driver hazard perception and risk decisions appear to play a prominent role. The project will then use that situation as the basis for a very detailed and comprehensive case study of hazard perception and its control through traffic engineering measures. The project will provide both specific guidance for highway design and operations for the selected situation, but will also develop and validate methods that are appropriate for future research in this program area. The intent is that a very detailed and rigorous analysis for a specific situation will provide important "lessons learned" about methods, research issues, subject criteria, driver models, statistical treatment, and design/countermeasure development.

Product(s):

(1) Improved design and operational practice for a key driving situation with a high incidence of collisions related to problems of driver hazard recognition.

(2) Exhaustive case history for the study of driver hazard perception issues that will guide future work in terms of methods, designs, analysis, models, and traffic engineering guidelines development.

Project #2: Traffic Operational Factors. This project investigates the influence of key operational parameters on drivers' risk-related decisions about time, speed, and space. Because driver decisions about time, speed, and space (e.g., gap acceptance) are known to be sensitive to roadway operational factors, traffic engineering practice should take into account risk behaviors that can be anticipated for the range of operational conditions at a site. The project is conceived as two sequential studies. This first is a research effort to understand the role of a broad range of operational factors and to develop design and countermeasure recommendations related to these. The second study is a field implementation and evaluation of a selected number of these recommendations, based on their potential for greatest safety benefits.

Product(s):

(1) Improved design, operational, and countermeasure practices for minimizing hazardous driver decisions for a wide range of applications and operational factors.

Project #3: Driver Awareness of Hazards/Hazardous Operating Conditions. It is not known under what conditions drivers have an appropriate awareness of roadway hazards and an accurate perception of the involved risk. The purpose of this study is to directly evaluate the driver's awareness of hazards and the related effects on driving performance. The study will identify situations where driver perceptions are inappropriate, and will recommend traffic engineering changes or safety countermeasures to address these problems. The results will also be used to develop a conceptual model of driver hazard awareness, which will directly contribute to the activities of Projects #4 and #6.

Product(s):

(1) Traffic engineering recommendations for improving roadway design or operations for situations where drivers have poor recognition of hazards.

(2) Model of driver hazard awareness that will be useful for additional research and/or safety countermeasure development, including input for human performance modules used in future CAD systems for highway design.

Project #4: Unintended Consequences of Highway Improvements. This project investigates the means by which safety improvements to some portion of the roadway system may result in undesired safety or operational consequences at some other point in the system. It is intended to provide an understanding of when and where this occurs, the causal mechanisms, and the magnitude of the safety implications. Based on this understanding, the project will also recommend improved means for implementing highway improvements in order to maximize system safety benefits.

Product(s):

(1) Quantitative description and model of the process of "accident migration" and similar system-wide negative effects of spot safety improvements.

(2) Improved methods for implementing site improvements so as to minimize undesired consequences and maximize system-wide safety.

(3) Incorporation of unintended consequences into formulas or other methods used by state or local agencies to prioritize sites for safety improvements.

Project #5: Social Context. This project determines the effect of social factors on driver perception of hazards and decisions about risk. "Social" factors are broadly included at three levels: (1) the influence of other vehicle occupants; (2) the influence of other surrounding roadway users; and (3) local norms about acceptable actions. The project recognizes that social influences can have a major impact on driver risk behaviors, yet they have been largely ignored in previous work.

Product(s):

(1) Improved design and operational practice to meet predictable conditions that result in risky decisions.

(2) Methods to control the emergence of undesirable local variation in driving customs and produce greater homogeneity in driving practice.

(3) Improved models of driver behavior that will affect driver performance models for highway applications and decisions about the "design" driver.

Project #6: Engineering or Roadway Changes to Increase Driver Hazard Perception. This project addresses methods for manipulating driver hazard perception for roadways or sites with safety problems. Two separate studies are proposed within the project, since they address somewhat different issues and approaches. This first study concerns specific problem sites and elements (e.g., a curve that suffers a number of run-off-road accidents), and the approach is to directly modify the driver's immediate perception of that element (e.g., make the curve appear sharper, or make the vehicle approach speed seem faster). The second study concerns a more general manipulation of driver hazard recognition along a segment of roadway through manipulating driver expectancies about that roadway. For example, roadway aspects such as the apparent quality of the road shoulder can influence the driver's subjective sense that he or she may have to be more alert to take some driving action in the upcoming roadway s ction. Together, the two studies should provide a set of techniques for improving safety through techniques that modify hazard perception. The development of countermeasures will be facilitated by the findings and models of previous projects in this series.

Product(s):

(1) Guidelines, specifications, and warrants for the use of innovative techniques to directly modify the driver's perception of hazardous sites.

(2) Guidelines, specifications, and warrants for the use of modifications to roadway appearance that will influence general driver expectancies about potential hazards for an upcoming section of roadway.

CHAPTER 2

DRIVER HAZARD PERCEPTION RESEARCH PLAN

Hazard Perception Project #1: Multivariate Analysis of a Specific Traffic Situation

Problem Description: Driving a vehicle is a multidimensional task occurring within an overall system. Three major factors—driver characteristics, the task itself (including the vehicle), and the surrounding environment—all can affect the final performance of the system. Potential hazards may also occur at any point within the system. The driver responds not only to such hazards, but to his or her subjective perception of the hazard as well. Subjective judgments of the risk associated with hazards vary widely between individuals. That the perception of risk plays an important role in driver behavior is undeniable, even though risk perception is a difficult construct to operationally define and measure. Previous research on driver behavior has taken a unidimensional approach, with much effort devoted to analyzing a single or a few driver characteristics for any given driving maneuver, but, for the most part, ignoring hazard perception. For example, the correlation of age and gender with speed choice are popular individual and operational variables receiving a great deal of research attention. However, driving a vehicle is more complex. A broad multivariate analysis is needed for specific traffic situations, such as left-turn gap acceptance, which takes into account multiple driver, vehicle, or environmental variables and potential interactions that may occur between these variables.

Objective: The objective of this research is to conduct a broad multivariate analysis for one specific traffic situation. The chosen situation will be used as a prototype; a detailed approach should be taken to thoroughly study all aspects and interactions of the complete set of variables that make up this prototype. The purpose of this project is not only to address the particular prototype problem, but also to view the project as a "case study" to develop methods and general findings that could be applied to analyzing other traffic problems. Prior studies generally take a problem and look at it across situations; the proposed approach is the complete opposite in that it analyzes every aspect of one specific situation only. A primary focus of the case study should address driver perception and evaluation of hazards, including identification of the components to be included in an operational definition of risk perception, and standard ways to quantify *objective* risk. Other areas of study (for example, anthropology, sociology, life-span developmental psychology, or social psychology) should be explored for analytical methodologies that may be well suited to this problem.

Scope: This project will address all factors associated with driver hazard perception and performance for a specific driving situation. The intent is to conduct an in-depth analysis of all levels of factors that may influence driver hazard and risk perception for a specific driving situation. Both daytime and nighttime conditions should be included in the study of this driving situation. Operational factors, such as inclement weather, traffic speed, traffic volume, etc., should also be a part of this research project. The driver population to be included in the field data collection portion of this project should be a representative sample of drivers for the selected situation, including meaningful numbers of young (< age 21) and older (> age 65) drivers. The planned duration for the project is 3 years.

While the focus of the immediate study is primarily limited to the chosen prototype situation, another purpose of the study is to develop a battery of methods suitable for measuring driver hazard perception and risk taking in other traffic conditions. Therefore, the researcher should also bear in mind the applicability of alternative methodologies for other situations.

The products of this research will be: (1) improved design and operational practice for the identified traffic situation, and (2) a "case history" methodology for the study of driver hazard perception issues to guide future work in terms of methods, designs, analysis, models, and traffic engineering guidelines development.

Anticipated Tasks/Methodology:

Task 1: Choose appropriate situation for use as prototype. Conduct a thorough accident analysis and review to define specific driving maneuvers or traffic situations where drivers appear to be misperceiving hazards and taking undue risks. The driving situation associated with a high degree of accidents will be used as a model for developing a case history methodological approach. A suggested candidate situation for this research study is left-turn gap acceptance at intersections. This particular maneuver is a prominent problem associated with a varied set of risk-perception and risk-taking issues. However, if sufficient justification can be made to use an alternative driving situation, such as single-vehicle run-off-the-road accidents or lane-change maneuvers, a different situation should be used instead. The selected prototype situation should be justified based on: (1) the magnitude of the safety problem; (2) probable contribution of driver hazard and risk perception; and (3) range and generalizability of risk issues and required research methods.

Task 2: Conduct literature review and review of current practices. Review literature related to driver awareness of potential hazards and perception of risk at all levels (e.g., driver, vehicle, and environmental factors) for the prototype driving situation. Review current roadway practices (e.g., traffic control devices, pavement markings, lighting, etc.) that attempt to maximize driver awareness of hazard for the prototype situation.

Task 3: Conduct task analysis of situation. Using a systems approach, highlight all instances in which driver hazard perception can occur for the prototype situation. Analyze driver, task (vehicle), and environmental factors that affect hazard perception and risk taking. Evaluate potential contribution of hazard perception and risk taking at each specified instance and the resulting levels of severity for various consequential outcomes.

Task 4: Review and develop potential methodologies to measure and evaluate hazard perception. Conduct a comprehensive review of methodologies used to measure hazard perception and risk taking as related to driving behavior. This review should include identification of the components to be included in an operational definition of risk perception and standard ways to quantify *objective* risk. The final outcome of this task should be a battery of methods for measuring hazard perception that could be applied to a variety of driving situations.

Task 5: Develop research plan to test proposed methodologies. Based on the findings from Task 4, develop a detailed research plan for a series of controlled investigations to collect data that tests the feasibility of the potential measurement methodologies for quantifying hazard recognition and risk perception. The controlled investigations might include techniques such as on-road instrumented vehicles, test track studies, driving simulators, or traditional laboratory-based studies. The investigations should collect a combination of driver performance data, subjective self-reports, physiological measures, or other relevant information. To validate the measurement methodologies, the driver's subjective self-reports of risk perception are to be correlated with objective measures of hazardous operating conditions, including, but not limited to, accident rates and expert assessment of risk at the traffic site.

Task 6: Implement Task 5 research plan. Conduct the controlled investigations as defined in Task 5. Compare results obtained from the various methods for measurement sensitivity, statistical power, reliability, validity, and cost associated with the various methods.

Task 7: Document findings and make recommendations for measuring driver hazard perception and risk taking. Based on the findings of Task 6, recommend the most highly promising candidate methodologies for measuring driver perception of hazard and risk taking behavior as related to driving performance. An array or battery of methodologies should be suggested since no single methodology will probably be appropriate for all driving situations. Document the research findings to date in an interim report that includes for each methodological approach: (1) a full description of the measurement techniques, (2) strengths and weaknesses, and (3) the kinds of situations that are appropriate for each measurement approach.

Task 8: Define research plan for prototype situation. Based on the recommendations of Task 7, develop a detailed research plan that applies the most appropriate methodologies to the prototype driving situation. This plan should include a series of controlled investigations to collect data on drivers' perceptions of hazards for all aspects of the prototype situations. A full multivariate perspective should be used, and the chosen methodologies should be directly tied to the different levels (driver, vehicle, and environment) of the resulting task analysis from Task 3.

Task 9: Conduct laboratory studies. Implement the research plan as defined in Task 8. The controlled investigations should include a variety of driving situations, such as on-road instrumented vehicles, test tracks, simulators, traditional laboratory studies, or other appropriate methods. A range of sites with different geometric and operating features, as well as different populations of drivers, should also be included as part of the research.

Task 10: Conduct field validation studies. Gather field data to assess the degree to which results from controlled investigations generalize or predict driver behavior in actual roadway and traffic settings for the prototype driving situation. Traffic observational studies or other on-road methods should be used to gather the data for this task.

Task 11: Propose recommendations for countermeasures. Document results from Task 10, including a complete description of the prototype driving situation, and lessons learned from this case history study approach. Propose recommendations for countermeasures for the prototype situation.

Task 12: Prepare draft documents. Document research procedures and findings in a draft research report.

Task 13: Prepare final reports. Based on Federal Highway Administration (FHWA) review comments, finalize the draft documents.

Manpower: The estimated person-hours to complete the project are presented in the following table.

STAFF CATEGORY	HOURS
Sr. Human Factors Psychologist	2,000
Jr. Human Factors Psychologist	2,000
Sr. Traffic Engineer	1,000
Jr. Traffic Engineer	2,000
Statistician	200
Technician	3,500
Other	500
Total	11,200

Potential Benefits/Payoff: This project will provide a detailed understanding of driver hazard perception and risk-taking behavior for a specific driving situation. This will result in specific design, operational, and countermeasure recommendations for traffic engineering applications.

A second benefit of the research is a model for a multidimensional approach or methodology that can be applied to other driving situations as needed. It is expected to provide guidance on methods and research design, a framework for evaluation, and a model or theoretical basis for use in the subsequent studies of this program.

Hazard Perception Project #2: Traffic Operational Factors

Problem Description: Drivers' time/speed/space decisions will be influenced by traffic operational factors, but we do not have a good understanding of this process. Hazardous decisions for various situations are known to be affected by operational factors. For example, drivers may accept shorter gaps in traffic when volume is heavier and there are fewer opportunities, or they may be more likely to decide to proceed through a signalized intersection on yellow if the signal phasing results in a long delay. As a result, certain operational conditions may result in increased risk taking and more collisions. Better understanding of how critical time/space/speed decisions are influenced would allow the traffic engineer to select appropriate operational parameters and/or to employ roadway design practices that encompass driver time/speed/space decisions that will occur under real-world anticipated operational conditions.

Objective: This project should identify those operational parameters that have the potential to influence hazardous driver decisions. For example, these may include traffic congestion, vehicle mix, travel speed, platooning, signal timing, signal phasing, turn protection, recurring and non-recurring congestion, and so forth. The project should determine the magnitude of changes and resulting safety implications associated with each operational factor. The project should result in specific design or operational guidelines for minimizing hazardous driver decisions and developing countermeasures for situations where these problems are likely to occur.

Scope: This program area consists of two sequential studies. The scope of Study 1 covers the analytical and research work that results in the development of recommended practices and countermeasures. The scope of Study 2 provides a comprehensive implementation and evaluation of those recommendations. These two studies could be combined into a single larger contract. However, two independent studies would have the benefit of an implementation and evaluation of the Study 1 recommendations by a second organization that was not involved in their development. The planned duration for Study 1 is 3 years, followed by Study 2 with a duration of 2.5 years.

The investigation should include freeways, arterials, and two-lane roads for both urban and non-urban locations. Traffic observational studies should include multiple regions so that findings can be broadly representative. Both daytime and nighttime conditions should be included. The emphasis should be on fair-weather operations, except as inclement weather directly affects the operational factors selected (e.g., traffic speed, volume). The designation of the appropriate operational parameters to be included in the studies will result from a comprehensive review and analysis of existing literature, practices, and accident experience.

The primary population of interest for the field data collection efforts is a representative sample of existing traffic for the selected sites. For the on-road experiments, the range of driver ages should be encompassed, including meaningful numbers of young (< age 21) and older (> age 65) subjects.

The primary products of the research will be improved design, operational, and countermeasure practices for minimizing hazardous driver decisions for a wide range of applications and operational factors.

Anticipated Tasks/Methodology:

Study 1: Development of Recommended Practices and Countermeasures

Task 1: Review literature, practices, and accident data. Review literature related to the influence of operational factors on driver's time/space/speed decisions and related accident risk. Review current practices for minimizing undesirable driver decisions related to various operational factors or countermeasures for reducing such risky actions when problem sites are identified. Conduct accident database analyses to further determine how various time/space/speed choices are related to operational factors and the related accident outcomes. The accident database analysis should integrate and make use of other information sources that provide additional detail on operational factors related to the site.

Task 2: Identify and quantify key operational factors. Based on Task 1, identify the key operational parameters that relate to inappropriate driver time/space/speed decisions and their relationship to particular roadway situations (e.g., urban arterials, rural freeways, etc.). For each cell defined by the matrix of operational parameters and roadway situations, summarize: (1) how the operational parameter affects time/space/speed decisions; (2) order of magnitude of safety implications; (3) extent to which this is already addressed by current practice; and (4) gaps in knowledge related to this situation. Based on this, prioritize those situations for which driver behaviors induced by operational parameters are most likely to have significant safety implications.

Task 3: Design field data collection plan. Develop a detailed research plan to collect systematic field data on driver time/speed/space decisions for high-priority operational parameters and driving situations. For each operational parameter/roadway situation, include multiple sites to ensure generality, including geographically diverse regions.

Task 4: Design on-road experimental research plan. Develop a research plan that will permit valid measurement of the time/speed/space decisions of subject drivers as they encounter selected sites under a range of operational conditions. Experimental comparisons may include repeated drives through a given site under various operational conditions (e.g., different levels of congestion) and/or use of matched sites that differ in some operational aspect (e.g., signal phasing).

Task 5: Conduct field data collection and on-road experiment studies. Implement the planned field data collection study and the on-road experimental research study.

Task 6: Analyze implications for safety and traffic engineering practices. Evaluate driver time/speed/space decisions under different operational parameters, as related to current standards, practices, assumptions underlying design equations, etc. Determine adequacy of current practice.

Task 7: Develop recommended practices, warrants, and countermeasures. Based on the Task 5 analysis, develop recommendations for improved design or operational practices, warrants for implementing additional design requirements, and countermeasures for sites that suffer poor driver time/space/speed decisions under particular operational conditions.

Task 8: Prepare draft documents. Document research procedures and findings in a draft research report. Develop a formal set of traffic engineering guidelines, suitable for use by field engineers.

Task 9: Prepare final documents. Based on FHWA review comments, finalize the draft documents.

Study 2: Field Evaluation of Recommended Practices and Countermeasures

Task 1: Review and refine Study 1 recommendations. Review and critique the recommendations, warrants, and countermeasures recommended in Study 1. Identify possible limitations, questionable assumptions, and additional alternatives. Develop alternative versions for consideration where appropriate. Convene an expert panel to evaluate and refine the most promising concepts.

Task 2: Select and define study conditions. Determine the set of operational conditions that should be addressed and prioritize them based on key research questions, and potential safety and operational benefits.

Task 3: Design field evaluation plan. Develop a detailed research plan for field implementation and evaluation of recommended practices for the selected study conditions. The plan must include appropriate control conditions. Specify number and type of sites, type of data collected and its relation to driver risk behaviors, and means for quantifying projected safety and operational benefits.

Task 4: Select sites. Select multiple experimental and control sites for each study condition. Ensure appropriate range of geographic regions and local practices. Secure cooperation for implementation of treatments, where required, and for data collection procedures.

Task 5: Collect field evaluation data. Implement the field evaluation plan at the selected sites.

Task 6: Evaluate practices. Analyze the findings of the field evaluation and compare the performance of alternatives in terms of reducing risky time/space/speed decisions among roadway users. Determine the safety and operational consequences of alternatives. Compare costs and benefits.

Task 7: Prepare draft recommendations and draft report. Document procedures and findings in a draft report. Develop recommendations for any changes to Study 1 recommended practices, warrants, and countermeasures.

Task 8: Prepare final recommendations and final report. Based on FHWA review, finalize report and recommended practices, warrants, and countermeasures.

Manpower: The estimated person-hours to complete the project are presented in the following table.

STAFF CATEGORY	HOURS	HOURS
	STUDY 1	STUDY 2
Sr. Human Factors Psychologist	1,000	400
Jr. Human Factors Psychologist	2,000	800
Sr. Traffic Engineer	1,000	1,000
Jr. Traffic Engineer	2,000	2,000
Programmer	40	100
Statistician	200	400
Technician	3,500	4,000
Other	200	200
TOTAL	9,940	8,900

Potential Benefits/Payoff: The project will result in improved traffic engineering design and operational practices that more accurately reflect risk-related driver decisions under operational conditions that are critical to safety. Both safety and operational improvements should result.

Hazard Perception Project #3: Driver Awareness of Hazards/Hazardous Operating Conditions

Problem Description: Theories of driver behavior differ in the extent to which drivers are aware of potential hazards, the risk or danger associated with the hazard, and their motivations to control or minimize risk. At times, drivers may be consciously aware of potentially hazardous operating conditions, but frequently, they are unaware of both the potential hazard and their own ability to successfully negotiate that hazard. Driver actions are not always aimed at minimizing risk; other motives, such as getting to a destination quickly, pleasure, an outlet for aggression, or fulfilling social needs like peer recognition and approval, can also influence driving behavior. These other motives may cloud a driver's awareness of potentially hazardous outcomes associated with driving situations. The relative importance of extraneous motives upon the driving task is not well understood. Furthermore, how these motives may affect a driver's awareness of roadway hazards, which, in turn, may lead to unsafe driving decisions, is not known.

Objective: The objective of this project is to investigate driver awareness of hazardous operating conditions. Initially, traffic conditions in which drivers are aware of potential hazards and the risk associated with those hazards should be identified. In these instances, it is important to understand how drivers perceive their own ability to negotiate the hazard, as well as their perception of the risk or danger involved. If drivers *are* aware of hazardous conditions, the next question to be addressed is what actions should be taken to safely negotiate the hazard. Likewise, those operating conditions where drivers are unaware of, or misperceive, risk should be identified. For example, two common situations in which drivers may underestimate the degree of hazard are when entering a curve at too high a speed or tailgating other vehicles. A model of hazard awareness should be proposed and tested to identify and prioritize common hazard misperceptions. Appropriate countermeasures should be suggested that would enhance the driver's awareness of the risk associated with potentially hazardous traffic situations.

Scope: The scope of this work should address the normal driving public and general roadway environment. Particular attention should be given to the two outer age-related extremes of the driving population, i.e., younger and older drivers. Research to date has suggested different risk-taking behaviors in these two groups due to numerous causes, such as social pressure and physical or cognitive limitations that should be reviewed in this work. Thus, meaningful numbers of young (< age 21) and older (> age 65) drivers should be included as a part of the sampled population. Driver impairment due to alcohol, drugs, or excessive fatigue may be significantly related to the perception and misperception of roadway risk. These topics should be a part of the literature review because they are an important component to the conceptual model of driver hazard awareness. However, the field validation studies of the proposed driver hazard awareness model should be confined to a normal operator state of alertness.

The primary products of this project are traffic engineering recommendations for improving roadway design or operations for situations where drivers have poor recognition of hazards. A second product is a model of driver hazard awareness that will be useful for additional research and/or safety countermeasure development. The planned duration of the project is 3 years.

Anticipated Tasks/Methodology:

Task 1: Conduct review of literature, current practices, and accident data. Review literature related to driver awareness of hazards and perception of risk for all types of driving situations. Review current roadway practices (e.g., traffic control devices, pavement markings, lighting, etc.) that attempt to maximize driver awareness of hazards. Conduct accident database analyses to determine both specific instances and general patterns where driver misperception of risk may be causally related to accident outcomes. Compile a taxonomy of individual driver characteristics and traffic operational factors that may influence perception of risk. This taxonomy should include a list of traffic situations with a high potential for hazardous operations, how drivers perceive risk or danger associated with potential hazards, how knowledge/risk perception translates into driving behavior, and how behavior varies with traffic operational factors.

Task 2: Conduct focus groups of drivers. Conduct focus groups to collect firsthand information on drivers' perspectives of potential traffic hazards and how they might react in such situations. Meaningful numbers of young (< age 21), old (> age 65), and high-accident drivers should be included in these focus groups. Compare these self-reports to the review findings from Task 1 to identify and prioritize those instances where drivers could misperceive the risk associated with hazardous traffic conditions.

Task 3: Develop research plan. Based on the findings of Tasks 1 and 2, develop a detailed research plan. This plan should include a series of controlled investigations to collect data on driver awareness of hazards and perceived levels of risk for critical driving situations identified in Tasks 1 and 2. Some suggested techniques for recording driver risk perceptions may be verbal protocols, talk-aloud procedures as the event is occurring, or other rating methods relevant to subjective reports. Corresponding driver performance data for those situations should be collected simultaneously with the subjective data. Methodologies for direct observation of individual performance, such as on-road instrumented vehicles, test tracks, or simulators, as well as traditional laboratory-based studies, should be a part of the research plan.

Task 4: Implement Task 3 research plan. Conduct the controlled investigations as defined in Task 3. Compare data gathered from the investigations to the results of the focus group discussions in order to gain a better understanding of the driving situations in which individuals may be misperceiving risk. The data from both Tasks 2 and 4 would allow a comparison of self-reports to actual driving behavior.

Task 5: Integrate findings collected to date and develop a conceptual model of driver hazard awareness. Using the findings from Tasks 1, 2, and 4, integrate the scientific literature findings, driver self-reports, and resulting data from the controlled investigations of Task 4 to develop a model of driver hazard awareness.

The implementation of the model for computer software modeling programs based on expert systems should be explored. A research plan for field validation of the model should also be included.

Task 6: Conduct field validation studies and refine model. Implement the field validation and evaluation studies of the conceptual model defined in Task 5. Based on the findings, refine the model's details, or calibrate and quantify its operation.

Task 7: Propose countermeasures for enhancement of driver hazard awareness. Identify likely candidates for enhancing driver awareness of hazards. Countermeasures could include modifications to the physical roadway; traffic operational factors, including informational signs or other Traffic Control Devices (TCD's); increasing the driver's awareness of hazards with educational campaigns; or training materials for the traffic engineer.

Task 8: Prepare draft documents. Document research procedures and findings in a draft research report.

Task 9: Prepare final documents. Based on FHWA review comments, finalize the draft documents.

Manpower: The estimated person-hours to complete the project are presented in the following table.

STAFF CATEGORY	HOURS
Sr. Human Factors Psychologist	1,000
Jr. Human Factors Psychologist	2,000
Sr. Traffic Engineer	400
Jr. Traffic Engineer	650
Social Psychologist	160
Computer Programmer	200
Technician	3,000
Other	200
Total	7,610

Potential Benefits/Payoff: The final outcome of this research project is to develop a model of driver awareness of potential hazards based on a clearer understanding of the types of traffic situations tnat the driver perceives as being hazardous. The model will be a useful tool for developing research plans and for guiding traffic engineering recommendations in subsequent research projects in the hazard perception area. The model may also contribute to general human performance models for use in future Computer-Aided Design (CAD) modules for highway design. A set of guidelines for traffic engineers should be produced that would identify those traffic situations where driver awareness of a hazard is inappropriate and would list suggestions for engineering improvements to address these misperceptions.

Hazard Perception Project #4: Unintended Consequences of Highway Improvements

Problem Description: Localized site improvements to highway safety can, at times, precipitate unintended and possibly harmful side effects at other remote locations. For example, improvements to a problem intersection might reduce accidents at that site, but may also result in increased collisions at nearby, unimproved intersections. Or, the addition of a warning signal (active or passive) at a highway-railroad grade crossing might be associated with an increase in accidents at unprotected grade crossings elsewhere in the roadway network. The extent to which this shifting of accidents actually occurs, the causal mechanisms, and the degree to which the driver's perception of hazards is altered on a site-by-site basis is unknown. An understanding of the general mechanisms of unintended consequences of selected site improvements is required to better estimate and predict the outcomes of potential safety improvements.

Objective: The purpose of this project is to systematically investigate the unintended consequences of localized site improvements in terms of resulting safety or operational effects in other parts of the roadway network. The proposed research should derive models of possible unintended consequences based on concise network definitions that specify exact spatial parameters (e.g., kilometers, square kilometers, urban, rural, etc.) and operational characteristics (e.g., traffic flow) of the network. Once a network has been defined, research efforts should systematically make changes to high-frequency problem sites and then measure corresponding changes to variables of interest at other locations within the network. A second priority in this research area should be the definition and use of proper control groups so that reliable and valid statistical comparisons of implemented measures can be made between treated and untreated roadway sites. Recommended practices or guidelines for implementing roadway improvements should be proposed that minimize unintended consequences.

Scope: The investigation should include freeways, arterials, and two-lane roads for both urban, suburban, and rural locations. Although the prior focus of similar studies often has been on fatal accidents, other types of unintended effects (such as changes in accident type or severity of injury) may also occur both at the treated problem site and at other sites within the network. The scope of this project should be sufficiently broad to accommodate the range of all kinds of unintended consequences that may occur at any site within the defined network. A combination of accident data and other surrogate measures of traffic safety, such as vehicle speed, should be gathered to more thoroughly assess various kinds of unintended consequences, for example, increased approach speed or shorter gap acceptance, instead of focusing on migration of accidents only. Traffic observational data should be gathered at multiple sites in the network both before and after treatment to the selected site or sites in order to quantify any unintended consequences at other remote sites in the network.

The primary population of interest for the field data collection efforts should be a representative sample of existing traffic for the selected sites. In addition, a mix of vehicles (as found at that site) should be included in the study. The planned duration for the project is 4 years.

The products of this project are a quantitative model of the process of "accident migration" and similar system-wide negative effects of spot safety improvements, improved methods for implementing site improvements so as to minimize undesirable consequences and maximize system-wide safety, and incorporation of unintended consequences into formulas or other methods used by state or local agencies to prioritize sites for safety improvements.

Anticipated Tasks/Methodology:

Task 1: Conduct review of literature and review current traffic engineering experience. Review literature related to unintended consequences of roadway site improvements for all types of driving situations. Some prior studies have referred to this phenomena as "accident migration." However, the literature review should be sufficiently broad to accommodate "migration" or other similar system-wide negative effects of spot safety improvements. The role of driver perception of hazards and behavioral theories of accident migration effects should also be included to further study the role of driver perception as it relates to migration effects. Contact state and local agencies for their recognition and perspective of the problem, where and when they have noted such effects, and how they deal with them.

Task 2: Determine candidate sites for further study. Identify what kinds of changes and the potential severity of possible unintended effects that may be associated with particular site features. Candidate sites with high accident rates should be given priority. These sites could be determined by an accident analysis using existing databases.

Task 3: Define field study research plan. Develop a research plan to collect traffic observational data on the consequences of safety treatment(s) at a significant problem site or multiple sites. A series of field studies should be conducted that include a range of site types and treatments to those sites so that comparisons can be made between multiple improvements at a number of different locations. Each study should clearly define a roadway network in terms of geographical space, type, location, and temporal aspects, and then implement safety treatment(s) at a significant problem site.

Task 4: Implement Task 3 research plan. Conduct the field investigations as defined in Task 3. The outcome of this research should be: (1) a quantitative description of the magnitude and extent of the resulting unintended consequences and (2) a description of the situations under which certain consequences tend to occur.

Task 5: Propose model of migration effects. Derive a model of unintended consequences at remote locations based on the quantification of observed effects gathered in Task 4. This model should take into account the effects of treatments at the treated site, the anticipated effects at immediately adjacent sites, and the effects at remote sites in the network as well. That is, changes and effects on both a site-by-site basis, as well as for the entire network system, should be included in the model. In addition to being purely descriptive, the model should include consideration of causal factors, particularly driver risk perception.

Task 6: Develop guidelines for making changes to significant problem sites within a roadway network. Recommend practices that could serve as guidelines for traffic engineers to assist them when designing roadway systems for general operating conditions. The guidelines should also include the incorporation of unintended consequences into formulas or other methods used by state or local agencies to prioritize sites for safety improvements.

Task 7: Draft reports. Document research procedures and findings in a draft research report.

Task 8: Prepare final documents. Based on FHWA review comments, finalize the draft documents.

Manpower: The estimated person-hours to complete the project are presented in the following table.

STAFF CATEGORY	HOURS
Sr. Human Factors Psychologist	500
Jr. Human Factors Psychologist	500
Sr. Traffic Engineer	2,000
Jr. Traffic Engineer	4,000
Operations Research Specialist	2,000
Statistician	1,000
Technician	4,000
Other	200
Total	14,200

Potential Benefits/Payoff: The outcome should be a determination and better understanding of the possible unintended consequences of roadway improvements. A quantitative model of "accident migration" or other similar system effects for a defined roadway network system should be proposed. With this kind of model, traffic engineers can better predict the consequences at other sites in a network when remedial changes are made at a significant problem site. This could lead to more precise estimates of how improvements may affect overall safety for inclusion procedures to prioritize site improvements. An understanding of the circumstances and processes that lead to unintended safety consequences should also suggest better methods for designing and implementing roadway changes.

Hazard Perception Project #5: Social Context

Problem Description: Driving is a complex behavior that occurs in a social context as well as a physical context. Perceiving hazards and making decisions about them can be strongly influenced by factors that may be broadly defined as "social." Previous research has tended to focus largely on the psychomotor and information-processing aspects of driving, and may not have incorporated the appropriate range of social contexts, thus distorting or narrowing our view of risky driver decisions. As one example, gap acceptance at a stop-controlled intersection can be influenced (in either direction) by the presence and type of other passengers, the presence of queued traffic behind the waiting vehicle, and expectations about the way approaching drivers will interact with entering traffic (e.g., slowing to let vehicle enter). This illustrates three levels of social influence that should be considered: passengers accompanying the driver in the vehicle; surrounding road users; and social norms related to driving (which may be locality-specific).

Objective: This project should look at various important hazard-related driving behaviors as they are affected by social context. Driving behaviors to be considered include speed choice, headway selection, gap acceptance for various situations (turns into traffic, left turns across approaching traffic, crossing traffic, merging, lane changing, passing), rail-highway crossings, compliance with traffic control devices, response to warning devices (e.g., curve warnings), and other behaviors that might be related to risk or aggressive driving. Based on preliminary analyses, selected behaviors will be examined in research experiments. The project should estimate risks associated with changes in driver behavior as a result of: (1) presence and type of passengers ("type" may need to be specified relative to driver, e.g., not just age or sex, but same or different peer group); (2) presence and actions of surrounding and interacting road users (surrounding drivers, conflicting traffic, pedestrians, cyclists); and (3) local consensus norms regarding appropriate behaviors. The project should: (1) identify geometric or operational situations that may require design reconsideration based on the actions of drivers in reasonable worst-case conditions; (2) evaluate implications for "design driver" specification and highway safety research procedures; and (3) determine the range and safety importance of local custom variation for various risky driving behaviors, the manner in which these informal norms evolve, and what can be done about it.

Scope: The study incorporates three parallel efforts that address different levels or aspects of the social context of driving as these relate to risky choices about time/space/speed. These aspects are: (1) vehicle occupants; (2) road users; and (3) local norms. Although these aspects can be researched in parallel, they will be related through theory and the development of practical traffic engineering practices. The planned duration of the project is 3 years.

Hazard Perception Project #1 (Multivariate analysis of a specific traffic situation) will probably have examined some of these factors for the single, specific situation selected for that project. This project should consider the methods and findings of the earlier project, and should not duplicate applications already adequately addressed in Project #1.

The designation of appropriate dependent and independent variables for inclusion in the study will result from a comprehensive literature analysis and expert panel input, representing a range of appropriate disciplines in addition to traffic engineering and human factors. The safety and operational effects of people's reactions to diverse social factors (reactions such as aggression, competitiveness, compliance, conformity, embarrassment, courtesy, attitudes about "proper" behavior, etc.) should be considered.

Geographic diversity in data collection will be essential to this project, particularly since local variation is a specific interest. A variety of urban, suburban, and rural sites in different regions must be included. Subjects recruited to take part in the research must be appropriately matched for the particular social factors identified as being important for the study (e.g., if aggressive reactions to certain driving interactions are under study, some screening procedures for achieving the appropriate range of aggressive tendencies should be provided).

The primary products of the research will be improved design and operational practices to meet predictable conditions that result in risky decisions, methods to control the emergence of undesirable local variation in driving customs, and improved models of driver behavior for use in performance modeling.

Anticipated Tasks/Methodology:

Task 1: Review literature. Review literature on the influence of social variables on driver risk decisions and time/space/speed choices. The review should include social influences at all three levels of social variables described above (vehicle occupants, road users, local norms). Theories of driver behavior and performance should be reviewed with regard to the role played by social factors, and the role of individual differences should be considered. The review should also go beyond the traditional highway safety and human factors literature to include potentially relevant data and theory from other disciplines (e.g., anthropology, sociology).

Task 2: Driver focus groups. Conduct focus groups with drivers to discuss driver reactions to, and attitudes about, social factors related to other vehicle occupants, other roadway users, and local norms. The purpose of these focus groups is to provide additional insights or hypotheses not revealed through the review of more formal published literature. Because local variation in driver norms is one of the interests, the focus groups should be conducted in several diverse geographical settings.

Task 3: Develop preliminary model. Develop a preliminary working model that describes the effects of social context, at all levels, on driver risk decisions. The model should integrate theory and findings from the various perspectives of Task 1 (traffic engineering, human factors, social psychology, sociology, etc.). As part of this task, convene an expert panel, representing a range of appropriate disciplines, to discuss findings to date, interpret the implications, and consider alternatives for driver models of social effects.

Task 4: Define key situations. Determine the probable influence of social factors for all potentially important driving situations. This analysis can be structured around a matrix of traffic situations (e.g., gap acceptance, freeway speed choice, rail-highway grade crossing) and social levels (vehicle occupants, road users, local norms). For each cell, indicate the nature and magnitude of the effect on risk decisions, the adequacy of the knowledge base, and the likely magnitude of safety effects. Based on this analysis, prioritize situations for further research.

Task 5: Design research plans. Develop a set of three research plans that will address each of the three levels of social variables (occupants, road users, local norms) for the selected situations most important for each level of social variable. A sequence of two or three experiments is foreseen at each level, although multiple levels could be addressed in the same experiment(s) where this is desirable. The methods should be based on the particular research issues so that they might include laboratory methods, simulators, on-road driving, field observation, questionnaires, and so forth.

Task 6: Conduct research studies. Implement the research plans.

Task 7: Develop preliminary recommendations, countermeasures, and implications. Based on the research findings, recommend changes to highway design practice and traffic operations that would better take into account the influence of social factors. Discuss implications for the "design driver" for key situations. Suggest countermeasures for situations where social factors cause a problem for existing sites. Also discuss the implications of the findings for the methodology of research on driver behavior and traffic safety.

Task 8: Design field study plan. Develop a research plan to implement and evaluate the design and countermeasure recommendations of Task 6.

Task 9: Conduct field study. Implement the Task 7 research plan.

Task 10: Prepare draft recommendations and report. Document the procedures and findings in a draft research report. Present final recommendations for site evaluation, design/operations, and safety countermeasures in a format useful for the practicing traffic engineer. Summarize the implications of the findings for driver behavior research, highway safety and driver behavior theory/models, accident projections, etc. Include a final version of the Task 2 model of social context influence on driver time/speed/space decisions.

Task 11: Prepare final recommendations and report. Based on FHWA review, finalize the draft documents.

Manpower: The estimated person-hours to complete the project are presented in the following table.

STAFF CATEGORY	HOURS
Sr. Human Factors Psychologist	2,000
Jr. Human Factors Psychologist	3,000
Sr. Traffic Engineer	1,000
Jr. Traffic Engineer	1,000
Social Psychologist, Sociologist	1,000
Statistician	200
Technician	2,500
Other	200
TOTAL	10,900

Potential Benefits/Payoff: The project will result in improved traffic engineering design and operational practices to meet those predictable conditions that result in risky driver time/space/speed decisions. It should provide means to prevent or control the emergence of undesirable local variations in driving customs (e.g., speed choice, running stops, violation rail-highway grade crossing TCD's), and to produce greater homogeneity in driving practices. It should also substantially advance research, theory, and measurement of driver behavior, as related to highway design and operations, as well as issues related to the "design driver."

Hazard Perception Project #6: Engineering or Roadway Changes to Increase Driver Hazard Perception

Problem Description: Engineers communicate warnings of potentially hazardous sites to drivers via roadway markings and traffic control devices (TCD's). At times, however, what is physically marked is not always appropriately perceived by the driver (that is, subjective perceptions of the hazard do not perfectly correlate with objective reality). Sometimes altered perceptions can be used to enhance the driver's immediate perception of the hazard. For example, placing line markings closer together on a curve may give drivers a sense of going faster than what they really are, inducing them to slow down to a manageable speed for controlling their vehicle through the curve. Other general roadway features, such as the appearance of the road shoulder, the apparent width of a lane, and various warning signs or TCD's, can set overall driver expectancy and influence hazard perception for a more extensive stretch of roadway. However, traffic engineers do not have a good understanding of the basic mechanisms of driver perception and how features of the roadway can be enhanced to increase driver awareness of hazardous operating conditions.

Objective: Two studies are proposed that have parallel objectives. The purpose of the first study is to identify physical characteristics of innovative pavement markings, TCD's, or other roadway features that could augment a driver's immediate perception of hazards for specific roadway sites. Such research should be sensitive to individual characteristics that may interact with the operating environment to affect the driver's perception of roadway markings. The objective of the second study is to identify general characteristics of roadway appearances and TCD's that may influence a driver's expectancy of hazard for a larger section of roadway. Once a basic understanding of driver perception of the roadway environment is identified, the most effective countermeasures to enhance the perception of hazards for various traffic situations can be recommended.

Scope: The investigation should include freeways, arterials, and two-lane roads for urban, suburban, and rural locations. The entire range of drivers should be encompassed with meaningful numbers of young (< age 21) and older (> age 65) drivers. However, special attention should be directed towards any subset of those drivers whose perceptual capabilities may be noticeably different from the normal driving population.

This program area consists of two studies with overlapping issues. Consideration should be given to conducting these studies in a parallel manner and time sequence. The planned duration for conducting both studies within the entire project is 3.5 years.

The scope of Study 1 is limited to the investigation of a driver's direct, immediate perception of hazardous roadway elements. This should include consideration of all highway elements that have significant hazard potential, such as curves, bridges, intersections, grade crossings, and so forth. The scope of Study 2 encompasses the types of general roadway features that may influence overall driver expectancy for a variety of features. It addresses sections of roadway that may have multiple hazards, such as curve sequences, driveways with entering vehicles, poor sight distance, and so forth.

The products of this project are guidelines, specifications, and warrants for the use of innovative techniques to directly modify the driver's perception of hazardous sites, as well as modifications to roadway appearance in a broader sense that will influence general driver expectations about potential hazards for an upcoming section of roadway.

Anticipated Tasks/Methodology:

Study 1: Perceptual Treatment of Highway Element

Task 1: Identify roadway markings currently used to enhance perception of potential hazards. Conduct a comprehensive review of current practices specifically designed to draw a driver's attention to immediate potential hazards at specific site locations. For example, current practice might be related to items such as placing line markings closer together on a sharp curve, or a unique lighting pattern created by a series of TCD's. The review should include an index or measurement of the incidence and effectiveness of these treatments. Both domestic and foreign practices should be included in this review since some current foreign practices have already been reported to be effective. Current practices may be identified by a review of traffic engineering manuals or other relevant documentation. Contacts with local, state, and federal highway agencies should also be made.

Task 2: Conduct literature review of relevant driver variables. Review literature relevant to human sensation, perception, and information processing that might have implications for driver perception of hazardous roadway elements.

Task 3: Identify and prioritize specific site locations that could benefit from perceptual enhancement improvements. Roadway locations that could benefit from new or additional markings should be identified on a site-by-site basis. Priority should be given to sites with high accident rates. A quantification or estimate of benefits resulting from potential improvements to that site should be a part of the analysis.

Task 4: Identify innovative methods or candidate treatments to enhance driver recognition. Based on the findings from Tasks 1 and 2, propose alternative treatments that might enhance driver hazard perception at the specific site locations identified in Task 3. The rationale for the candidate treatments should be based on: (1) how the physical characteristics of the treatment may be manipulated to enhance hazard perception for that site; and (2) order of magnitude of safety implications.

Task 5: Develop research plan. Based on the findings of Tasks 1 through 4, develop a research plan to collect data on the perceptual characteristics of the most promising candidate treatments that might further enhance a driver's immediate perception of hazardous roadway elements. A series of controlled investigations, including traditional laboratory studies, on-road instrumented vehicles, test tracks, or driving simulators, should be used to investigate these effects.

Task 6: Implement Task 5 research plan. Conduct the controlled investigations as defined in Task 5. The outcome of this research should be an indication of the relative degree of effectiveness of the proposed treatments compared to current practices.

Task 7: Conduct field evaluation studies of candidate treatments. Implement the recommended treatments at the specific site locations identified in Task 3. Gather field data to assess the degree to which results from the controlled investigations are applicable to those treatment sites. The effectiveness and safety benefits of the proposed roadway improvements should be compared to the adequacy of current practices.

Task 8: Design guidelines, specifications, and warrants based on laboratory and field test results. Develop recommendations for roadway improvements, operational practices, and warrants for implementing additional design requirements. These guidelines should describe specific solutions for the problem sites identified in Task 3 and other sites with similar features, such as a sharp curve in the roadway or an intersection with high accident rates. Common characteristics shared among multiple-site treatment improvements should be identified so that similar treatments can be applied to other sites.

Task 9: Prepare draft reports. Document research procedures and findings in a draft research report.

Task 10: Prepare final reports. Based on FHWA review comments, finalize the draft documents.

Study 2: Modification of Driver Expectancy Through Manipulation of Roadway Feature

Task 1: Review current practices. Conduct a review of current practices, including domestic and foreign practices, relevant to altering general roadway appearances that attempt to influence driver expectancy about a segment of roadway. For example, current practice may be to alter the appearance of the texture of the roadway shoulder so that drivers may exert more caution while traveling that portion of the roadway. Current practices may be identified by a review of traffic engineering manuals or other relevant documentation. Contacts with local, state, and federal highway agencies should also be made.

Task 2: Conduct literature review of relevant driver and roadway variables. Review literature relevant to human sensation, perception, and information processing that might have implications for general driver expectancy of potential hazardous operating conditions. Roadway variables that influence subjective perceptions of risk or hazardous operating conditions should also be included in this review.

Task 3: Determine candidate roadway situations that could benefit from perceptual enhancement treatments. General roadway types that could benefit from new or additional treatments should be identified. Priority should be given to roadway types having high accident rates. Quantification of benefits associated with each improvement should be a part of this analysis.

Task 4: Identify innovative methods that may enhance driver expectancy of potential hazard. Based on the findings from Tasks 1 and 2, identify key operational parameters that relate to driver expectancy of hazard for various roadway types. Propose alternative treatments that might enhance driver hazard perception for the roadway types as identified in Task 3. The rationale for the candidate treatments should be based on: (1) how the physical characteristics of the treatment may enhance driver expectancy of hazardous operating conditions; and (2) order of magnitude of safety implications.

Task 5: Develop research plan. Based on the findings of Tasks 1 through 4, develop and implement a research plan to collect data on features of the most promising candidate roadway treatments that might enhance driver expectancy of hazards for situations identified in Task 3. A series of controlled investigations, including traditional laboratory studies, on-road instrumented vehicles, test tracks, or driving simulators, should be used to investigate these effects.

Task 6: Implement Task 5 research plan. Conduct the controlled investigations as defined in Task 5. The outcome of this research should be an indication of the relative degree of effectiveness of the proposed improvements compared to current practices.

Task 7: Conduct field evaluation studies of candidate treatments. Implement the recommended treatments using on-road investigations for roadway types identified in Task 3. Gather field data to assess the degree to which results from the controlled investigations are applicable to actual roadway settings. The effectiveness and safety benefits of suggested roadway improvements should be compared to the adequacy of current practices.

Task 8: Design guidelines, specifications, and warrants based on laboratory and field test results. Develop recommendations for roadway improvements, operational practices, and warrants for implementing additional design requirements. These recommendations would serve as guidelines for traffic engineers to assist them when designing roadway systems for general operating conditions.

Task 9: Prepare draft reports. Document research procedures and findings in a draft research report.

Task 10: Prepare final reports. Based on FHWA review comments, finalize the draft documents.

Manpower: The estimated person-hours to complete the project are presented in the following table.

STAFF CATEGORY	HOURS	HOURS
	STUDY 1	STUDY 2
Sr. Human Factors Psychologist	500	400
Jr. Human Factors Psychologist	1,000	1,000
Sr. Traffic Engineer	500	400
Jr. Traffic Engineer	1,000	1,000
Statistician	150	150
Technician	2,000	2,500
Other	200	200
Total	5,350	5,650

Potential Benefits/Payoff: The final outcome of this program area is to provide guidelines for improved traffic engineering design and operational practices that enhance driver perception of potential hazards. More effective modifications to specific roadway sites and general practices of roadway treatments that capitalize on driver perception can be implemented to promote safer traffic operations.

APPENDIX A

LISTING OF EXPERT PANEL MEMBERS

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