

Designing for People:

Unlocking Human Behavior to Build a Better Transportation System

Part 2 of 2: Incorporating Human Factors Principles Into Transportation Engineering Design

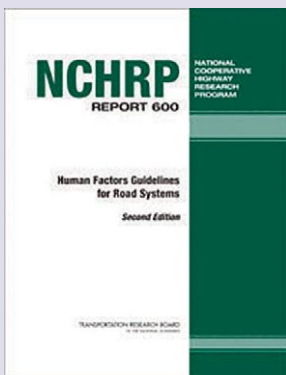
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Beginning in 2005, the National Motor Vehicle Crash Causation Survey (NMVCCS) collected on-scene information about events and factors associated with light vehicle crashes. An analysis of the data was performed by the National Highway Traffic Safety Administration (NHTSA) and found that the critical reason for a crash was assigned to the driver in 94 percent of the crashes. Recognition errors accounted for roughly 41 percent of the crashes, decision errors for roughly 33 percent, and performance errors for roughly 11 percent of the crashes.¹ With so many human-caused crashes with clear pathways to failure, it is apparent that transportation engineers understand user needs in order to best design a transportation system that is safe and efficient for all roadway users. Part 1 in this article series (published in the May 2016 *ITE Journal*) focused on the scientific discipline of human factors and outlined some human factors principles related to transportation, including examples of examining these principles in light of existing practices. This part 2 article continues the discussion and provides examples of applying human factors in transportation engineering and tools that practitioners can use to incorporate human factors principles when designing transportation projects.

Guidance Based on Human Factors Principles

One of the easiest things a practitioner can do to ensure that user considerations are incorporated into design is to become familiar with guidance documents where human factors principles held a major role in the document's development. The principal recent document that examines the application of human factors in transportation engineering design is the National Cooperative Highway Research Program (NCHRP) Report 600, the *Human Factors Guidelines for Road Systems* (HFG). This document addresses the needs, capabilities, and limitations of road users.

Human Factors Guidelines (HFG) for Road Users, Second Edition



From the Foreword:

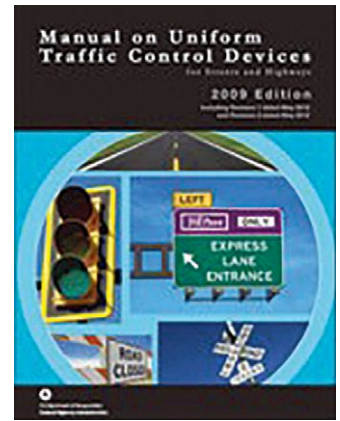
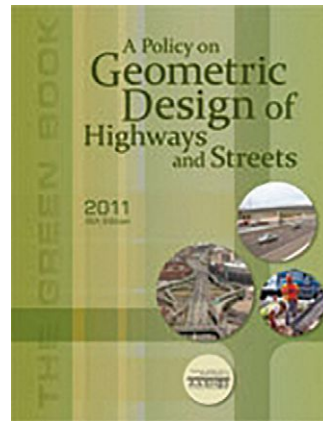
"The HFG provides data and insights from the scientific literature on the needs, capabilities, and limitations of road users, including perception and effects of visual demands, cognition and influence of expectancies on driving behavior, and individual differences including age and other factors. The HFG provides guidance for roadway location elements (e.g., curves, grades, intersections, construction/work zones, rail-

highway grade crossings) and traffic engineering elements (e.g., signing, changeable message signs, markings, and lighting)."

"... Each of the design guidelines in the HFG is presented using a consistent, highly structured format that is intended to maximize ease-of-use and interpretability. The guidelines focus on providing specific, actionable design principles, supported by a discussion and review of key research and analyses. Special design issues and considerations are included to help address design constraints and relevant trade-offs."²

In addition to the HFG, practitioners can use resources that address the design of traffic control devices and geometric design. *The Manual on Uniform Traffic Control Devices* (MUTCD) is published by the Federal Highway Administration (FHWA), and the long-standing guide, *A Policy on Geometric Design of Highways and Streets*, colloquially known as the "Green Book" for its color in recent editions, is published by the American Association of State Highway and Transportation Officials. While both of these books represent collaboration among geometric designers, traffic operations practitioners, transportation planners, and researchers, the MUTCD is a matter of Federal Regulation, being incorporated into Title 23 of the Code of Federal Regulations.

Other publications, such as the *Highway Safety Manual* (HSM), the *Roadside Design Guide*, and various NCHRP reports provide additional guidance that is rooted in research into crash causes and



The Manual on Uniform Traffic Control Devices and A Policy on Geometric Design of Highways and Streets are resources that practitioners can use in addition to the Human Factors Guidelines for Road Users to address the design of traffic control devices and geometric design.

corrective actions and human behavior, comprising decades of data. Many of these resources were designed to be complimentary and the foundation for other resources provided by practitioner organizations, including those published by the National Association of City Transportation Officials. For example, the HSM and the HFG were designed to complement each other and promote improved safety for highway users. The foreword to NCHRP 600 itself contains the statement: "The HSM can be used to develop possible design alternatives to improve safety on an in-service or planned intersection or section of roadway; the HFG can be used concurrently to identify design solutions or to enhance the alternatives suggested by the HSM." Additionally, it states, "Each should be used together; however, neither document is a substitute for national or state standards such as *A Policy on Geometric Design of Highways and Streets* (the AASHTO Green Book) or the *Manual on Uniform Traffic Control Devices* (MUTCD)."

Applying Innovative Concepts

When an engineer or planner addresses a design for a situation that has unique characteristics or one that incorporates new technologies, it is quite common for innovative concepts to be included in the design. Innovative concepts, by their very nature, have not been subjected to thorough research, unlike many existing standards, guidelines, and policies. Even heuristic evidence, while less likely to justify the inclusion of a traffic control device or design element into literature today, incorporates observations from other implementations of commonly-designed devices. While these novel concepts are evidence of the creativity and innovative thinking that competent transportation professionals bring to the table, the rigor of human factors research in simulations and in the field can justify the suppositions that practitioners must make when addressing a novel design with new approaches.

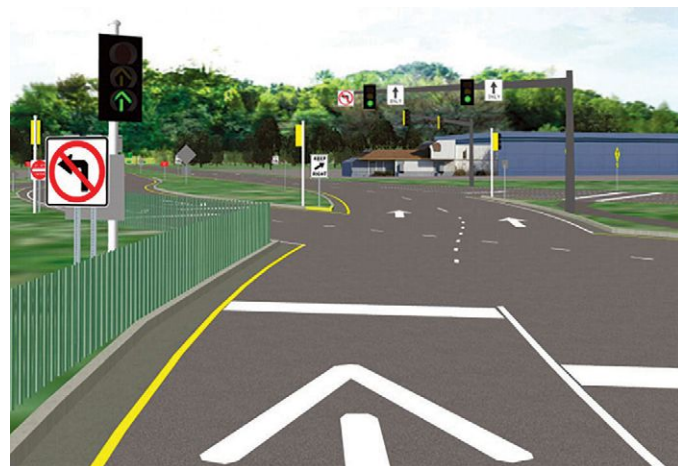
For example, various alternative intersection designs have been developed over the past 20 years that provide benefits such as increased capacity, reduced delay, and fewer conflict points. However, modeling a scenario in a traffic operations microsimulation program may not always produce the same results as when the concept is introduced in the field. In other words, concepts that show promise in increased mobility may not actually be inherently safe. The word “inherently” is carefully chosen because with careful thought and human factors research, the design may meet or exceed performance targets, since the needs of users will have been addressed in a consistent, deliberate manner. For example, while a new type of intersection may require additional traffic signs in order to provide enough information to motorists, the signs initially chosen by a designer may be inferior to other potential choices or even novel signing that has yet to be tested in a conventional population.

A superlative example of applying innovative concepts while incorporating human factors testing can be found in a study from 2007 evaluating a Diverging Diamond Interchange (DDI) in the FHWA Highway Driving Simulator.³ Researchers had already proven the operational benefits of the DDI, and the Missouri Department of Transportation (MoDOT) had developed plans for a proposed DDI at the interchange of Interstate 435 and Front Street near Kansas City, MO, USA. Although there were theoretical safety benefits of the DDI because of the reduced number of potential conflict points, the simulation built by FHWA allowed for MoDOT’s design to be driven by human subjects and carefully evaluated prior to the expense and effort of construction.

The visualization drive-through enabled engineers from MoDOT and FHWA to look at proposed locations of regulatory, warning, and guide signs, as well as signals and other traffic control devices. That team was able to identify potential issues regarding traffic control device conspicuity and sightline problems and make modifications to the plan accordingly. They even discovered that some revisions to signal placement led to unintended driver behavior. FHWA also conducted additional experimentation to determine how different signing and marking features influenced driver behavior and to see how unfamiliar drivers would navigate the interchange. More than 70 participants were recruited to participate in the study. Drivers generally had no issues navigating the DDI interchange, and the results showed a speed reduction for drivers in the DDI, when compared to traditional diamond interchanges. The study suggested that, where used, the DDI will provide safety benefits.

“But This is the Way We’ve Always Done It!”

Despite the apparent success of “heuristic analysis,” that is, analysis of what is existing and its performance, it is often critically erroneous to assume that because something has been done a



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Figure 1: Visualization of Diverging Diamond Interchange.³

certain way for a long time, it therefore works effectively. In some cases there may be truth behind such a theory, whereas in other cases, a careful look as to whether something *actually* works well is necessary. By itself, a traffic control device may function, but another as-yet-unused device may produce better results, or, perhaps, poorer results.

Traffic control devices in the United States are being evaluated as resources permit, to validate long-standing assumptions and provide additional information concerning various practices. In the Design and Evaluation of Selected Symbol Signs study and the follow-on Design and Evaluation of Selected Symbol Signs, Phase II, several signs included in the MUTCD across multiple editions showed very low comprehension scores even though the signs are used extensively across the United States and in other countries.^{4,5} Other signs performed quite well. In both studies, drivers were recruited to participate and were asked what the sign meant and/or what action they should take. Researchers then scored the responses for correctness; a comprehension score of around 85 percent is typically considered very effective while important regulatory or warning signs should likely score higher for consideration. A summary of a few of the signs is shown in Table 1.

Transportation professionals can sometimes be perplexed as to why certain design elements are not well understood by motorists even though the elements make sense to the designer or seem to have provided acceptable past performance. As an example of this, consider the object marker sign panel depicted in Table 1. It is intended to mark a hazard such that the approaching road user should steer to the left of the sign. The comprehension results from this study, however, do not support the supposition that this sign is understood by road users. There are other signs in Table 1 that exhibited similarly poor comprehension. After testing some existing signs against some potential alternatives, signs were developed that were well-understood by motorists and were legible enough to be

Table 1. Comprehension of Selected Symbol Signs

	Tourist Information	Object Marker	Electric Vehicle Charging Station	DO NOT ENTER	FLAGGER AHEAD
Sign					
Year Incorporated into the MUTCD	1978	1935	2003	1971	1978
Year Removed From the MUTCD, if applicable	2009	Still Included	Still Included	Still Included	Still Included
Comprehension Score	68%	24%	17%	100%	94%

seen from adequate distances. Some examples of replacement signs and new signs are depicted in Table 2.









The limitations of human factors testing however, generally considered cost and complexity, may be overlooked in the selection of devices to be tested. The sign warning motorcyclists of hazardous pavement conditions, for example, features a plaque mounted below the motorcycle. While this itself may have produced adequate results, a basic principle of signing practice was not upheld in the design, that being the use of a noun-verb order. In this case, the message of the sign is “MOTORCYCLISTS / USE CAUTION ON GROOVED PAVEMENT” and not “GROOVED PAVEMENT / MOTORCYCLES,” which is implied by the sign. Similar messaging related to “RIGHT TURNS” or “RAMP” plaques is employed in various states, where the idea of indicating applicability and then the condition is in use.

This speaks to the importance of addressing a wide variety of regional practices in testing in addition to testing populations from different regions, ideally using the same equipment and platforms.

When to Call an Expert

Many practitioners who work in transportation are required to take formal coursework in mathematics, statistics, chemistry, physics, geology, and other fields that are related to their work discipline. A transportation engineering or planning student does not become an expert in any of these subjects by taking the class; rather, the courses teach the aspiring engineer the fundamental concepts related to each area of study. If a geometric design designer wanted to procure a design for a bridge, that designer would likely turn to a structural engineer to assist with the design of the structural components of the project.

Table 1. Comprehension of Selected Symbol Signs

Sign	Tourist Information	School Bus Stop Ahead	Truck Parking	Wireless Internet	Motorcycle Warning
2003 MUTCD				N/A	N/A
2009 MUTCD					

Similarly, becoming familiar with human factors principles and reading human factors guidelines is not a replacement to working with scientists and engineers who have practical and research experience in human factors. Human factors expertise is particularly critical when a project involves innovative concepts where there is a lack of existing practice or policy.

Is your agency considering a novel device unfamiliar to the motoring public in your municipality, region, or country? Perhaps you might start by performing a relatively inexpensive study to determine if road users can identify the meaning of the sign or marking when compared to several alternatives. Next, a simulator study can help practitioners determine if road user reactions to signing and pavement markings are desirable, timely, smooth, and completed without undue hesitation. Following these initial analyses, the deployment of devices and systems of devices exhibiting good comprehension and suitable road user reactions is appropriate, with a Request for Experimentation from FHWA or your country's corresponding administrative regulatory body. This deployment is the foundation of field tests to confirm that user response in the real world is appropriate and consistent with research. This entire process, from concept development to the final report on field test comparisons between devices, is designed to protect your professional credibility and optimize operations while promoting safety.

Some organizations employ human factors personnel (including those described in Part 1) as key experts, integral to their policy teams. In some larger departments of transportation, human factors experts hold significant roles in safety or research offices. Universities and specialized consulting firms employ human factors experts who provide specialized skills, often in multi-disciplinary teams. Facing a challenging implementation of a novel traffic control device is not a task that traffic engineers must face alone. Rather, the human factors experts in transportation engineering or a closely-related field are allies in solving these problems in a changing world. Working closely with your team and understanding your objectives, they can help you evaluate new approaches to solving traffic operations and safety problems. They can provide you with relevant results that justify new concepts and improve on concepts that have already been developed. Human factors professionals can provide you with the data and analysis you need to justify your experience and intuition! **itej**

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