IVHS and the Truckmaker:

Identifying the Need for Research

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16. Abstract

The study identifies the domain of research on Intelligent Vehicle-Highway Systems (IVHS) that might be proper to the interests of original equipment manufacturers (OEMs) of medium and heavy duty trucks. Interviews of engineering and marketing persons employed by truck manufacturing companies serve to indicate the current OEM perspective on IVHS. Based upon the combined considerations of what we might call "the culture" of the truck specification-and-purchase process, the technological opportunities, and the general environment for IVHS in the United States, a rationale for truckmaker research is developed.

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IVHS and the Truckmaker:
Identifying the Need for Research

1) Introduction

This document reports on a brief study conducted by the University of Michigan Transportation Research Institute under sponsorship by the Motor Vehicle Manufacturers Association of the United States (MVMA.) The objective of the study was to identify the domain of research on Intelligent Vehicle-Highway Systems (IVHS) which might be proper to the interests of the MVMA members who operate as original equipment manufacturers (OEM's) of medium and heavy duty trucks. The companies in question include Ford Motor Co., General Motors Corp., Navistar International, PACCAR, Inc., and Volvo GM Heavy Truck Corp. Although these manufacturers have gained a certain level of IVHS awareness through individual initiatives, the MVMA members sought to study the subject as a group, identifying the portions of IVHS that are especially pertinent to the business of truckmaking and defining the corresponding research needs.

Although the trucking applications of IVHS include the group of functionalities that the Intelligent Vehicle-Highway Society of America (IVHS America) has classified as, "Commercial Vehicle Operations," or CVO, they also include concepts called, Advanced Traveler Information Systems (ATIS) and Advanced Vehicle Control Systems (AVCS.) At this juncture, as part of a surging U.S. interest in IVHS, the truck manufacturers seek to better define their fit within this overall array of concepts and potential products. In particular, if the MVMA member companies are to undertake research in the IVHS arena, or participate in projects initiated by others, a rationale is needed that helps in steering the research choices. This project was intended to flesh out such a rationale and thus to help guide the choices.

This study was carried out with the aid of interviews involving the author and engineering and marketing persons employed by each of the MVMA's truck manufacturing companies. The interviews addressed a broad range of IVHS functions and sought to establish the perspective of the truckmaker as a potential seller of products falling into various categories. Having attempted to define the role that the OEM truck manufacturer might play in IVHS-related business, the intent was to identify the knowledge gaps calling for research which supports that role.

The results of the interview process are presented in Section 2.0 of this report. In order to better understand why the interviewees said what they said, it is necessary to consider the general issue of a truck manufacturer's outlook on prospective products whose functionalities are neither being demanded by truck buyers nor required by regulation. To place these considerations on a proper footing, Section 3.0 of this report discusses the truck manufacturer's outlook in light of the stereotypical relationship that exists between them and their customers relative to product innovation. While the truckmakers, themselves, obviously understand these matters very well, Section 3.0 is included here in order to lay foundation for a research rationale and to inform others who may collaborate with truck manufacturers in the future.

In Section 4.0, the functional concepts posed by IVHS are examined in terms of the possible opportunity for new value-added components of the OEM truck. Each of these functions can be conceived to require a certain system of on-board components which, in some cases, link with a ground-based infrastructure. The prospect for actually reaching the implementation of any specific system, however, may be significantly determined by "environmental" factors such as are discussed in Section 5.0. Based upon the combined considerations of what we might call "the culture" of the truck specification-and-purchase process, the technological opportunities, and the general environment for IVHS, a rationale for MVMA research is addressed in Section 6.0.

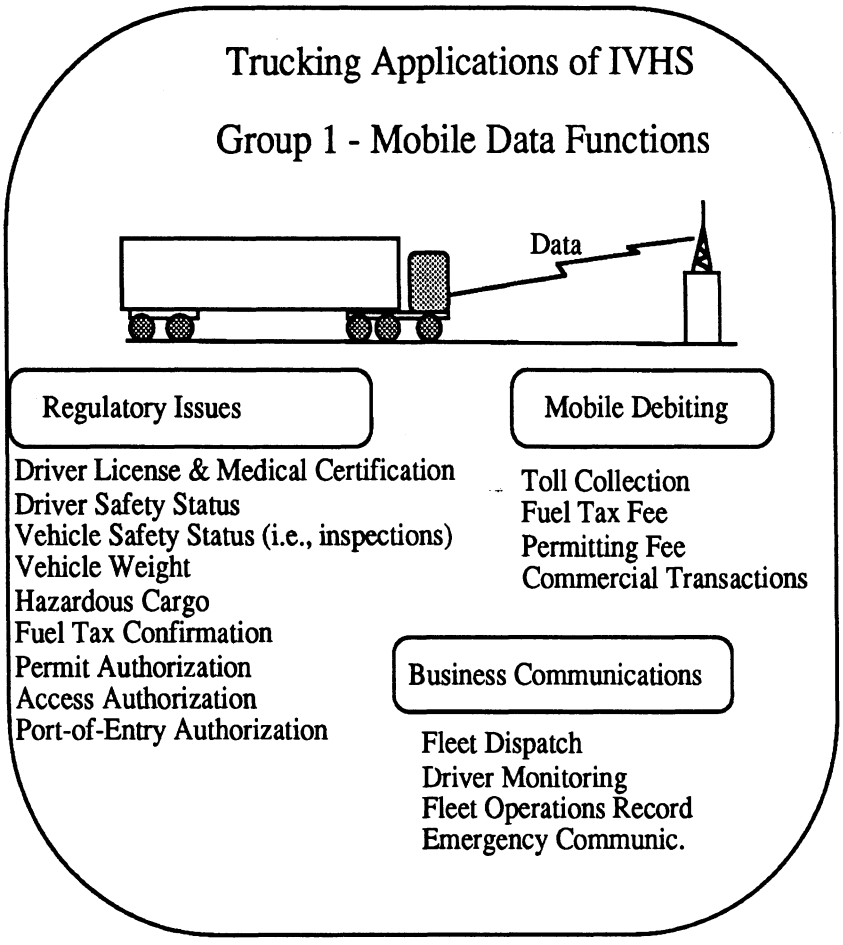
2.0 Results of Interviews with Truck Manufacturers

Interviews were conducted in order to gain a general sense of the expectations of truck manufacturers for expanding their product technology so that the OEM truck would increasingly offer IVHS functionality. Since the truck manufacturer's interests potentially covers all IVHS applications that might be made by the trucking community, the system concepts of potential interest span the entire range from information-based systems to control systems. In order to help simplify the interviewing process, the functional modules were sorted into one of two groups, namely,

Group 1 - Mobile Data Functions, and,
Group 2 - Innovations to the Driving Process

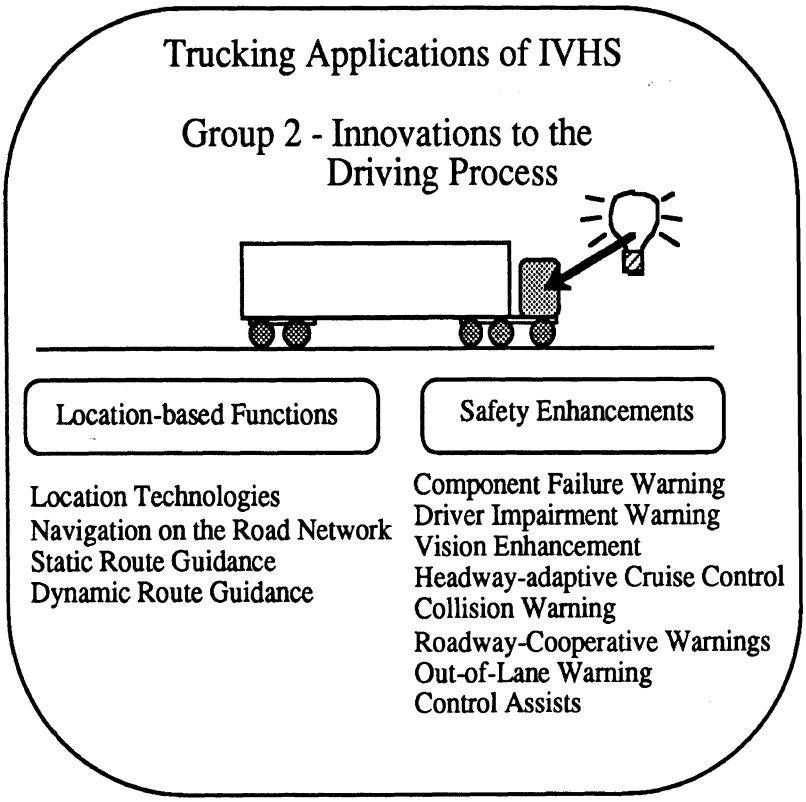
In Group 1, the applications are characterized almost exclusively by information exchange between the vehicle and the roadside. In Group 2, the applications serve to assist the driver, somehow, in the task of driving the truck.

Examples of data elements and communication transactions falling into Group 1 are shown below...



In this category of functions, there is generally no high-level processing needed on-board the vehicle. Noting that all of the regulatory items involve only logged documentation of status, there are no sensors, actuators, or complex displays incorporated into the vehicle assembly. The vehicle is essentially just a node in a communication network, although memory and perhaps modest accounting-type processing are likely to be required on-board the vehicle. The principal enabling technology is mobile digital communications. Across the set of functions indicated above, some can be achieved with short range communications and some more typically require wide-area communications.

In Group 2 applications, involving innovations to the driving process, the current state of the driver/vehicle system is sensed at some level in order to enable a real-time function assisting the driver. (It is recognized, of course, that some of the functionalities shown under Group 2 are strongly synergistic with mobile data functions shown previously under Group 1—for example, the utility of both vehicle location and mobile data communications in support of fleet dispatch.) Example functionalities classed as innovations to the driving process are shown below:



The vehicle features effecting the indicated functions could be achieved either as autonomous enhancements to the vehicle, itself, or as cooperative technologies that require active communication or sensing from the roadside. While the navigation and even route guidance features on the left of the figure pose new interactions with the driver, they require only that the vehicle be located relative to the reference frame of a computerized map. The lead time within which the driver must assimilate and act upon such "location-based" information is typically measured in minutes, or at least tens of seconds. The safety enhancements listed at the right constitute far more ambitious achievements, aiding the driver in the vehicle control task by locating other vehicles, lane edges, and fixed objects that may constitute safety hazards. The lead time for driver interaction with such safety functions is typically measured in seconds and, perhaps, fractions of a second. None of

the Group 2 functions is likely to be achieved without very significant augmentation of on-board equipment.

The interviews were conducted in reference to the array of IVHS concepts as were listed under the two Groups. While some discussion was generally needed to clarify certain of the concepts, in general the interviews addressed the overall prospect for innovations of this sort, as a class. The interviews supported the general finding that essentially none of the functions shown as examples under Groups 1 and 2 is currently achieved by means of original equipment on any heavy duty truck that has been manufactured in the United States. Nevertheless, a number of the Group 1 functions is attainable through aftermarket products and some are the object of collaborative demonstration projects involving government agencies and the trucking industry. Only a small number of the Group 2 functions can be attained today, and then only through aftermarket products.

A central observation in the "IVHS-for-trucks" discussion is that (a) the opportunities for application are largely undeveloped, (b) the great majority of fleet owners or individual operators are thought to be largely unaware of, and thus lacking in evaluative judgment on, the functionalities that might be achievable, and (c) the higher-order issue of which concepts, among the lot, are prospects for system integration within OEM trucks is almost totally unexplored. It is certainly the experience of U.S. truck manufacturers that virtually no customers of theirs have requested IVHS features for sale on trucks. Accordingly, the truck manufacturer looks out on the IVHS discussion and sees: (a) a remarkable tech-push stimulus emerging from the milieu of military, aerospace, computing, and telecommunications industries, with some modular systems appearing in passenger cars (b) a substantial volume of ideas for systems that may have some applicability to trucking, but (c) a general absence (with a few notable exceptions) of actual implementation as systems delivered to trucking operations. Any deliveries that have been made have been via aftermarket channels.

Thus, if the truck manufacturer appraises the IVHS proposition by the conventional scale—i.e., customer demand—he tends to conclude that it constitutes a non-issue, at present. The strategic question is, what issue will IVHS pose for truck manufacturers in the years just ahead?

Notwithstanding the absence of interest on the part of the great majority of truck buyers, some of the interviewed OEM parties took the view that, perhaps, we're on the threshold of a new era in trucking—the era in which technological assistance arrives in real-time to assist operations. When this era materializes, the trucking services that are offered and the competition among those who offer them may change in a wholesale manner. This view holds that truck-buying customers are not yet demanding IVHS-type hardware from the OEM's because the era is still in its nascent state and because the buyer is not inclined to think of the OEM manufacturer as the likely party to deliver much of the related hardware. Moreover, IVHS-for-trucking is simply not yet recognizable as the thing that it will become—except in the view of a few visionaries who, although rather inspired at the moment, are also at high risk of error in their specific prognostications.

So, there is a dearth of hard evidence which might convince the truck manufacturer that IVHS will, indeed, impact upon his business in a significant way. But there is concern that the technological boom is destabilizing the climate and perhaps calling for reconsideration of the truck manufacturer's role now that wholly new "systems questions" may be on the table.

Below, specific comments made by truck manufacturer representatives in the course of the interviews have been consolidated and paraphrased. Together, they constitute a sort of collage of the truckmaker's view on the IVHS subject as a whole. They also include specific views which tend to discriminate among various systems concepts that were listed under Groups 1 and 2, earlier.

ON THE ROLE OF THE OEM

- As for IVHS marketing, we're sitting back and waiting on the customer.
- We expect to be the system integrator, but what can we do before our customers really figure it out?
- If customers think of IVHS-type functionalities, they go to aftermarket suppliers to dig out the products.
- The business issues are supplier-to-truck user, not OEM.
- Most OEM's are quite conservative in new systems such as IVHS poses; the development is risky and expensive, the tooling may be costly, and the developmental role doesn't match the OEM's tradition, for the most part.

- In the near term, look for OEM's to do little more than install bracketry such as for satellite antennas when demanded by customers.
- The truck OEM's are already sophisticated in supporting electronic systems, such as for engine controls, antilock brakes, electronically-controlled transmissions, trip recorders, CD players, external cellular phones, etc.
- The OEM will install almost anything a customer wants as a special equipment order if engineering compatibility can be reconciled and if the customer is willing to pay for it.
- Relative to implementation, the OEM is very concerned that there be standards for interfacing equipment; otherwise, there's the chaotic need to support every variation in proprietary items.
- Because of electromagnetic interferences and power requirements, the OEM would rather integrate new electronic modules with the original vehicle and would much prefer a single type of communication interface.
- The medium and heavy duty truck is sold to a "customer-pull" market. Thus, the OEM's are unlikely to push much of any IVHS innovations toward the truck-buying customer.
- If NHTSA gets involved and either mandates or heavily promotes IVHS-related equipment, then the OEM product will become necessarily involved.
- The OEM's would likely applaud NHTSA development of active safety technologies—stimulating movement toward systems that might otherwise languish due to a lack of market pull.
- OEM's would like to see ISTEA money going into development of truck-enhancing systems, where the public benefit warrants a stimulus of the application.
- The role of the OEM in fielding IVHS-related products will be constrained in part by the technical skills and the modus operandi of the truck salesperson. Although knowledgeable fleets order vehicles without much salesperson interaction, the introduction of new items and the representation to naive buyers is dependent upon a realistic match of the sales task to the abilities of the sales support staff.

ON THE ENGINEERING OF INDIVIDUAL TECHNOLOGIES

- Relative to the impact of new technology on the human factors issue—OEM's recognize that truck driving is less tolerant of driver distraction than car driving. Thus any systems interacting with the truck driver must be designed to minimize additional driver loading.

•Electromagnetic compatibility will be a serious issue, since the modern vehicle is already rather sensitive due to the large quantity of on-board electronics.

•Diagnostic electronics are being increasingly implemented in modern trucks; prognostic (failure prediction) functions are not being provided yet.

•Multiplexing is coming soon on medium-duty trucks. This development will facilitate the integration of intelligent modules within the vehicle and can tilt the relative economies of aftermarket vs. OEM-integrated electronic packages.

•The total demand for on-board electrical power is already high in full-option trucks and may need to be significantly expanded as required by IVHS products.

•Systems for self-certifying the weight carried on tractor and trailer axles will require tamper-proof provisions. Credible precedence has been provided by the secure algorithms that are now employed within engine emission controls, but the feasibility of self-certified weights is unknown.

•Regarding collision warning and intervention, it is unlikely that OEM's would be in front of the adoption wave. Rather, they will prefer to monitor the liability experience of others before jumping in. When adapted to trucks, warning systems must be calibrated to suit the high-mileage and long-hour exposures of truck drivers.

•Headway-adaptive cruise control is readily enabled via modern, throttle-by-wire, electronic engine controls. Application is much tougher with manual transmissions, however, since speed reductions to accommodate headway closure will require down-shifting. Also, trucks suffer almost constant cut-in intrusions by cars in heavy traffic, perhaps rendering a useful headway controller infeasible (except for light-traffic environments in which the headway control feature has little value.)

•Driver impairment monitoring/warning is a function that would be naturally integrated within the OEM truck. The fact that this product appears to require integrated installation, plus its potential market if the quality of the truck driver pool declines, tend to argue for OEM initiative.

•Vision enhancement is seen by OEM's as very hard to implement in the heavy vehicle. It is appraised as a far-out, unrealistic expectation for the commercial trucking application.

•The need for interchangeability of products over multiple model years tends to impede innovation by OEM's in very large fleets. On the other hand, large fleets have definitely innovated by large-scale retrofitting using aftermarket systems.

•Rollover warning systems are appraised as rather far out because of the need to infer current loading and load height in order to calibrate the current warning protocol.

ON THE OEM'S KNOWLEDGE OF TRUCK BUYERS' OPERATIONS

- The OEM's have very limited knowledge about truck operations. They and the engine manufacturers know a great deal about the speed, acceleration, and loading characteristics aggregated across an operation, including the typical duty cycles on-route, but not the time-based dependency of operations on information, communications, and decisionmaking. Thus, it will not be straightforward, at all, for OEM truckmakers to assess the market, let alone design and implement systems supporting fleet operations via information and communications technology.
- Most OEM's have selected a few customers with whom they conduct iterative development programs. In these few cases, the truck manufacturer tends to know a good deal more about the operation, but the focus of interest has been on duty cycles, maintainability, and the in-field performance of the vehicle rather than on the owner's decision process for deploying the vehicle as a function of the temporal and spatial variables that are peculiar to his business.
- The trucking industry is extremely diverse. No party is known to hold a significant understanding that spans the gamut of operations in terms of the potential application of information technology.
- Recognizing great diversity across trucking enterprises, products sold to support the information needs of many types of operations must be fantastically adaptable and tailorable. While software could afford great adaptability, the need for hardware variation is unknown but may also be high.
- Some early attempts by OEM's to adapt location systems and digital communications for some customers were discouraging. There seems to be simply a mismatch in competencies between those needed to manufacture and assemble a vehicle and those needed to support an information and telecommunications system for enhancing logistics.

ON THE MARKET FOR IVHS-IN-THE-OEM-TRUCK

- The OEM's have received almost nil in the way of customer request for navigation or routing-related products. Nevertheless, truck manufacturers anticipate some market at least as a route-orientation tool for fleets having a high frequency of driver turnover.

Dynamic routing of trucks, incorporating real-time traffic data in the route selection, is thought by some to have distinct value for many types of truck operations, when the supporting infrastructure becomes widely installed.

- There is a general sense that truck buyers are more inclined to purchase safety-enhancing products, but the trend is still very subtle. Some manufacturers are seeing modest growth in the request for antilock brake systems by fleets that perceive favorable in-field accident experience from their antilock brake-equipped trucks.
- The owner operator represents the largest user segment for heavy duty trucks and may provide a market for IVHS products that are perceived as enhancing the driver's status or physical well-being. Attractive items may include collision warning and intervention, emergency communications and the mayday function, and information aids that save time through congested areas.
- Fleets will look to amortize IVHS investments over a reasonable pay-back period. If a certain package has been tailored for a specific operation, and cannot be readily transferred to another vehicle when the original vehicle is disposed of, the payback period must be achieved within the 3- or 4-year term of the typical fleet ownership since the resale value of the package may be zero. Of course, it is true that information-based systems tend to obsolesce quickly such that each subsequent version of the device is likely to offer profound improvements that call for disposal of the predecessor, anyway. Thus, the need for short payback is reduced in a climate of rapid improvement in the replacement species.
- Relative to the general absence of a current market for truck-borne IVHS, it is assumed that the technology expectations of truck drivers and fleet owners will tend to percolate upward as people gain experience with IVHS equipment in cars. While this observation does not suggest a rapid process, it does speak to the tradition of truck adoption of technologies that have first been mass-produced and refined for use in cars.
- Implementation processes across the trucking industry are typically conservative and thus incremental. It is unrepresentative to characterize most of the industry by the few large, for-hire, fleets that are known to be technologically innovative. Rather, the majority are represented by owner-operators, fleets of just a few trucks, and private trucking fleets (whose prime business is not trucking.) The OEM's experience suggests that this majority of truck operators does not adopt novel, non-mandated, technologies except over a long period of acquaintance and acceptance; some obviously buying-in sooner than others.

- In the current national forums on IVHS, there is a remarkable absence of potential users from the trucking community. At the 2nd Annual Meeting of IVHS America, an informal count showed that approximately 1 out of every 100 attendees was from the truck-user community. Thus, except via the public media and trade magazines, it is assumed that the trucking enterprise is essentially unaware of the vision and expectations of the IVHS community in this country.
- OEM's recognize the possibility, however remote, that a resurgence of the periodic public complaint regarding truck safety could conceivably rally around active safety countermeasures and force the mandating of collision avoidance technologies, especially if antilock brakes become widely selected on a natural basis, or mandated, and thus serve as a partial enabler of other safety functions.

3) Understanding the IVHS Perspective of OEM Truckmakers

In order to view the above comments in the context of a typical truck manufacturer's business, it is useful to briefly consider the nature of the OEM marketing and manufacturing tasks. While this discussion is highly simplified, it assists in rationalizing a research program befitting the truckmaker's interests.

Heavy Truck Marketing

The heavy duty truck is purchased by means of a buyer's order that includes a very great deal of specificity regarding the desired equipment. The order sheet will typically include selections from among hundreds of optional specifications for, say, a road tractor. In each specification, the buyer may choose from a variety of alternatives in selecting individual components—including frames, axles, springs, brakes, engine, transmission, instruments, seating, fuel tanks, batteries, and on and on. In the case of the power train, the choices that have traditionally been available in terms of hardware are now vastly expanded through the tailored setting of programmable engine control software. Further, the trend is toward more and more specificity and selectability on the part of purchaser.

In short, when it comes to truck-buying, the customer has a very high degree of authority in selecting the equipment. Conversely, the truck manufacturer exercises much less assertiveness in pushing certain equipment packages on the buyer, than is seen in the marketing of passenger cars. In the vast majority of medium and heavy truck sales, there is simply a "pull-marketing" relationship between the truck buyer and the truckmaker—very

little is bundled into inseparable groups of optional components. This way, what the truck buyer doesn't want, he doesn't get. This principle was confirmed in recent years by certain European manufacturers who attempted to introduce highly integrated vehicle packages into the medium and heavy truck market in North America, meeting with very little success, indeed.

The traditional buying assumption in the U.S. is that the differences which distinguish one trucking operation from the next must be reflected in detailed specifications for the vehicle, itself. The tradition of detailed spec'ing yields a system that is maximally responsive to the truck buyers' desires while holding truck innovation hostage to the buyers' level of technical awareness and understanding. And the buyer is typically tilted toward conservatism, as well, in selecting unproven features since the vehicle will be used intensively. The larger fleet, for example, will be "stuck" with its buying choices for, say, 300,000 to 500,000 miles of usage before it sells off the acquired truck or tractor. With an owner-operator, the span of original ownership may typically range from 500,000 to 1,000,000 miles of operation.

If innovative features are to be sold on OEM trucks, the crucial interactions will occur between potential truck buyers and (a) component salespersons who visit in advance of vehicle-ordering to prompt the selection of proprietary items when the truck order is placed, and b) the OEM salesperson who facilitates the ordering, itself. If the vehicle is to incorporate an innovative item, the truck buyer must have been persuaded to take it through one of these two exchanges, or through some other input. But if the item's functionality is unrecognized, unfamiliar, or simply unfathomable to the buyer, the chances of its inclusion on the order list will be low, indeed. If the buyer does not request the feature on his own, then the outcome rests upon the skills and understanding of the salespersons and upon their ability to cast the merits of the feature in terms matching the peculiar needs of each particular trucking operation.

This latter item lies at the core of the challenge with IVHS functions that offer improvement in decision-support for the real-time trucking operation, itself. In order to sell these functions, they must be tailored to the operation—like the power train and chassis are currently tailored to satisfy the hauling mission. For each truck purchaser, it would be necessary to describe who is moving what types of freight from which origins to which destinations, over which roads at which times of the day, using which vehicle types operating singly or from fleets, with what intermediate pickups or deliveries, receipt

confirmations, requests for special services, and so on, based upon what information generated from and communicated by whom? But how can the truck salesperson know enough about the intricacies of a given operation to define, and then sell, the needed system? It doesn't seem plausible until the applications become reduced to a simple box-checking prescription. In the meantime, the OEM's approach to marketing does not appear to support the possible introduction of tailored information-based systems to serve the operational needs of individual fleets.

Heavy Truck Manufacturing

Most heavy truck manufacturers in North America are primarily assemblers (although Mack does produce many of its own components.) Speaking generally, it is estimated that only about 15% to 25% of the manufactured cost of the vehicle is fabricated by the typical OEM corporation whose name appears in chrome letters on the front of the vehicle. Further, the OEM's contribution to fabrication is largely confined to the cab—that is, the housing for the driver, the controls, and the instrumentation. While most manufacturers design their own frames, the fabrication is normally done by a vendor. All other components (with a variety of modest exceptions) are manufactured by specialized equipment suppliers, many of whom conduct their own marketing programs through direct contact with truck buyers, as mentioned above. Increasingly, many of the supplied components incorporate advanced electronic features and modular controllers whose interconnection and electrical power needs are looked after by the OEM assembler. The OEM is concerned with integrating all vendor modules within the truck environment but is not typically engaged in the design of electronic systems and does not manufacture them.

The point of this manufacturing issue is that the OEM truckmakers have a tradition that is not significantly engaged in the technologies needed to achieve IVHS functions. (The only exceptions to this involve the few truck manufacturers that exist within corporate structures having large electronic product divisions. In general, these divisions have not been tapped significantly in behalf of medium and heavy truck businesses, but they could conceivably offer a path toward IVHS products in the future.) As a bottom line, the actual development of IVHS products by the OEM truckmakers is unlikely insofar as their competencies do not generally include the areas of wireless communications, computing, reconfigurable displays, data entry devices, remote sensing, signal processing, electronically-controlled actuators, and the like.

On the other hand, every vendor-supplied component which is incorporated within the OEM truck must be integrated in such a way that it actually works in the end-use environment. While the vendor's competence may be focused upon the immediate component and its input-output characteristics, the OEM's competence covers a host of mechanical, electrical, thermal, human- and highway-interface issues that pertain to the truck usage environment and that, together, pose the challenge for component integration. Thus, it is inevitable that IVHS modules, however manufactured, will require some degree of "integration engineering" to assure their suitable adaptation to the OEM vehicle. In the end, if anyone is ultimately responsible for the driver- and highway-suitability of the equipment as incorporated within a total vehicle, it is the OEM organization.

4) Environment Factors that May Influence Truck Implementation of IVHS

Six factors have been selected for giving a rough picture of the governmental and industrial setting for IVHS implementation. Each is discussed below in the context of its potential impact on commercial vehicle applications.

IVHS America and its Strategic Plan

The IVHS America Strategic Plan includes projections for CVO implementation as well as suggested research areas. Three of the seven major truck OEM companies in the U.S. are represented on the CVO committee which produced these projections. The Plan shows expected evolution of product availability and the penetration of products and infrastructure deployment in 5-, 10-, and 20-year time frames. The "vehicle technologies and products" identified in the plan include:

- automatic vehicle identification (AVI)
- automatic vehicle location (AVL)
- voice communications
- data communications
- man-machine interface features, including:
  - reconfigurable displays
  - digitized voice outputs
  - touch screen as an input device
  - trainable voice recognition as input

Deployment of CVO elements is seen as developing first with information-based products sold to the large fleets, employing communications infrastructures that are owned privately. Based upon AVI for regulatory enforcement and toll debiting, public infrastructures will be increasingly deployed along Interstate routes, with the more innovative state DOT's as first-adopters. Public infrastructure elements include roadside readers of the AVI transponder, backed up by electronic data transfers along highway corridors and between state agencies. Most of the effort needed here will deal with institutional innovation.

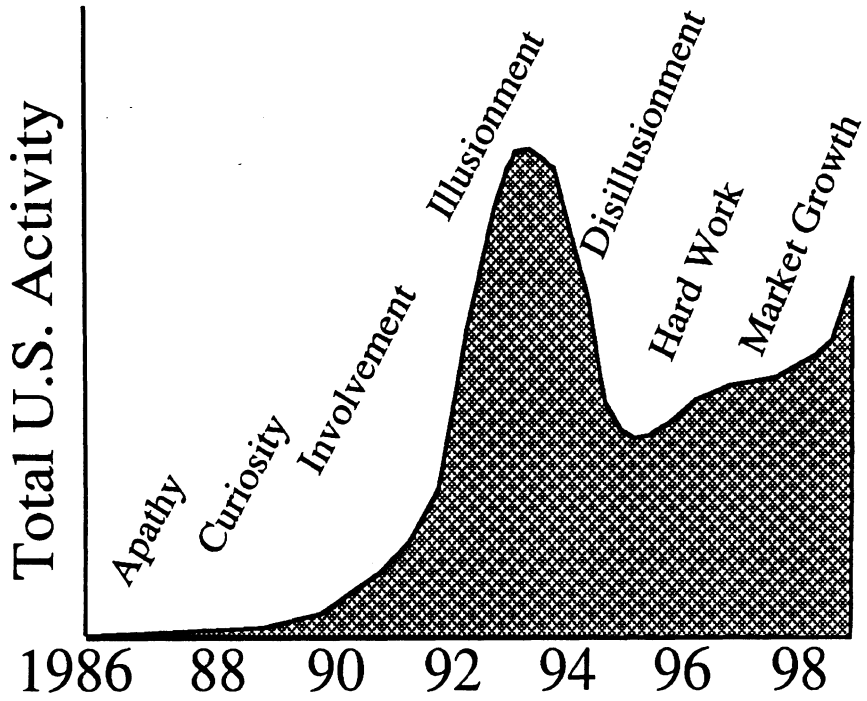
The CVO plan portion of the IVHS America plan does not include active safety functions, since these have been classified under Advanced Vehicle Control Systems (AVCS.) The AVCS plan, while predicting a variety of warning, smart cruise control, automatic braking, and vision enhancement products to appear over the next 5 to 10 years, does not explicitly address the commercial truck application. Thus, a timetable for truck adoption of such features is not presented. Although large trucking fleets are beginning to adopt certain AVL and data communications services in advance of the individual motorist, past practice suggests that truckers will not quickly adopt the active safety products of AVCS.

The IVHS America Plan projects that some $86 million in public funds will be committed to research, development, and operational testing of CVO concepts over the next five years. The cost of deploying CVO *infrastructure* over the same period (that is, actually installing roadside-connected systems) is estimated at $825 million in public funds.

The significance of the IVHS America strategic plan is that it constitutes official advice for the U.S. DOT. In that regard, the trucking community has an advanced notice on what may develop as a major government initiative in delivering IVHS functionality to support commercial vehicle operations. Of course, public funds will emphasize the functions having distinct public benefit, such as the orderly and efficient enforcement of road-use laws. The rate of growth in systems directly supporting fleet coordination and dispatch or active safety features, however, depends almost entirely upon private initiative.

When the OEM truckmaker, or any other party, addresses strategic planning for IVHS, it may be very difficult to make judgments on the likely pace of events leading up to widespread implementation. Among the unknowns is the potential that disruptions may occur in the national collaboration on IVHS that has been so stunningly launched in just the

last three years, or so. Notwithstanding this launch, or perhaps partly because of its steep rise, the author expects a near-term scenario for IVHS activity in the U.S. such as depicted in the figure, below. Namely, a shakeout is anticipated due to the combination of (1) the rapid "bandwagon" nature of the program startup, (2) the excessive rallying to IVHS that derived from coincidental "hot button" issues such as U.S. industrial competitiveness, downturn in the military complex, and the symbol of Interstate Highway completion, (3) the artificial lure of relatively large federal dollars, most of which on closer inspection may not be generally available due to earmarks, and 4) the industrial, if not government, pragmatism that will swiftly follow as the "bandwagon-riders" size up the difficulties of IVHS implementation. Among the difficult lessons that lie ahead is that IVHS may require ten units of institutional innovation for every single unit that is technological in nature. And, clearly, the former moves more slowly than the latter.



Expecting a Shake-out

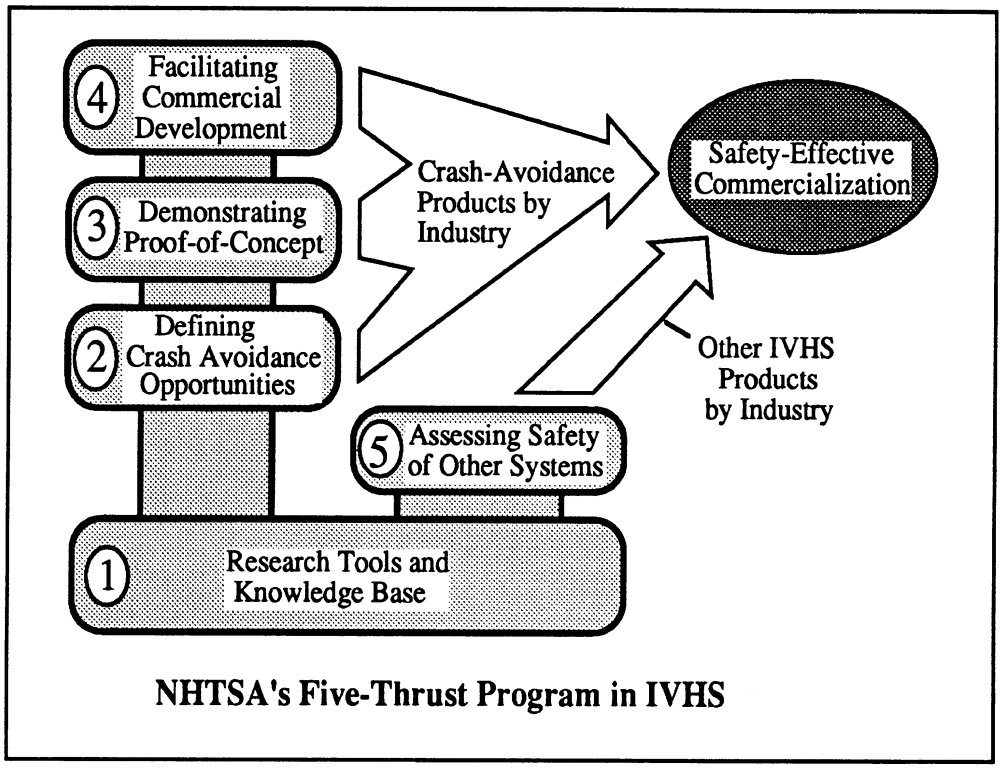
This is not to imply that IVHS will be seen, shortly, as a loser. On the contrary, there is plenty of evidence supporting the argument that large portions of the IVHS vision are, one way or another, simply inevitable. Rather, there is risk of undue dropout from the

IVHS pursuit when the uncommitted elements of the current IVHS community begin to blanch at the difficulties. The IVHS brainchild may go through a rocky adolescence as its conceptualization matures from the purely qualitative to the accountably quantitative.

Accordingly, OEM truckmakers who undertake a methodical exploration of IVHS and its long-term applicability to trucking must configure their programs to survive the phase when IVHS grows thin as a fad, but is still not much of a fact. Although one can take encouragement and guidance from the IVHS America Strategic Plan, and from its expectations of progress, we should note that the pendulum of national IVHS sentiment took its inaugural move in the direction of optimism. An opposite overshoot will probably precede the more stable stage.

NHTSA's Agenda

Shown below is a sketch depicting NHTSA's Plan for IVHS. The planning document, released in June, 1992, would appear to have significance for the potential long-term interests of the OEM truckmaker. Namely, NHTSA sees a substantial portion of its future



NHTSA's Five-Thrust Program in IVHS

mission as helping to enable the "safety-effective commercialization" of what it calls "crash avoidance products" by industry. In that regard, the agency will be developing new public resources through its thrust no. 1, Research Tools and Knowledge Base. Truckmakers

and others can benefit by accessing information on the driving process, tolerance of driver workload, quantification of pre-crash conflicts, and objective characterization of the performance of active safety technologies. While public benefit demands that the agency focus upon key crash avoidance opportunities in its thrust no. 2, NHTSA will encourage vehicle manufacturers and suppliers to collaborate in demonstrating proof-of-concept using real vehicles in the real traffic environment in thrust no. 3.

While the other elements of NHTSA's plan are described in the released document, it suffices to say that OEM truck manufacturers seeking to join in the development and field trial of innovative crash avoidance aids will find plenty of encouragement, and perhaps substantial co-funding, from NHTSA. Clearly, the substance of NHTSA's plan, and the cooperative relationships that it proposes to cultivate, represent a significant aspect of the environment for pursuing the active safety segment of IVHS.

Innovative Fleets

Certain large fleets are moving early in the IVHS era to achieve higher efficiencies and presumably improved competitiveness through the adaptation of information-based systems. Schneider Nationwide, J.B. Hunt, and UPS are among a number of major companies that have invested in information and communication systems offering better real-time control and utilization of their fleets. These operations have apparently added new value-added services as well, once they began to compound system features to cover more and more types of information management. In the process, both the technology and the operations have tended to change.

Clearly, the innovative fleets are engaged in a learning process which has potential value for the OEM truckmaker. OEM's maintaining close association with such fleets gain a "horse-to-ride" for exploring the IVHS landscape and assessing the potential for future extensions to the OEM product.

Telecommunications Readiness

The telecommunications industry is increasingly active in the development of wireless data services for the mobile user. A variety of wireless data media are available today, although none has been expanded to provide ubiquitous coverage and there is uncertainty over which mode might become the "winner" in terms of low-cost popular usage. In one compelling scenario, the move of cellular telephony to provide digital packet data services may, by virtue of its coverage, capacity, cost, and convenience advantages, emerge as the de facto

architecture serving much of the mobile data needs of truck and car applications. By another, a constellation of low-earth-orbit satellites may appear within ten years and compete strongly as a cost-effective mobile data utility that is inherently nationwide and seamless.

For our purposes, here, it is useful simply to note that a wireless data infrastructure exists today and that it is expected to grow to meet the needs of a multi-faceted marketplace. (See, for example, the discussion in "Intelligent Vehicle-Highway Systems: Private Sector Investment Capital and Regulatory Issues", a Research Paper published by Alex Brown & Sons, April 9, 1992.) The trucking community can assume, it appears, that mobile data services will be available from the telecommunications industry at reasonable cost (perhaps less than 10¢ per kilobit transmitted over cellular, for example.) Most believe that the likelihood of service availability will be more or less immune to any fluctuations of interest in the national IVHS program, per se.

Accordingly, while there is broad national debate over the best likely communication architecture for IVHS, there are already mobile data providers that offer services using existing architectures. While no significant infrastructure exists today to effect the very short range communications that support toll collection and the enforcement transactions involving trucks and public agencies, most of the mobile data requirements of interest to truck fleet operations can be met currently through cellular telephone, networks of specialized mobile radio, satellites, paging services, or other media. The ability to communicate information exists—what's needed is the tailorable systems and the applications savvy for generating, processing, interpreting, and distributing information in a way that facilitates the service operation of each trucking enterprise (which number in the hundreds of thousands of corporate entities, nationwide.)

Digital Map Readiness

Another enabling technology is the digital map database. At present two major parties are rapidly codifying the U.S. and Canadian road systems and the protocol for finding addresses which lie along all roads. With preference being given to coding urban areas first, highly detailed maps currently cover the 40 largest metropolitan areas, or some 40% of the U.S. population. This enormous resource is obviously crucial to any truck routing systems that must quickly compute a path from a current location to a codified destination. It can generally be assumed that the deployment of truck routing systems will not be impeded for lack of basic digital map data anywhere in the U.S. after about 1994.

Federal Mission and Appropriations

Aside from the relatively modest role of NHTSA, mentioned above, the major federal players in the IVHS environment are the Federal Highway Administration (FHWA) and the committees of Congress having authorizing and appropriations authority for IVHS. The FHWA draws its assignment in IVHS primarily through the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 which authorized a $660 million federal IVHS program over the '91 through '97 time period and which gave the lead responsibility to FHWA. The highway agency is active in the CVO component of this program through both research and operational test activities which are coordinated by FHWA's Office of Motor Carriers. FHWA is central to the defining and future co-financing of public IVHS infrastructure that may be deployed within State and local jurisdictions, such as that for enforcing truck regulations through the aid of mobile communications.

The current CVO test activities by FHWA focus on the transponder-based systems for expediting and removing the paper from the roadside transaction of truck regulatory enforcements. While this technology appears to have little if any significance for the OEM truck manufacturer, it may also be that FHWA will undertake testing of certain safety concepts that do imply a greater integration with the vehicle, such as site-specific rollover warning. In regard to such active safety types of technology, however, the distinction between FHWA's and NHTSA's interests becomes blurred, especially when the technology does not operate with strict autonomy on-board the vehicle (i.e., NHTSA's apparent realm of statutory authority.) If the OEM truckmakers become interested in active safety technologies, they may find that both FHWA and NHTSA offer collaboration opportunities in operational testing. The industrial sector will be cautious to note, however, that government interest in certain technologies may be only coincidentally related to the market potential of the system. Thus, it falls on industry's shoulders to cultivate those government collaborations having both public attraction and apparent market viability.

5) Considerations of an IVHS Research Agenda for MVMA's Motor Truck Manufacturers

Given the above discussion, it is clear that the domain of potential interest of the OEM truckmaker is narrow relative to the whole of IVHS. Thinking firstly about the OEM product, itself, the central issue has three parts, posed as questions below:

1) what IVHS elements are likely to be installed as components on the OEM truck?
2) which of these are likely to involve a major component engineering and/or manufacturing role by the OEM?
3) for the components not likely to be manufactured by the OEM, what is the scope of the OEM's "integration" engineering task that will assure compatibility with the motor truck system?

The three aspects of the OEM involvement are addressed for each of a set of possible IVHS element groups in the table, below. Over a total of ten elements, the information gained in this study suggests that the OEM truckmaker is unlikely to "build" (that is, take on major component engineering or manufacturing tasks in behalf of) any IVHS item. The exception, again, could occur in the case of a truck manufacturer that is one of a vertically-integrated set of business units in a more diversified corporation.

	Element	OEM-Installed?	OEM-Built?	Extent of Integration Task
1	short-range transceivers (transponders, beacons)	maybe	no	low
2	wide-area transceivers (for cellular, satellite, etc.)	maybe	no	low
3	data-entry and display devices	maybe	no	medium
4	integrated transceivers, processors, entry &display	maybe	no	medium
5	vehicle location system a) dead - reckoning	maybe	no	medium
6	vehicle location system a) GPS or LORAN	maybe	no	low
7	vehicle navigation & routing (with audio & visual display)	maybe	no	medium
8	driver monitoring and warning system	maybe	no	high
9	collision warning, smart cruise control, automatic braking, vision enhancement	maybe	no	high
10	self-certifying weights	yes	no	high

The rows of the table are shaded to delineate IVHS elements calling for low, medium, or high levels of "integration engineering" on the part of the OEM, according to the following generalizations:

- A *low* level of integration applies when the element does not require mounting within the driver's console and does not engage the vehicle control devices or the running gear (i.e., wheels, axles, and drive train.) The element simply constitutes a black box requiring electrical power, mechanically-suitable mounting, and perhaps an antenna space.

- A *medium* level of integration applies when console space is required and issues of driver workload and compatibility arise or when a modest adaptation with the running gear is required.

- A *high* level of integration applies when the element presents a safety-critical function and/or requires a carefully tailored adaptation of the running gear.

Of the group of ten elements, only the self-certifying weight function is seen as *necessarily* an OEM-installed item due to the highly-integrated (and perhaps simply infeasible) nature of the concept, given the stringent need for system credibility that seems to be implied.

Looking at the group of items, it would appear to be in the OEM's interest to move toward integrating those elements calling for *medium* and *high* levels of integration effort. The implication is that a strong case is made whenever integration of the element will assure compellingly higher functionality or safer driving. OEM-integration of such items may not be mandatory, but may yield a more desirable product. An example of this need might be seen in the contrast between vehicle navigation equipment that has been integrally installed within OEM passenger cars (such as in premium automobiles for domestic sale in Japan) as opposed to add-on systems (such as the Bosch Travelpilot) that are installed in aftermarket garages. Even if the component is essentially the same in both cases, the integrated installation may deliver far greater value.

This observation exposes one of the most basic (and perhaps obvious?) principles of original equipment truckmaking: namely, that the careful *integration* of components is, itself, the central value-added of the OEM organization. Further, the cab and the driver's

workspace is at the centroid of the OEM's engineering effort. Thus, packages requiring a carefully-arranged presentation to the driver appear to virtually require integration by the OEM. The ability to balance esthetics with in-depth knowledge of driver anthropometric and ergonomic characteristics (and the ability to make available the priority "real-estate" in the driver's console for installation) represents the niche by which driver-interactive information systems may be captured by the OEM product rather than waived to the aftermarket.

Research Suggestions

Given the range of likely IVHS technologies that may find truck application, the environment for IVHS innovation, and the OEM tradition and areas of competency, the research interests of the OEM truckmaker are likely to emphasize the performance of the overall driver-and-truck system, not the component technology. Thus, the OEM would collaborate with a component supplier, or a government-sponsored research study, largely in the context of the integrated-system issues. Research areas fitting this general outlook will seek to:

1) guide the truck-adaptation of technologies providing:
   - new information interfaces to the driver;
   - new means of supplementing the driver's control of vehicle motion;
2) reveal the broader picture of truck operations and the opportunity for new value-added roles by the OEM vis-a-vis mobile information systems;
3) facilitate standardization of items making it easier to apply IVHS technologies to the OEM truck;

Specific research thrusts that line up with each of these three areas are as follows:

Relative to truck-adaptation of new information interfaces

There is a general need for human factors research that will help guide the design of effective and safe information interfaces for the mobile application. Since a portion of the needed learning will pertain to the ergonomic issues of display placement and size, eye-tracking as a function of display vibrations, and visual and audio contrast in a noise environment, there is a clear need for truck manufacturers to participate, somehow, in such research. Since NHTSA has targeted this area, for pursuit of safety issues in interface design, the truckmakers might seek a complementary stream of research as a partner to NHTSA. Following the "walk-before-run" approach, truckmakers might first undertake a

study to assess the effectiveness and safety implications of various text-display systems that are currently being used in a variety of fleets (see ATA Foundation Report, "A Survey of the Use of Six Computing and Communications Technologies in Urban Trucking Operations, 1991.) Using text-display as an example, the initial study might serve to introduce a framework for considering all of the truck-specific issues that arise from in-cab information displays.

Relative to new means of supplementing the driver's control of vehicle motion

This entire area technology is also targeted by NHTSA in its new IVHS Plan. Thus, one could assume that opportunities for collaboration exist. As one example, NHTSA will procure, over 1992-1994, a entirely new data collection system for measuring the so-called "Vehicle Motion Environment." As the system proceeds to generate a computerized archive on detailed vehicular movement at selected road sites across the U.S., truckmakers could access the archive and process data showing inter-vehicular conflicts and patterns occurring in the vicinity of trucks. Such research would confirm and quantify, for example, the previously mentioned "cut-in" behavior of motorists that so impedes truck movement in heavy traffic. Research of this type would focus upon the truckmakers' specific interests as a potential integrator of collision warning and avoidance aids.

In the meantime, and perhaps as a good-faith expression to work complementarily with NHTSA, truckmakers could conduct a program to evaluate existing rear-end collision warning, and headway-control, technologies in terms of the systems performance achieved in heavy duty trucks. Since the developers of the technologies appear to have had little experience with trucks, per se, a focused study bringing the savvy of truck dynamicists, human factors researchers, and truck product engineers would have value.

Relative to gaining a broader picture of truck operations vis-a-vis the opportunity for mobile information systems

The long term question that seems to be facing truck manufacturers in the context of IVHS is, "How big is my system?" Traditionally, the "system" embraced by the OEM truckmaker has been confined to the truck, itself, as it is conventionally used by individual operator. Expanding the system definition to embrace information technologies that are meant to improve the logistical and time-dependent deployment of a fleet of trucks clearly goes beyond the domain of any current OEM truckmaker. Should OEM's consider fielding products addressing this larger system? Or, should OEM's seek special-technology partners in order to move over the long term toward bigger, integrated, systems? In order

to better assess the scale and potential opportunity of mobile information systems for trucks, the MVMA might undertake a study of various truck operations. The purpose of the study would be to identify the role of information in the conduct of each trucking business. The processes of information generation must be defined to the extent possible and all of the implicit and explicit flows of information identified. We need to define, essentially, the "anatomy" of a truck operation, in terms of the geographical, temporal, and informational components of the operating system. Based upon such anatomies of, say, ten to twenty characteristic types of truck operations, the potential utility of IVHS for improving the efficiency and quality of trucking services. The results would be expressed in terms of the possible match between the operational needs of trucking enterprises and the special positioning that the OEM's represent. Without such research, the truckmakers would probably remain in their present conviction that such information systems, however big the potential market, provide no new role for the OEM.

Regarding the standardization of items making it easier to apply IVHS technologies to the OEM truck

It would appear that a long-term commitment by MVMA, in behalf of its truck manufacturing members, may be warranted in the arena of standards development for IVHS. The question might be put this way: "Who will attend to the truck-suitability of any future IVHS standards?" While the general issue may include many standards that involve truck component suppliers and, perhaps, fleets, it remains that the OEM truckmaker will be especially concerned with a certain class of standards that impact upon whole-truck integration and assembly. While this subject prompts no specific research effort at the present, it seems to warrant inclusion in a long-term rationale for MVMA research in truck-IVHS, perhaps calling for specific studies in the future.