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This report details a project to study the relationship between highway design and human behavior as influenced by roadside environments.

In a visualization phase, computer simulation modeled an actual segment of urban highway planned for reconstruction in Tofte, Minn. Using a driving simulator, project design team members test drove the highway reconstruction project and evaluated the planned elements. In an experimentation phase, researchers tested drivers' responses to different design scenarios to identify the architectural and aesthetic elements with the greatest potential for calming or slowing traffic.

Results indicated that the visualization phase increased communication among project team members and state agencies, facilitated problem identification-resolution strategy development, and contributed to decision making concerning potential design options and design elements. Data also indicated that white pavement treatments produced desirable traffic calming effects. Analyses of drivers' speed patterns indicated a consistent speed profile, characterized by both decreases and increases in speed. The report concludes with recommendations for the expanded use of visualization in general, and the implementation of white pavement treatments in the target reconstruction project specifically. It also recommends further consideration of landscape architecture treatments.

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Investigating the Effects of Roadway Design on Driver Behavior: Applications for Minnesota Highway Design

Final Report

Prepared by

Stephen Scallen, Ph.D.

Human Factors Research Laboratory
School of Kinesiology
University of Minnesota

John Carmody

College of Architecture and Landscape Architecture
University of Minnesota

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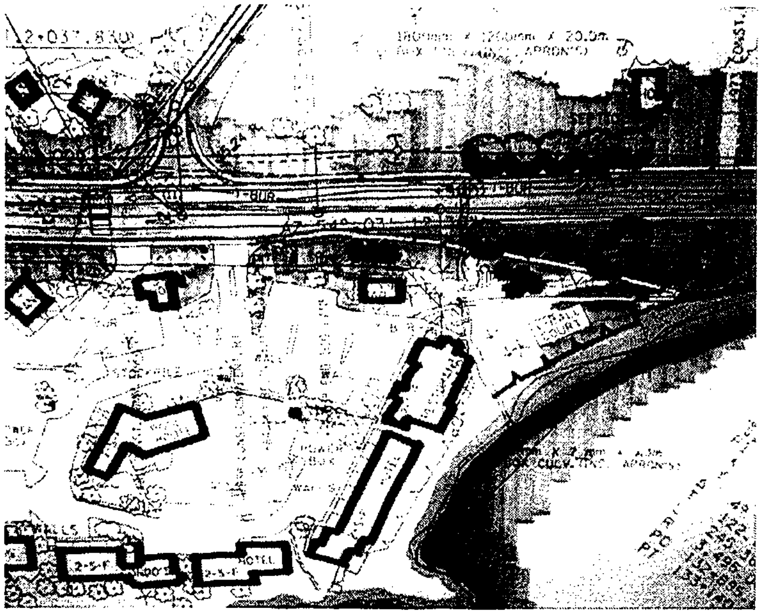

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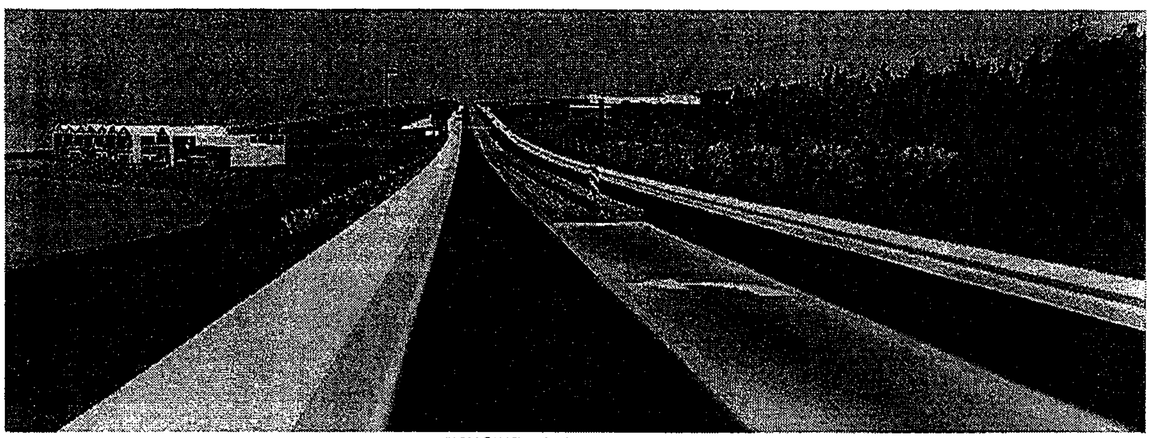
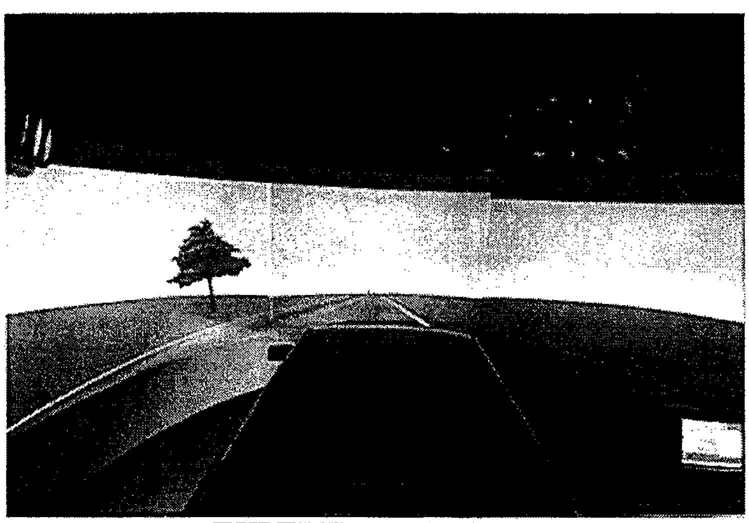


VISUALIZATION



EXPERIMENTATION

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EXECUTIVE SUMMARY

This report details a project to study the relationship between highway design and human behavior as influenced by roadside environments. The project was developed in two phases. In the visualization phase, computer simulation was used to model an actual segment of urban highway planned for reconstruction in Tofte, Minnesota. Using a driving simulator, project design team members could test drive the highway reconstruction project and evaluate the planned elements. In the experimentation phase, drivers' responses to different design scenarios were tested, so that architectural and aesthetic elements having the greatest potential for calming or slowing traffic could be identified. Results from the visualization phase indicated increased communication among project team members and state agencies. Interactive visualization also facilitated problem identification, resolution strategy development, and decision making concerning potential design options and design elements. Results from the experimentation phase indicated that white pavement treatments produced more moderate speeds and larger speed change, a desirable traffic calming effect. Data also indicated that landscape architecture treatments on the medians and road edges can also produce desirable effects in drivers' choice of speeds, although effects were inconsistent. The presence of lighting poles did not contribute to traffic calming. Analyses of drivers' speed and speed change patterns also indicated a consistent speed profile, characterized by marked decrease in speed until the third island, after which speed increased steadily. The report concludes with recommendations for the expanded use of visualization in general, and the implementation of white pavement treatments in the target reconstruction project specifically. Landscape architecture treatments were also recommended for further consideration.

INTRODUCTION

There are a number of roadway settings where drivers must adjust their speed and alignment in response to changing driving environments. These places often represent the locations where the greatest safety hazards and accident rates occur. One example is a town located on a trunk highway, where drivers are required to reduce speed as they transition from higher travel speeds in rural environments to lower travel speeds in urban environments. Normally, road signs are used as the main visual information to influence the driver. However, the elements of the roadway environment (e.g., paving materials, furniture and fixtures, signs and markings, color, planting, lighting, etc.) also give visual cues about speed and alignment.

This report details a visualization and research project designed and coordinated by the Human Factors Research Laboratory (HFRL), University of Minnesota, in association with the Minnesota Department of Transportation (Mn/DOT) to study the relationship between highway design and human behavior as influenced by roadside environments. This project used a wrap-around driving simulator developed by the Human Factors Research Laboratory to test driver responses to roadside patterns and environments. Computer simulation was used to model an actual segment of urban highway (TH 61) planned for reconstruction in Tofte, Minnesota. Models were then loaded into a driving simulator and driver performance was monitored in a controlled experiment. The experiment tested various roadway design options developed by Mn/DOT to reduce the negative impact of car traffic on the municipality with an emphasis on speed reduction and urban space enhancement.

The project was developed in two phases. In the first phase (visualization), an interactive and representative driving simulation of the planned highway construction was developed. Project design team members could test drive the highway reconstruction project and evaluate the planned elements. Additional test drive scenarios were also developed, representing potential design changes. In the second phase (experimentation), drivers' responses to different design scenarios were tested, so that architectural and aesthetic elements having the greatest potential for calming or slowing traffic could be identified. Thus, the conclusions of this report address the relationship between highway engineering, behavioral science and aesthetic design, and how attention to pleasing aesthetic solutions, together with functional and economic considerations, can satisfy the broader requirement of promoting greater highway safety and improving quality of life.

These highway visualization and experimentation initiatives represent the first use of the HFRL driving simulator as part of the Mn/DOT highway design process, thereby allowing designers to visualize the project and 'test drive' various design options before completing plans and construction documents. The project is a significant undertaking because the highway design solutions tested were themselves both innovative and experimental. As Mn/DOT designers learned more about their specific project, University researchers broadened and refined their skills and research methods created by engaging in the study process. Ultimately, both Mn/DOT and the University will validate the research and development process by participating in a field test which is planned following completion of the actual highway construction project.

PROJECT TEAM

Mn/DOT Project Design Team

Rod Garver – TH61 Corridor Manager
Pat Huston – Project Design Engineer
Duane Hill – Project Development Engineer
Dave Pickett – District Traffic Engineer
Gary Mueller – Project Landscape Architect

Mn/DOT Project Oversight Team

James Reierson – Site Development Unit Manager
Dennis Moline – Visualization Unit Manager
Ronald Casellius – Research Program Administrator

University of Minnesota Visualization and Experimentation Development Team

John Carmody, College of Architecture & Landscape Architecture
Steve Scallen, Director of Research Operations, Human Factors Research Laboratory
Jim Klinge, Laboratory Engineer, Human Factors Research Laboratory

Peter Easterlund, Real-Time 3D Applications Developer, Human Factors Research Laboratory

Janelle Monette, Graduate student, Human Factors Research Laboratory

HIGHWAY PROJECT DESCRIPTION

To facilitate the vision of a safer Lake Superior North Shore Highway 61 route, the Minnesota Department of Transportation (Mn/DOT) has prepared a comprehensive development plan, which is now in various stages of refinement and implementation. This plan, which carefully and respectfully guides more than $66 million of highway improvement investment, addresses both highway safety and roadside aesthetics, consistent with the needs and expectations of the highway users and the communities through which the road passes. One such community, which is also at the center of this research project, is Tofte, Minnesota.

Both existing and proposed trunk highway 61 (TH61) bisect the municipality of Tofte, which is centrally located within an 80 mile stretch of road regarded as the key economic and social lifeline connecting Minnesota's arrowhead region with the rest of the state, nation and Canada. Like most other cities and towns located along this route, Tofte developed largely because of the presence of the trunk highway, although development occurred in the absence of a strong planning focus, a situation that both Mn/DOT and Tofte were anxious to change.

At meetings hosted by Mn/DOT, the local community voiced its desire for safe roads, especially with respect to the high rates of speed for pass-through traffic. Residents were also concerned about the effect that the proposed highway project would have on the community, or rather, the loss of community. Like many other communities, including those along this highway route, the citizens of Tofte wanted to protect their unique, vibrant community from the permanent destruction of highway expansion and the invasive behavior of traffic which long has dominated this route. Thus, the local community expressed a desire to explore all options and techniques related to slowing pass-through traffic, collectively known as 'traffic calming'.

Traffic calming is a form of traffic planning that seeks to equalize the use of streets and roads among automobiles, pedestrians, bicyclists and playing children. Traffic calming is achieved through the use of devices and techniques that reduce traffic volume and speed while maintaining mobility and access. It is so new and antithetical to traditional thinking and planning that the techniques invite a certain amount of skepticism. In order to successfully implement traffic calming in a community, planners and engineers must look at the transportation system as a whole within the area or community affected. Thus, a focus on traffic calming provides opportunities to examine other highway design related issues that will have affect on the quality of life in a community. While traffic calming and context-sensitive planning approaches are becoming more widely accepted within planning and resident communities, traffic calming in a rural setting like the TH61 Highway Corridor is unique and will qualify the proposed highway redevelopment project as an important pilot project in the United States.

Among the design changes proposed for two-lane rural segments of the TH61 highway corridor are wide shoulders and adequate ditching added to provide for safe pullover and maneuver space and control highway drainage. In the urban segment of the route, through towns like Tofte where lower traffic speeds are required, a center turn lane and crosswalks will be added and narrower shoulders, curb and gutter and sidewalks will replace the wide shoulders and ditches. While the changes of the urban section are intended to improve traffic flow and increase safety, they also will change the psychological feel of the road. Alone, wide and straight stretches of paved roads say to a motorist, " Speed up. Drive faster". However, roads that look more like city streets, use paved strips or narrowed lanes and include furniture and landscaping, have a relaxed, pedestrian feel that say to the driver, " Slow down and beware, this is shared space." Properly implemented, traffic calming techniques can use the physical environment to alter the ways that drivers and all other users of the road 'experience' the route. Most importantly, drivers recognize the street or road as a shared place that has an identity or character, rather than as a channel designed for the singular focus of the automobile.

To accomplish the objective of reducing traffic speeds through Tofte while preserving and improving a sense of community, Mn/DOT landscape architects proposed a context-sensitive Design Opportunities Plan recommending both traditional and non-traditional design treatments and features. Among the traditional treatments were traffic medians with landscaping designed to create a gateway effect at the city entrances. The gateways were to be heavily planted with trees in a non-traditional way, to create a narrowing effect of the roadway environment. Another strategy involved the use of colored asphalt paving (using white rock in the bituminous mixture) to create the illusion of paved strips and/or narrowed lanes. While colored asphalt paving itself is not new, the intentional use of colored pavement to slow traffic represents a newly developed traffic calming strategy.

Because many of the ideas in the Design Opportunities Plan were based on new and cutting-edge philosophies, some of which had not yet been tested or implemented, Mn/DOT wanted demonstrated assurances for success prior to actual implementation. As a first step, Mn/DOT desired an opportunity to visualize the design proposal, including all planned applications and traffic calming measures. In addition to general questions concerning the effectiveness of traffic calming measures, the Project Design Team had a number of specific concerns about design elements of the proposed traffic calming plan, including:

- What effect will colored bituminous pavement have on driver behavior? Specifically, will white pavement contribute to speed reduction?
- What effect will median landscape treatments have on driver behavior? Specifically, will shrubs and bushes on the median and road edge contribute to speed reduction?
- What effect will vertical element have on driver behavior? Specifically, will lighting poles or trees placed at or near to the edge of the road contribute to speed reduction?
- Are any specific design measures more or less effective than others?
- What is the minimum degree of presence required for effectiveness?
- Are various designed elements too subtle to be noticed by drivers?

Answers to these questions framed the basis of the experimental effort.

RESEARCH PROJECT

The MN/DOT project team approached the Human Factors Research Laboratory, University of Minnesota, to explore questions about the potential effectiveness of the Design Opportunities Plan. John Carmody and Steve Scallen at the University had received a Mn/DOT grant through the Center for Transportation Studies, which was intended to assist Mn/DOT in exploring these kinds of problems. The Human Factors Research Laboratory provided the facility for studying these questions.

The project team worked with the University team to develop experimentation concerning the effectiveness of the proposed design. The 3 km urban section of Highway 61 through Tofte, Minnesota was selected for testing. Using the wrap-around driving simulator at HFRL, a computer model of the roadway was created and the effect of different design features on driver behavior were tested.

In the early development of the project, it became apparent that the interactive model, in conjunction with HFRL's driving simulators served two unique functions. First, as a visualization tool that enabled the team to better understand their design and communicate with each other about potential problems and design alternatives. Second, as a tool for testing driver behavior and predicting the effectiveness of different elements of the design. This dual role of the project, as a visualization tool and as an experimental test platform, is reflected throughout this report.

PROJECT PURPOSE AND GOALS

Visualization

The purpose of visualization is for the project team to envision the design options in a realistic computer simulation. General goals of the visualization are to facilitate increased communication among team members, contribute to efficient decision making on all aspects of project development, and to identify problems and issues and develop resolution strategies. Specific goals for the visualization initiative are:

- To develop a realistic interactive three-dimensional model of the planned construction project including roadway features, elevation features, and environmental features (e.g., local buildings)

- To provide team members opportunities to interact (drive) with the planned design and develop design alternatives based on the interactions.

- To provide rapid prototyping of potential design changes.

Experimentation

The purpose of experimentation is to quantify driver responses to the planned design in general and to particular design elements specifically (pavement treatment, landscape treatment, and lighting treatment). Particular emphasis is on the identification of potential design elements that will contribute to reduced and moderate driver speeds. General goals of the experimentation initiative are to identify design elements that contribute to safe driver behaviors, contribute to the selection of design elements to be included in the final design, and to explore the potential of human factors experimentation to contribute to highway design. Specific goals for the experimentation initiative are:

- To evaluate driver responses to presence of landscape treatments proximate to the roadway, specifically the presence of shrubs on the medians and shoulders.

- To evaluate driver responses to presence of pavement treatments on the roadway, specifically the presence lighter colored pavement in the center turn lane and shoulders.

- To evaluate driver responses to presence of lighting treatments proximate to the roadway, specifically the presence lighting poles at regular intervals along the roadway.

METHODS

VISUALIZATION

The project team selected the urban section at Tofte, Minnesota because it is an upcoming project with design features common to many other two lane roads passing through towns. The Mn/DOT Highway 61 corridor team in Duluth had developed the design to the point where road alignment and profiles were set. The Mn/DOT landscape architects in St. Paul had developed a design for Tofte that included traffic calming features.

The University team met with the Highway 61 corridor team and the landscape designers to clarify the design and create a computer model of the Tofte section of the highway. Developers at the Human Factors Research Laboratory used architectural design, engineering cross-sections of the Tofte area (detailing elevation changes), and photo surveys of area terrain and landmark structures to develop an initial three-dimensional model of the project. The team regularly reconvened to view and revise the computer simulation. This process was repeated several times until the model was a satisfactory representation of the roadway and surrounding environment.

This iterative process was not simply a means of making the roadway more realistic and faithful to the original design. It was also a design and communication tool for the team to evaluate their design intent, make assessments of their decisions, and make modifications to the original design. Several versions of the model were developed, representing a wide array of potential designs.

Once the team refined the model to a satisfactory level, the team selected the main traffic calming design features they wanted to evaluate. There were two overriding principles in selecting the scenarios. First, there must be a limited number of variables (2 or 3) resulting in 4 to 8 total scenarios. This is necessary to ensure that a single subject can drive a complete set of scenarios. Second, the design features selected for testing should represent significant, rather than subtle, variations. For example, in these initial rounds of testing, it was most efficient and useful to compare the presence or absence of trees and shrubs by the roadway rather than compare the size and shape of the shrubs. If there is any effect at all from trees and shrubs, then more detailed evaluations can follow. The team selected the following main variables to be tested in the Tofte urban section:

- The presence of white-colored asphalt (see Figure 1) in the center left turn lane and shoulders. Black color is standard (see Figure 2)
- The presence of shrubs (see Figure 3) on the median and close to the road edge at the town entrances and crosswalks. No landscape elements are standard (see Figure 4)
- The presence of light poles on both sides of the roadway (see Figure 5). The alternate is no poles (see Figure 6)