ASSESSMENT OF ITS SAFETY BENEFITS

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INTRODUCTION AND BACKGROUND

The Intelligent Transportation Systems (ITS) program has become a very visible and important part of the surface transportation system since the early 1990s. It was the subject of specific legislation in the ISTEA of 1992 and has seen significant growth in its federal funding, national support and number of national activities. To those who have not followed the highway research program in previous decades, the ITS may indeed seem to be a major new program which makes large claims for an array of future benefits for the transportation system. These claims include significant safety benefits for highway users.

In fact, the present ITS program has evolved from a small set of studies and projects in the 1960s to today's reasonably complex set of technologies and systems which now support approximately 29 defined user services in the transportation arena. It's essential in understanding ITS and the safety benefits it will yield to recognize that ITS is not a single system or even a set of closely coupled systems. Rather, ITS is broadly scoped around the development and application of advanced communication and control technologies and systems focused on improving the operational performance of the transportation system. This broad evolutionary nature of ITS was recognized early by those instrumental in the late 1980s in developing national attention and support for what was then becoming known as Intelligent Vehicle Highway Systems (IVHS). An early group known as Mobility 2000 noted in 1990:

> IVHS includes a range of technologies and ideas that can improve mobility and transportation productivity, enhance safety, maximize existing transportation facilities and energy resources, and protect the environment. IVHS are based on modern communications, computer and control technologies.

Further, the program was correctly understood to be much more than a federal or even public sponsored program. It was a given that IVHS, to be successful, would require stakeholders throughout the public and private sectors. Again, its early organizers noted:

> the program will involve significant cooperation among government at all levels, universities, and industries such as those producing motor vehicles, electronics, communications, computers, and transportation services.

Thus, IVHS and now its renamed and broadened successor ITS, is simply a part, albeit a current major part, of the natural evolution of our surface transportation system in particular and our society in general. This perspective should not diminish the motivation of those associated with the program. But it does argue that much of ITS will naturally find its way into our everyday transportation journeys just as more and more we utilize increasingly advanced communications and computer based systems in our everyday business and private lives.

This is particularly true in the area of user safety which is the subject of this paper. ITS will not normally replace the need for today's safety design practices and safety systems which are fundamental to our modern streets and highways. What ITS does provide for is two levels of improved user safety. First, a general enhancement of user safety by reducing driver stress and indecision, achieving smoother vehicle flow, and generally, providing for a driving environment which yields improved safety as one of its byproducts. The second level, however, is much more specific. These are those unresolved specific safety issues where an ITS technology is being developed as a countermeasure. Central to these expected safety improvements is the ability for ITS technologies to provide critical advisory, warning and control information and action based on actual roadway, traffic, and environmental conditions. Thus, real and focused safety improvements are expected to result to the extent that the products are affordable, marketable and effective.

ITS SAFETY FOCUS

Initially, the IVHS program was bundled around the following four major system application areas:

- Advanced Traffic Management Systems;

- Advanced Driver Information Systems (later to become *Traveler* Information Systems);
- Commercial Vehicle Operations; and
- Advanced Vehicle Control Systems.

As program interest increased, more potential applications were identified and today the program is described by ITS AMERICA and the US DOT to include 29 User Services consolidated into seven User Service Bundles shown in Figure 1. Collectively, these user services are expected to provide for a very broad set of national benefits as follows:

- Improved safety;
- Increased capacity and operational efficiency;
- Enhanced mobility;
- Enhanced trip quality;
- Reduced environmental and energy impacts; and
- Enhanced US productivity and world competitiveness.

Regarding safety benefits, much attention has been given since the late 1980s to trying to develop an objective and sound estimate of the types and quantity of safety benefits derivable from ITS. Initial estimates were obviously hampered by lack of specific system concepts, let alone specific designs. Thus, safety benefits were projected more in the context of what are the problems and, therefore, if you could achieve a reduction of x percent with an ITS system what the safety benefits would be.

Based on some preliminary work, the proceedings of the 1990 Mobility 2000 National Workshop suggested that IVHS technologies might be capable of saving over 11,000 lives per year by 2010. These estimates were of course recognized as preliminary and simplistic. Subsequent research was initiated to get a much better understanding of the safety issues and to provide a sounder basis for future government sponsored R&D activities. The National Highway Traffic Safety Administration (NHTSA) through its Office of Crash Avoidance undertook a set of research studies to better identify and describe operational safety problem areas that would be potential candidates for focused ITS systems. (See Additional Reading List). The Federal Highway Administration's Office of Safety and Traffic Operations R&D also undertook a broad, exploratory research contract in 1990 titled "Potential Safety Applications of Advanced Technology." This contract was completed in 1993 and the report became available in January, 1994.

Both the above FHWA and NHTSA set of studies focused on those ITS User Services bundled under the group titled Advanced Vehicle Control and Safety Systems in Figure 1. This ITS area places heavy emphasis on technologies located on-board the vehicle to improve safety in specific accident probable situations. The on-board equipment would operate either autonomously or, in selected cases, cooperatively with roadway located hardware to achieve its function.

Before exploring these systems and their projected safety benefits further, it should again be noted that the 29 User Services taken collectively are expected to achieve a wide range of benefits as previously noted. A quick examination of the titles of the individual User Services demonstrates that many of these do not have highway safety as their primary objective but are focused on other important needs such as congestion reduction, regulatory efficiency, etc.

To better classify those User Services that have primary safety focus, the author has classified the 29 User Services into three categories of expected safety benefits as shown in Figure 2.

- Category I are those User Services which incorporate technologies focused on a specific safety problem. These consist primarily of the Advanced Vehicle Control and Safety Systems. A well known example of this group would be some form of automated braking system which would apply the brakes in specific driving situations where some detector system and decision logic determined that a crash was imminent.
- Category II are those User Services which, while not focused primarily on safety, are still expected to have some meaningful safety component in their benefits. Among the many examples would be the electronic clearance of commercial vehicles. Here the focus is on improving the efficiency of the regulatory process but an expected benefit in doing so is to more effectively identify and remove from service the unsafe commercial vehicles and operators.
- Category III might be classified as generally creating a higher quality driving environment which yields an indirect, but positive highway safety benefit. This assumes that by implementing ITS technologies, such as pre-trip travel information, that a transportation environment results which has smoother flow, improved driver confidence and more accurate driving decision making, etc. and a by-product is enhanced safety.

Thus, to summarize to this point, the broad suite of projected ITS User Services differ substantially in their intended performance objectives. Improved safety is the primary goal in many but only a secondary or possibly by-product benefit in others. Establishing a numerical safety assessment of the Category II and III type systems is generally difficult but it is expected that the evaluations of a number of large scale field operational tests will eventually yield this information.

It should certainly be stressed, however, that there is clear evidence of the safety benefits of these Class II systems such as in ATMS. For example, in Minneapolis/St. Paul modern freeway management techniques including ramp metering provided for an increase in freeway speeds of 35 % and a reduction of 27% in accidents. Just recently Oakland County, Michigan has reported that an initial assessment of their new signal control system has shown a 6 % reduction in accidents.

SAFETY ASSESSMENT OF ADVANCED VEHICLE CONTROL SYSTEMS

The primary ITS safety improvement directed at the driving process is expected from those User Services contained in the Advanced Vehicle Control and Safety Systems bundle. It is these systems, which if successfully developed and deployed, are presumed to directly improve the highway users ability to avoid vehicle crashes or, at least reduce the severity of those crashes. The remainder of this paper will focus on these systems and their projected safety benefits. The source of this summary is the previously noted FHWA funded research performed by the University of Michigan Transportation Research Institute and titled "Potential Safety Applications of Advanced Technology".

To provide a factual analytical base for this research study, a specially prepared set of data from the 1984-1986 NHTSA CARDfile was used by the researchers. Given the extremely large size of the file, a selected set based on five per cent of the cases at the accident level were drawn from each of the six States in the files for each of the three years. The data set was further reduced by restricting it to two or less vehicles in the collision and a requirement for at least one car, light truck or van to be involved. The final data set included 55,186 single vehicle records and 124,329 two-vehicle records. The collision type distribution for two-vehicle collisions is illustrated in Figure 3.

This data set served to develop a rationale as to the types of driving maneuver/crash situations which resulted in significant number of crashes and/or presented the type of driving situation where an ITS technology could be effective. Further analysis of these data resulted in identifying six predominant crash types: run-off-the-road, pedestrian or object, crossing paths, turn left into path, rear end and head on. (Figure 4).

These six situations accounted for 122,458 of the crashes in the total examined sample of 211,874 crashes. They further accounted for 892 fatalities and 24,152 injuries of Severity A & B out of the total 1,281 and 36,860 respectively. These six classes of crashes were then further analyzed from the available data as to such factors as night time, presence of alcohol, snow/ice, etc.

Next, the researchers postulated various countermeasure systems which could reduce the probability of the crash or its severity. A total of 18 such countermeasure systems were identified which included 14 distributed across the six crash types and four which were considered cross cutting. (Figure 5).

These countermeasures were then considered from the perspective of their high level system architecture requirements. That is, whether they required communications to another vehicle, and/or to the roadside, etc. Five general groups were described consisting of autonomous intelligent vehicle, inter-vehicle communicating, autonomous intelligent roadsite, vehicle-roadside communicating, and inter-vehicle and roadsite communicating. (Figure 6) This postulated system structure provided the basis for making estimates of market penetration such that projections could be made of actual reductions in crashes for the six types identified.

The results of the UMTRI analysis identified the following six systems as having the most potential for safety benefits:

- Headway control;
- Lane-edge detection;
- Lane-keeping;
- Night vision enhancement;
- Impaired driver warning; and
- Longitudinal control for avoiding objects in the road.

Systems believed to have lower potential than the above and labeled medium potential were

- Low-friction detection; and
- Cooperative intersections.

Finally, four systems were described as having spot improvement potential, but were otherwise not seen as cost effective for general deployment. These were

- Horizontal curve speed advisory;
- Pedestrian detection at mid-block crossings;
- On-coming vehicle warning; and
- Left-turn warning.

Although a detailed summary of the study's many conclusions is beyond the scope of this paper, a single figure which captures the essence of the study's results was a ranking of the previously defined 18 countermeasure systems by their percent reduction in total accident cost. The results are shown in Figure 7. This figure was based on the researcher's "generic" method which was the simplest of three assessment used in the study. The estimated reduction in accidents ranged from about 13.5 % for the universal application of headway control measures, to 12.5 % for lane-keeping countermeasures, and down to 1.2 % for impaired driver warning.

CONCLUSIONS

The conclusion from the preceding discussion is that there are clearly real and important safety benefits that are realizable through the development and deployment of various ITS technologies and systems. These range from more subtle safety benefits which result from an improved driving environment through systems which increase safety by enhancing regulatory enforcement and, finally, to systems which are specifically focused on resolving particular known driving situations with large accident potential. The total number of accidents that could be eliminated and lives saved by full implementation of the full suite of the 29 ITS User Services remains a difficult unanswered question. However, the six collision types in the previously discussed study account for 68 % of all single and two vehicle accidents. Clearly, the study results demonstrate a real opportunity for highway driving safety improvement based on this advanced technology.

But, as was discussed in the beginning of this paper, these projected ITS safety benefits must be understood and used in the broader context of how ITS relates to the transportation system and our society. That is, ITS is part of the march of new technology which brings new tools to bear on transportation needs. These tools are the result of our nation's continued evolution of advanced communication and control technologies. Will these new advanced technology tools resolve all of the existing safety problems or eliminate the need for current safety practices and hardware? Of course not. The errant vehicle, resulting from whatever set of events, still needs barriers, guardrails, crash attenuators and whatever form of protective safety hardware we can apply. Similarly, safe geometric design practices, interstate design standards, etc. have conclusively demonstrated their safety value and will not easily be replaced by any particular ITS technology.

But, the advanced technologies which are the core of ITS do provide a tool in the safety arsenal which has not been available until now. This generic new tool is the ability to develop specific new systems which are aimed at many troublesome highway safety problems that are the result of poor driving behavior, lapses in attention, etc. which have been highly resistant to correction to date. To illustrate this further, the highway fatality rate has steadily dropped by a factor of three since the 1960s. The reasons are many ranging from improved roadside safety hardware, vehicle crashworthiness, seatbelts and airbags, more miles of interstate design level highways, to increased enforcement of drunk driving laws. But even with these tools the number of annual fatalities has appeared to hold around 40,000 and the reduction in rate appears to be leveling off around 1.8.

This is not particularly surprising given that upwards of 90 % of all accidents are the result of driver error. Further, despite intensified enforcement of drunk driving, approximately 40 % of all fatalities still involve one or more parties that are legally drunk. Again, ITS offers a new and perhaps the only realistic opportunity for dealing with many of these difficult safety problems.

So, in this author's opinion, there is clearly a whole new range of safety benefits that are possible through ITS. What is more difficult to assess is whether and/or how soon the more safety aggressive ITS systems will be available and deployed in sufficient quantities to see measurable national benefits. The realities of almost 4 million mile of roads and streets (or even just the National Highway System with its projected 150 plus thousand miles), 195 million registered vehicles and 175 million licensed drivers are just indicators of the lengthy time constant facing deployment of new safety technologies. On the other hand, the passenger vehicle fleet does turn over in something like 12-15 years and we do have national experience such as air bags which show that a meaningful percentage of the fleet can be affected in just a few years.

Achieving the safety benefits of ITS will be significantly driven by three factors. First, those systems whose operation requires hardware or some interconnection with the infrastructure will, as always, see their deployment controlled by public (federal/state/local) funding priorities. Given today's increasing funding needs and reduced budgets makes this a difficult problem.

Second, as most of the systems focused specifically on safety are based on technology which will be located primarily in the vehicle, their deployment will be controlled by consumer interest in these technologies, their affordability and the other market realities of liability issues, warranties, etc.

Third, there may be some safety systems which offer such important safety benefits that they are seen as being in the public's benefit to such an extent that they become required by safety standards — as were passenger restraint systems, high mount tail lights, etc. The issue here will also be the mood of the federal government, Congress, and society as a whole for mandating any new systems.

So, in conclusion, an assessment of ITS safety benefits results in a strong conviction of their real ability to reduce accidents, injuries and fatalities and especially in those unsafe driving situations which have been resistant to the safety design tools and hardware available today. But, also, this assessment does not see these ITS technologies displacing the need for maintaining a strong commitment to the existing and proven safety practices of the present. Further, many of the ITS safety benefits will evolve over many years as their deployment in the numbers required to influence significantly the national statistics will require a number of years.

SUGGESTED ADDITIONAL READING

1. *Potential Safety Applications of Advanced Technology*, Federal Highway Administration, FHWA-RD-93-080, January, 1994
2. *Proceedings of a National Workshop on IVHS*, Texas Transportation Institute, Texas A&M University, March, 1990
3. *National ITS Program Plan*, Vol. 1 and 2, ITS AMERICA, Washington, DC, March, 1995
4. *Assessment of IVHS Countermeasures for Collision Avoidance: Rear-End Crashes*, National Highway Traffic Safety Administration, DOT HS 807 995, May, 1993
5. *Examination of Lane Change Crashes and Potential IVHS Countermeasures*, National Highway Traffic Safety Administration, DOT HS 808 071, March, 1994
6. *Examination of Unsignalized Intersection, Straight Crossing Path Crashes and Potential IVHS Countermeasures*, National Highway Traffic Safety Administration, DOT HS 808 152, August, 1994
7. *Examination of Intersection, Left Turn Across Path Crashes and Potential IVHS Countermeasures*, National Highway Traffic Safety Adminstration, DOT HS 808 154, September, 1994
8. *Examination of Signalized Intersection, Straight Crossing Path Crashes and Potential IVHS Countermeasures*, National Highway Traffic Safety Administration, DOT HS 808 143, August, 1994
9. *Examination of Reduced Visibility Crashes and Potential IVHS Countermeasures*, National Highway Traffic Safety Administration, DOT HS 808 201, December, 1994