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TRB
Transportation Research Board

August 14, 2000

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Program Manager, Operations
Director, ITS Joint Program Office
Federal Highway Administration
400 7th Street, S.W.
Room 3401
Washington, D.C. 20590

Dear Dr. Johnson:

The Committee for the Review of the Intelligent Vehicle Initiative (IVI) held its third meeting on May 18–19, 2000, in Woods Hole, Massachusetts. The enclosed committee roster indicates the members in attendance.

The purpose of the meeting was for the committee to continue carrying out its charge of reviewing the IVI program and to prepare this second of three letter reports. The agenda was organized to help provide the information needed to address the four key questions raised by the U.S. Department of Transportation (DOT) program sponsor at the outset of the study:

1. For the amount of money DOT can invest in this research effort, is the government doing the right things? Is DOT investing its money and human efforts wisely?

2. Is the planned human factors research enough? Is it appropriate?

3. What proportion of effort should be invested in nonpassenger (i.e., truck, bus, and specialty) vehicle platforms?

4. Is DOT's relationship with the industry appropriate?

Before turning to these questions, I would like to extend the committee's thanks to the DOT staff for their responsiveness in providing much of the information requested in the committee's interim letter following the second meeting. Since that meeting, several committee members have engaged in follow-up activities. The chair met with Raymond Resendes, the IVI Program

Manager, on February 28, 2000, to discuss general programmatic issues and concerns. In addition, human factors experts Thomas Sheridan and Alison Smiley met with DOT program staff (Raymond Resendes and August Burgett) on January 11, 2000, to discuss the role of human factors in the IVI program; contacted seven of the key human factors experts at DOT by telephone to discuss their role and the extent of their involvement in the program; and held a conference call with DOT program staff and the committee chair on March 29, 2000, to discuss remaining issues. The committee extends its appreciation to Raymond Resendes and August Burgett, who prepared a point-by-point response to follow-up questions raised by both the committee chair and the human factors experts.

The committee would also like to thank the invited speakers who participated in the meeting. Robert Ervin provided a thoughtful framework for consideration of human factors issues in the development and deployment of IV driver assistance technologies. William Gouse, Nicholas Rini, Guy Rini, and Kate Hartman (moderator from the IVI program staff) engaged in an informative roundtable discussion of the program's heavy truck Generation 0 partnerships.[1] Finally, William Gardner and Max Donath described the program's specialty vehicle Generation 0 partnership and its potential application to other vehicle platforms. With these briefings and that on the GM/Delphi-Delco light vehicle Generation 1 partnership presented at the Toronto meeting, the committee has completed an examination of each of the current IVI partnerships.

This letter report presents the consensus findings and recommendations of the committee (highlighted in bold). **In summary, the committee recommends that DOT broaden the strategic vision and mission of the IVI program to focus greater attention and more resources in the future on evaluation of safety impacting technologies.[2] As indicated in the committee's previous letters, DOT should acknowledge the rapid pace of deployment of information technology in passenger vehicles and the need to evaluate the effects on driver safety. The committee does not intend to suggest that DOT should sharply reduce its current focus on safety enhancing technologies. Rather, the committee believes that over time, more recognition should be given to the evaluation of safety impacting technologies and more resources deployed for this purpose than is the case under the very limited current effort. This more balanced approach would**

[1] DOT has developed a classification system of vehicles with increasing levels of capability to address each problem area. Generation 0 systems, the least complex, are expected to enter production planning by 2003; generation 1 systems by 2008; and generation 2 systems by 2012.

[2] DOT has categorized IV technologies from the point of view of design into two categories—safety enhancing and safety impacting. Safety enhancing technologies, which represent the major focus of the IVI program, are directed specifically toward enhancing driver performance through such means as forward collision warning systems, automated cruise control systems to maintain adequate vehicle headway, and night vision enhancement systems (JPO 1999a, 4–7). Safety impacting technologies, by comparison, are those aimed primarily at providing convenience or comfort (e.g., route guidance and navigation systems, cellular telephones, in-vehicle computing) whose use may affect driver attention and workload, and hence safety (JPO 1999a, 7).

require a modified federal role, stronger industry ties, and a greater emphasis on human factors.

The sections that follow provide the reasoning behind the committee's recommendations, and include responses to each of the four key questions previously outlined (though not in the order in which they were listed). The first section explains the need to broaden the vision and mission of the IVI program and responds to question 1 concerning program direction. The next three sections, respectively, cover the changes necessary to achieve this shift in focus as noted above. The second section addresses modifying the federal role and responds, in part, to question 4 on DOT's relationship with industry. The third section deals with strengthening the industry connection; it, too, responds to question 4 and also to question 3 on allocation of resources among platforms. And the fourth section presents the committee's views on the need for a greater focus on human factors in the IVI program, thus responding to question 2. The final sections offer some suggestions regarding the reporting of program progress and briefly describe the committee's next steps.

BROADENING THE IVI PROGRAM STRATEGIC VISION AND MISSION

DOT views its role in accomplishing the primary stated mission of the IVI program—a significant reduction in motor vehicle crashes—as one of facilitating and encouraging industry's rapid deployment of vehicle-based safety enhancing technologies, such as collision warning systems, that can assist the driver in avoiding crashes (JPO 1999a, 2). When this vision was conceived at the outset of the IVI program, it was consistent with the relatively slow introduction of new IV technology at that time, particularly by the automobile manufacturers. This environment required a proactive federal role in which DOT would orchestrate a logical sequence of public–private activities based on the assumption that research on and operational tests of IV technologies would precede and help hasten their deployment in the marketplace. Thus, the primary thrust of the IVI program and the vast majority of its resources (more than 90 percent) are focused on facilitating the development of such safety enhancing technologies. Figure 1 shows the committee's conception of the various elements of the IVI program.

Since the program's inception, the environment in which it operates has undergone a dramatic change. Many safety enhancing devices are now appearing on automobiles or are in development (e.g., night vision systems, advanced cruise control, back-up obstacle warning systems, driver alertness warnings), which suggests that vehicle manufacturers now recognize the marketability of such devices. In addition, the automobile industry has fully embraced the revolution in information technology and is rapidly working to deploy navigation systems, fax machines, Internet access, and even "infotainment" systems on passenger vehicles. As previously noted, these safety impacting technologies are directed mainly toward customer convenience and comfort rather than safety per se. However, their

introduction is likely to have a profound impact on safety, both directly as the proliferation of technologies affects driver workload and attention, and indirectly as the technology may introduce unintended safety consequences. A minor part of the overall IVI program mission and a correspondingly small portion of the current IVI program budget are devoted to evaluating these safety impacting technologies (see Figure 1). In the committee's judgment, this level of investment is hardly commensurate with the rapid pace of deployment of these technologies.

The committee recommends that DOT (1) broaden the strategic vision and mission statement of the IVI program to acknowledge the rapid pace of deployment of information technology in passenger vehicles, and (2) focus greater attention and resources on evaluation of these safety impacting technologies. This does not mean that DOT should eliminate or even sharply reduce its work on safety enhancing technologies, but that it should shift the program toward a more balanced deployment of resources and incorporate work on safety impacting technologies as a more integral part of the program.

The committee also encourages DOT staff to develop a graphical representation of the basic elements of the IVI program. The complexity of the program, with its many different vectors of analysis (e.g., problems, platforms, generations), makes it difficult to grasp the core elements. A simplifying diagram would provide a vehicle for communicating the essential program elements and their interrelationships. Figure 1 presents such a simplified diagram, but the committee recognizes that it may require modification by DOT staff to reflect the broadened and more integrated strategic vision recommended in this report.

MODIFYING THE FEDERAL ROLE

DOT should focus more attention and resources on evaluation of safety impacting technologies through monitoring, coordination of research, and development and validation of evaluation protocols and tools. Doing so would enable DOT to represent the public interest, helping to ensure that the electronic systems and information technologies that are rapidly appearing in automobiles do not have adverse affects on or unintended consequences for safety.

Monitoring. DOT should monitor the effects on safety, both domestically and abroad, of the deployment of IV technologies not necessarily intended for safety.[3] An enhanced monitoring function is critical so that DOT can remain current in its understanding of these technologies and participate

[3] Of course, DOT should also monitor the effects on drivers and driving of safety enhancing technologies. Although their intent may be to enhance safety, these technologies may not fully achieve this goal, or may have unintended safety consequences.

with industry in the development of realistic tools for evaluation of their safety effects (as discussed in greater detail below).

Coordination of Research. DOT should more aggressively catalog, coordinate, synthesize, and document lessons learned from ongoing and prior research related to the development of appropriate technology evaluation tools (e.g., for measuring workload and human performance and attentional demands) and to safety outcomes (e.g., studies on the effects of in-vehicle use of cellular telephones on driver visual search, vigilance, and reaction times). A logical place to start is with relevant research of the agencies participating in the IVI program—the National Highway Traffic Safety Administration, the Federal Highway Administration, and the Federal Motor Carrier Safety Administration. The net should be more broadly cast, however, to include university research, as well as research sponsored by such organizations as the Society of Automotive Engineers. Salient research in other fields, such as aviation, should also be accessed and synthesized.

Development and Validation of Evaluation Protocols and Tools. DOT, working with industry, should take the lead in the development of appropriate protocols and evaluation methods and techniques that can be used by industry to provide an "early alert" of potential safety problems. Ideally, use of such tools should occur before technology deployment (i.e., in the design phase and in operational tests), but this may not always be possible given the rapid pace of commercialization of IV technologies. In addition, with DOT taking the lead, protocols should be developed and evaluation undertaken after commercialization, when the technology has adequately penetrated the market, and sufficient on-road experience makes it possible to undertake the difficult task of linking technology performance with crash data.

In considering this proposed broadened mission, DOT must examine whether it has the necessary resources to accomplish the above functions. The committee recognizes that the IVI program cannot single-handedly evaluate the effects of the information technology revolution on automobiles. However, DOT can redeploy more of its future program funding toward these activities. Moreover, a more compelling strategic vision that reflects the realities of the marketplace, together with a clear federal role in the public interest, may give the IVI program greater visibility and result in increased congressional appropriations to support the expanded vision.

STRENGTHENING THE INDUSTRY CONNECTION

Properly addressing the effects of safety impacting technologies will require DOT to strengthen its connection with industry, particularly the automobile manufacturers and first-tier suppliers. As previously mentioned, strengthening these ties is critical both for monitoring activities and for the development of realistic technology evaluation protocols and tools.

The desired association with industry may be easier to achieve if the federal role is modified as proposed above than if DOT is operating in its primary IVI role as technology facilitator, for the following reasons. First, if the major functions of DOT with respect to safety impacting technologies are monitoring, coordination of research, and development of protocols and tools, all of these functions can be defined as precompetitive activities. Such activities involve few issues of intellectual property rights or problems of sharing privileged data among industry competitors, which are of greater concern in the case of technology development and testing. Second, industry has an incentive to participate with government in dealing with potential safety issues that could arise from the rapid deployment of IV technologies. The automobile companies and suppliers perceive the need for a seamless, car-based communications system, and many recognize that rushing to commercialization without adequate consideration of driver overload and distraction risks government regulation (Moran 2000, 79).

Finally, DOT has a mechanism—the enabling research consortium of six partners,[4] which is in the final stages of negotiation—that offers a model on which to base the desired relationship with industry. One of the proposed research projects—development of a laboratory-based workload evaluation tool to assess the effects of advanced in-vehicle technologies on drivers' visual and cognitive functions—is a good example of a useful precompetitive evaluation tool that could be developed collaboratively in a partnership arrangement. **The committee recommends that DOT move expeditiously to finalize arrangements for the enabling research consortium, use this model to develop other "win–win" projects with industry, and expand the partnership to include first-tier suppliers.**

In its focus on strengthening ties with the automotive industry, the committee has not ignored the existence and potential of the other three vehicle platforms. The briefings provided at the meeting by the lead partners in the Generation 0 field operational tests for heavy duty and specialty vehicles described valuable work.[5] Some of the technologies address safety problems (e.g., heavy truck rollover) that are relevant only for a specific platform. Others (e.g., enhanced visibility systems for snowplows and emergency vehicles) appear to have potential for other platforms. However, until that potential is better understood, the committee cannot judge whether the allocation of resources to nonpassenger vehicle platforms is appropriate.[6] **The committee urges DOT to increase its efforts to examine the results of field operational tests on nonpassenger vehicles for information on**

[4] The six partners, which include Daimler Chrysler, Ford Motor Company, General Motors, Nissan, Toyota, and Navtech (a digital map database supplier), submitted an unsolicited technical proposal to DOT on August 13, 1999 (JPO 1999b).

[5] There is no transit Generation 0 field operational test, but several transit Generation 1 projects are in process (JPO 2000a).

[6] According to DOT calculations, 63 percent of the fiscal year 1998–2000 IVI program budget is directed toward the light vehicle platform (JPO 2000b).

technologies and approaches that could be generalized to nonprofessional drivers.

INCREASING THE FOCUS ON HUMAN FACTORS

The rapid pace of IV technology deployment in the marketplace makes it more critical than ever to address difficult human factors issues properly.[7] **Human factors research must have a central role in the IVI program with respect to both safety impacting and safety enhancing technologies. The committee believes the current effort is inadequate despite the commitment to human factors expressed in the IVI Business Plan**.[8]

The committee perceives two fundamental problems with the current effort. First, there appears to be no comprehensive view of how human factors issues are to be integrated into all stages of the IVI program. DOT staff provided a useful handout at the meeting on all current projects in the human factors area (JPO 2000b). The effort, however, is scattered, with many small projects and little strategic sense of how those efforts fit together to address key issues that cut across many of the technologies, or how they might feed back into technology design or redesign. Second, as a related concern, the committee notes the absence of a senior manager with a strong human factors background as part of the IVI program management team who can provide the necessary vision and leadership in this area.

The committee therefore recommends the addition of a senior manager in human factors research to the IVI management team. This individual would have lead responsibility within DOT for management of the enabling research consortium, including successful development of the workload evaluation tool and the advancement of other such projects. In addition, the new manager would have broad responsibility for overseeing human factors research within other critical IVI projects to ensure that each has an adequate human factors foundation and that appropriate human factors personnel and research in other agencies are tapped. This broader, cross-cutting responsibility would involve at least two tasks. The primary task

[7] Human factors is an interdisciplinary field of study that attempts to apply experimental findings from behavioral and life sciences to the design of machines, operations, and work environments so they match human capacities and limitations (Chapanis 1959, vii). The aim of human factors research is to optimize the human–machine interface in order to reduce human error and accidents and increase comfort and efficiency. Human factors research is also concerned with behavioral responses to system complexity, for example as associated with increased automation. Too much automation can lead to operator complacency and inattention. On the other hand, when automation fails or acts in unanticipated ways, or when the normally required human sensing and control actions are too numerous or too complex, the operator can be overwhelmed.

[8] The IVI Business Plan identifies as a "major part of the program . . . the study of human factors and how they relate to driver performance . . . to create the systems approach to vehicle-based safety improvements" (JPO 1999a, 12). A predecessor study to the IVI program (TRB 1998, 2) urged that "human factors considerations [be] thoroughly integrated into program plans and [be] prominent at all stages of research, development, and deployment." (More information about this study can be accessed on the web at http://www.nationalacademies.org/trb/publications/sr253.html.)

would be to articulate a general approach for the evaluation of IV technologies and systems prior to specific product design and testing that would anticipate some of the key overarching human factors problems. Another task would be to ensure that information from the planned field operational tests related to human factors is fed back into technology design, development, and deployment. **The committee identified at least four overarching human factors issues that merit more attention.**[9]

Integration of Technologies. Integration of the various advanced technologies and information systems rapidly being deployed in diverse vehicle makes and models is a key concern from a human factors perspective. How can devices such as cell phones, heads-up displays, navigation systems, and collision warning systems best be designed to sequence the information and communicate it to the driver in ways that minimize misunderstanding and give priority to more critical safety messages? How can current and future technologies be developed with sufficient operational commonality so that drivers can shift from one vehicle type and model to another with minimal confusion? DOT currently has one small project ($250,000) at Oak Ridge National Laboratory that deals with the integration issue of message priority, but this effort is insufficient relative to the magnitude of the problem.

Driver Attention and Distraction. Related to the integration issue is the concern that the improved situational awareness provided by driver assistance technologies not come at the expense of diverting driver attention from core driving tasks or, conversely, reducing mental effort to the extent that the driver becomes complacent or inattentive. DOT staff noted that a public meeting sponsored by the National Highway Traffic Safety Administration would be held to address the issue of how new technologies affect driver attention and distraction.[10] This is a good start that could help synthesize current knowledge and identify problems, but a much greater effort is required in this area.

Behavioral Adaptation. Anticipating drivers' likely responses to new technologies is important to ensure the best design from a safety perspective. Both short-term and long-term adaptations will occur. A change in how the driving task is carried out will result in immediate adaptations (e.g., maintaining pressure on antilock brakes rather than pumping them, looking more at a navigation display and less at the road as compared with driving with a map). Over the longer term, the presence of new driver assistance technologies may cause some drivers to change their strategies in ways that offset some of the safety benefits of the technologies. For example, with night vision systems, some older drivers who have voluntarily restricted their night driving because of problems with glare, reduced visibility, and general feelings of discomfort may now be tempted to drive more at night, increasing their

[9] A more complete discussion of several of these issues can be found in Smiley 1996.

[10] The agency held this public meeting on July 18, 2000, and also conducted a multiweek Internet Forum on the Safety Implications of Driver Distraction When Using In-Vehicle Technologies. A follow-on technical workshop will be organized for invited researchers and technology developers, to be scheduled at a later date.

exposure and crash risk. These longer-term effects should be monitored, and will likely influence expectations concerning the magnitude of safety improvements to be achieved from future technology introduction.

Mental Models. As more complex IV technologies are introduced, there is a risk that drivers will not understand how the systems function. For example, more attention to the design of antilock brakes (i.e., pedal flutter) might have resulted in a design closer to traditional braking, so that more drivers might have used the new technology appropriately. With adaptive cruise control, drivers may not realize that these systems currently do not respond to stopped vehicles.

REPORTING REQUIREMENTS

In view of the complexity and multiyear time frame of the IVI program, the committee recommends that DOT program staff consider reporting on the progress of the IVI program annually. Such reporting could serve as a barometer of the rapidly changing external environment in which the program operates. It could also assist in tracking whether program objectives continue to be relevant and resources appropriately targeted.

The committee envisions a brief report that would (1) identify the strategy for each safety problem area, (2) set forth performance metrics (both evaluation protocols and outcomes) for achieving goals in each area, (3) track annual progress against goals, (4) describe any changes in the external environment, and (5) identify any needed shifts in program focus and resources. The committee is aware that the IVI program is obliged to track performance as part of the National Performance Review currently required of all federal agencies. The committee believes DOT staff could build on that effort to develop a report more tailored to the IVI program. Such a report should help program staff convince key constituencies, such as congressional appropriators, that the program continues to be relevant and on track. It could also attract the attention of nontraditional suppliers and innovators from new industrial sectors (e.g., software developers) to the field of improving driver safety by identifying unmet needs and difficult problems yet to be resolved.

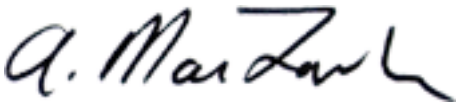
NEXT STEPS

Before and at its next meeting, the committee will pursue two key tasks in its continuing review of the IVI program. First, selected committee members will talk with high-level managers as well as safety research managers in the automotive sector in an effort to better understand their incentives and concerns with respect to participating in the IVI program. The results of this effort should enable the committee to provide more helpful guidance to DOT concerning its relationship with the automobile manufacturers. In addition, the committee will investigate the issue of liability, in particular, the extent to

which it represents an impediment to the rapid introduction of safety enhancing IV technologies.

The committee thanks the DOT staff for providing an opportunity to review the IVI program in more detail at this meeting. We hope the comments and recommendations provided in this letter report will help the IVI program managers meet the challenges posed by a rapidly changing technology environment.

Sincerely,



Alexander MacLachlan
Chair, Committee for the Review
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Abbreviations

JPO	Joint Program Office
TRB	Transportation Research Board

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*Members who attended the third committee meeting.

FIGURE 1 Study Committee Conception of IVI Program Elements