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REFEREED PAPERS

A MEMOIR OF THE ADVANCE PROJECT

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The ADVANCE Project, conducted from 1990 through 1997, was one of the first attempts to undertake a large-scale field test of an emerging technology in the ITS field, specifically in the area of in-vehicle dynamic route guidance. It was also an early example of a public–private partnership involving a large corporation, two university research centers, state and federal governments, and other participants in more specific or minor roles. This memoir, initially written at the close of my involvement in the Project in early 1996, seeks to describe the many institutional difficulties of this undertaking, as well as some of the lessons I learned.

Keywords: ATIS; field operational tests; route guidance

PREFACE TO THIS MEMOIR

In late 1995, following seven years of continuous participation and leadership of the ITS in-vehicle route guidance development project known as ADVANCE, I decided to leave the effort. As my final contribution to the Project, I was asked to draft 1 of 12 sections of a report known informally as “Lessons Learned” on the topic, Public–Private Partnerships, and later published as “Contractual and Management Challenges of the *ADVANCE* Project” (Boyce, Dowell, and Ligas, 1997). During a substantial period of time I devoted to drafting that report, I attempted

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to reflect thoughtfully and critically on my experience of the past seven years. I was not surprised to learn later, however, that many of my reflections, and especially those regarded as critical of Project participants, were removed from the document.

Subsequently, I presented a number of seminars during my 1996 sabbatical travels in Europe based on my draft. Generally, my remarks were viewed as both provocative and instructive, I was told. Believing there was something of value here, I thought it might be worthwhile to publish an edited version of the draft report at some point, long after the participants had moved on to other endeavors. Now seems to be an appropriate time, especially since the last remaining project participant at Motorola has retired. In addition to removing the names of the participants and reflecting the passage of several years, a brief description of the ADVANCE system design is added.

INTRODUCTION

The ADVANCE Project was an operational field test of an Advanced Traveler Information System (ATIS) undertaken with the support of the Federal Highway Administration (FHWA) beginning in 1991, as one element of its Intelligent Transportation System (ITS) program. Many of the operational field tests of that period involved both public agencies and private organizations, including entities from the corporate, academic, and consulting sectors.

The ADVANCE Project was representative of this mix of public and private participants. The public agencies were the Illinois Department of Transportation (IDOT) as well as FHWA. The principal corporate entity in the Project was Motorola, Inc.; moreover, many corporations participated at a lower level, including several automobile manufacturers, both domestic and foreign, a major computer hardware vendor, several software vendors, and other suppliers of ITS-related components. The principal academic participants were Northwestern University and the University of Illinois at Chicago, under the aegis of the Illinois Universities Transportation Research Consortium (IUTRC), a not-for-profit organization operated by the principal transportation research universities in Illinois. The fifth principal participant was the American Automobile Association, in conjunction with its affiliate, the Chicago Motor Club, which joined the project near the end of its design phase. De Leuw, Cather & Company was the systems integration and project management consultant and Argonne National Laboratories was the evaluation manager.

The ADVANCE Project, therefore, was a primary example of a *public–private partnership.* Such partnerships seek to combine the capabilities and benefits of public agencies and private organizations, both for-profit and not-for-profit, in advancing their jointly held and individual objectives. The objective of this paper is to review the organization and experience of the ADVANCE Project from the standpoint of such a partnership.

The paper is organized in the following way. First, the origins and background of the project, and the apparent objectives of the participants, are reviewed. Then, the feasibility study that led to the project is described and its shortcomings addressed. The negotiation of the IVHS Agreement, one principal outcome of the feasibility study, is then described. Finally, several issues related to the experience and outcome of the partnership are examined. Although some of these issues relate to technical matters, this paper focuses on their effect on the partnership.

ORIGINS AND BACKGROUND

The genesis of the ADVANCE Project occurred at a meeting held at the District One Office of IDOT in March 1989, but the impetus for this meeting occurred somewhat earlier. Motorola formed its IVHS Strategic Business Unit to enter the emerging field of intelligent vehicle highway systems (IVHS) in 1988. Its objective was to invest in this emerging technology in order to position itself as a major supplier of ITS equipment. Specifically, Motorola was engaged in the design of a dynamic, in-vehicle route guidance system. Its expertise and strong market share in communications, computer components, and automotive electronics made ITS a natural arena for new technology and product development.

Faculty at two Illinois academic research centers had coincidently identified route guidance as a target for research and evaluation studies. In early 1988 they had described a research project related to dynamic route guidance based on Boyce (1988a,b, 1989) in a University Transportation Center proposal to the U.S. Department of Transportation and IDOT. Moreover, they were beginning to explore linkages with the private sector, including Motorola. Their objective was to undertake research on a variety of issues related to this emerging topic, as well as to raise research funds and involve graduate students in this research activity.

The Federal Highway Administration was a pioneer in the ITS field as early as the late 1960s with its ill-fated electronic route guidance system (ERGS) (see Rosen, Mammano, and Favout, 1970). In response to staff and industry interest, as well as increasing activities in Europe and Japan, FHWA began formulating plans for an ITS program in the late 1980s. One example of this activity was the Mobility 2000 Workshop held in

1989 (Texas Transportation Institute, 1990). FHWA's objective was to lead the ITS technology development effort on behalf of the United States. A principal strategy in this effort was a program of operational field tests with substantial federal government funding. The implicit assumption of this program was that the technology development process was sufficiently advanced that operational tests of the technology were a meaningful next step. Although FHWA had no technology development program, such as the earlier ERGS program, it was undertaking contract research on route guidance management systems.

Finally, the Illinois Department of Transportation had been a leader in the innovation and early deployment of traffic surveillance systems. It viewed the interest of Motorola and the university consortium as a sound basis for entering the emerging area of ITS. Moreover, IDOT recognized the economic development potential for the State of Illinois of a major technology innovation.

The joint interests of Motorola, IUTRC, and IDOT merged in March 1989, at a presentation by Motorola to IDOT staff. Motorola requested the assistance of IDOT in undertaking a field test of the dynamic navigation and route guidance system it was developing, recognizing that information on the status of the roadway system was necessary to the implementation and testing of its conceptual design. Motorola had understood, incorrectly, that traffic information was available for the entire highway system, whereas in fact such data only existed for IDOT's expressways in the Chicago area, and not even for Illinois tollways, much less for arterial streets. The president of IUTRC proposed to IDOT that IUTRC and Motorola jointly undertake a feasibility study of the conceptual design with partial funding from IDOT. A proposal was prepared and approved; the study was initiated in August 1989.

FEASIBILITY STUDY AND ITS SHORTCOMINGS

The feasibility study for ADVANCE was performed jointly by IUTRC and Motorola. IUTRC's work was partially funded by IDOT and partially by the participating universities; Motorola funded the work of its own staff. In this section, technical issues identified in the feasibility study, and their relationship to the public–private nature of the operational test are examined. Then, the system concept is described.

In retrospect, five technical issues either emerged, or should have emerged, in the feasibility study:

- dynamic capabilities of the proposed route guidance system; that is, the use of current travel time information to plan and update routes;

- proposed sources of the dynamic travel time data, and their implications for a two-way communications system;
- need to determine the number of equipped vehicles, or probes, to conduct an operational test;
- centralized versus distributed (on-board) route planning;
- inadequate definition of the components of the system with regard to traffic engineering and network performance.

These issues are now discussed with regard to their implications for the emerging partnership.

Main Technical Issues

From the outset, the Motorola team asserted that the route guidance system should be dynamic, a seemingly reasonable objective given that static systems were already available in the United States from Etak and Delco, as well as General Motors Research Laboratories. Beacon-type dynamic systems were being implemented in Berlin (LISB) and Tokyo (CACS); in addition, the TravTek test was being designed for Orlando with modest dynamic capabilities.

What was not questioned concerning the dynamic system objective was the difficulty, and the time and cost requirements, for designing and implementing such a system from scratch. Given the proprietary nature of Motorola's development effort, and the lack of familiarity with computer software development and electronics on the part of the university team, no assessment of the feasibility of this effort was made, especially at the outset of the feasibility study.

As noted earlier, the status of dynamic road travel time data was not understood correctly by the Motorola team. In fact, detectors networked to a central location were only available for a few miles of one expressway (I-290/IL-53) in the field test area originally proposed by Motorola. The university team took the issue of dynamic data as an intellectual challenge, and debated the merits of a localized beacon system, based on infrared communication between equipped vehicles and roadside beacons, versus an areawide two-way radio frequency (RF) communication system between equipped vehicles and a central traffic information center.

In view of Motorola's strong qualifications with RF communications, and the apparent high cost of infrastructure for the beacon system, the former was recommended to Motorola, and accepted essentially without discussion, as the solution to the dynamic data issue. In the feasibility study report (Boyce, Kirson, and Schofer, 1990), the options were not even presented as design alternatives. The acceptance of this solution without an assessment of the requirements of the communication system, or its cost, reflects the uncritical nature of the study process. In fact, the capacity of the RF communications system became a major constraint during the design phase; because the eventual solution was never implemented and tested, however, its ability to serve the system was never determined.

The adoption of the areawide design alternative led naturally to the question of how many equipped vehicles were needed to conduct the test over an arterial network. This question resulted in the only actual analysis that was presented in the feasibility study. Members of the university team applied a sampling procedure to the results of a static route choice model to determine the frequency of link traversals in a prototype field test area. The result was on the order of 4,000 vehicles operating in the network during congested periods of the day.

This estimate, accepted relatively uncritically by the Motorola and university teams, had huge implications for the cost and design of the in-vehicle unit. It meant that these units would need to be manufactured on an assembly line, rather than being assembled by hand, as was eventually done for the approximately 50 units deployed. It also implied that the units would need to be designed with cost as a major concern, meaning that the computer chip would need to be relatively inexpensive, even in the first model. Toward the end of the design phase, the initial Motorola unit director was heard to state that all he had in mind was to drive 50 equipped vehicles up and down a major arterial, a scale of test never discussed during the feasibility study. In the end, this was the actual result achieved by the test. However, there was little effective, critical discussion between the two teams of alternative designs in terms of scale and level of deployment. Two design issues were not discussed in the feasibility study; had they been considered, the design phase could have proceeded differently and perhaps more successfully. These two issues are discussed next.

Acceptance of the two-way communications concept, required for equipped vehicles to serve as traffic probes, also could have opened the consideration of centralized route planning at the Traffic Information Center (TIC) as an alternative to on-board route planning. The concept design for the in-vehicle unit had the functions of navigation, route planning, and display assigned to its computer. All were defined as real-time functions, implying a rather substantial computing requirement. Moreover, thousands of units were to be produced, meaning that cost was now an important consideration. (The estimate of the in-vehicle unit cost at the time of the feasibility study was $4,000; subsequently, this cost estimate was increased to $6,000. Because no units were ever manufactured, the actual cost remains undetermined.)

One way to reduce the requirements on the in-vehicle unit would have been to perform the route planning centrally, and transmit the route, and possibly route updates, to the vehicle. In a centralized route planning facility, a large engineering workstation with several processors and a large memory could solve a route planning heuristic much more rapidly than would be possible by the on-board unit. Thus, the additional time for sequencing of route planning requests and transmission of the recommended route could be offset by the faster computational time. At the time of the feasibility study, the university team did not include a computer scientist; moreover, because Motorola was viewed as having unlimited expertise in computer engineering and computer science issues, the university team naturally deferred to the Motorola team on such matters. If a more critical and frank assessment of the concept design had been made, perhaps this issue would have come to the fore.

Subsequently, when RF communications capacity became a design constraint, the concept of centralized route planning was raised. At that juncture, it was also clear that the route planning issue was presenting a difficult technical problem to Motorola's operations research staff. However, by that time, the division of responsibilities between Motorola and the universities had been determined, and a substantial redesign would have been required to utilize centralized route planning.

The final issue discussed here concerns the definition of the traffic and transportation network elements of the system during the feasibility study. These elements, which ultimately became known as the Traffic Related Functions (TRF) component, were notably missing from the concept design of the feasibility study. Some of the elements of TRF are present: incident detection is described, as is near-term prediction of travel times. However, these elements were included as part of a related research program proposed in conjunction with the field test, not as inherent elements of the design. Barely mentioned is the notion of data fusion; the use of a network model to prepare initial estimates of network travel times, as was successfully done, is nowhere found.

This evident confusion on the part of the university team arose in two ways. First, a myopic inability to identify and define the traffic-related properties of the system persisted, perhaps because they were too obvious. In fact, as became apparent later, neither Motorola nor the university computer scientists later assigned responsibility for software development for the Traffic Information Center had the technical knowledge to design these elements.

Second, the university team, seeing themselves as researchers and evaluators rather than system designers, were already looking beyond the design and implementation phases to challenging research and evaluation projects. In this case, the Motorola team properly deferred to the university team as the experts on traffic. But, no critical review of this aspect of the design concept was made by the authors of the feasibility study.

Having little internal research capability, and a recent positive experience with IUTRC as an external research arm, IDOT saw its role as facilitating the completion and implementation of the feasibility study. An advisory committee composed of experienced IDOT staff was appointed, but few searching questions were asked, and IDOT deferred to Motorola's expertise on questions related to the in-vehicle unit.

Lessons from Hindsight

What might have been done differently? First, IDOT could have sought external reviews of the feasibility study from the emerging ITS field, with a request that a critical review was desired. Second, IDOT could have applied its own project management capability and experience more aggressively. For example, the cost estimate provided in the feasibility study was only an estimate of the cost of implementing the proposed system, ignoring the cost of designing it. This omission was identified immediately following the completion of the study, and could have been noticed earlier by a more searching review. Third, IDOT could have funded the university team more adequately than the modest level of $25,000 for a $35 to 42 million project, permitting it to involve more academic disciplines, such as computer scientists and communications engineers, in the feasibility study.

IDOT's receptiveness was directly related to its perception of its own role and objectives as a facilitator of a national field test, and its hope that a successful design and deployment would lead to important economic development benefits for the State of Illinois. Motorola did not make matters easier for a state agency by its intensive lobbying at the state and federal levels for its activities. Critical questioning by IDOT staff could easily have been interpreted as obstructionist behavior by the staff of a governor eager for a successful public–private collaboration. In retrospect, critical questioning of the feasibility study could only have helped to improve the design concept and the realism of the size of the design and implementation task. But, it also could have detracted from the support for the project.

Likewise, the Federal Highway Administration did not undertake a critical review. When its representative attended an advisory committee meeting in March 1990, few hard questions were asked, and a general receptiveness concerning an operational test of the probe concept was offered. No written comments were received on the feasibility study from FHWA. Thus, the considerable past experience of FHWA with ITS design, and with operational tests, was not brought to bear on the feasibility study.

ADVANCE System Design

With this description of the feasibility study and its shortcomings as background and context, the system design of the ADVANCE dynamic route guidance system is presented next. This design, however, did not fully emerge until about 1994. An overview of the system design is shown in Figure 1.

The ADVANCE system consisted of four subsystems that may be briefly described in the following way. A detailed description is given in De Leuw, Cather & Company (1995); an earlier version is given by Boyce, Kirson, and Schofer (1994).

- A *Mobile Navigation Assistant* (MNA) providing route guidance functions, and serving as a travel time probe, in each equipped vehicle communicates with the vehicle, the driver, and the TIC through vehicle sensors, a man–machine interface, and the COM, respectively.

  The MNA determines the vehicle's position using GPS, heading and distance sensors, dead reckoning, and map matching. Using the vehicle's current position, the MNA measures the travel time over each link traversed, plans routes, and performs route guidance (visual and voice). The MNA communicates with the TIC to transmit travel times and assistance messages. The MNA in turn receives GPS correction factors and travel time updates. Within the MNA a CD database contains estimated travel times for each link and a map database.
- The *Radio Frequency Communications Network* (COM) provides the ability for MNA-equipped vehicle probes to communicate with the TIC as these vehicles traverse the roadway system. The COM provides an areawide two-way transmission system supporting mobile data communications. As originally envisaged, the COM would support several thousand probes.

  In the vehicle, the COM provides a mobile communications link between the MNA and the TIC computer, bringing the mobile data communications back to the TIC and converting it for use by TIC software. There is no operator interface; transmission of messages

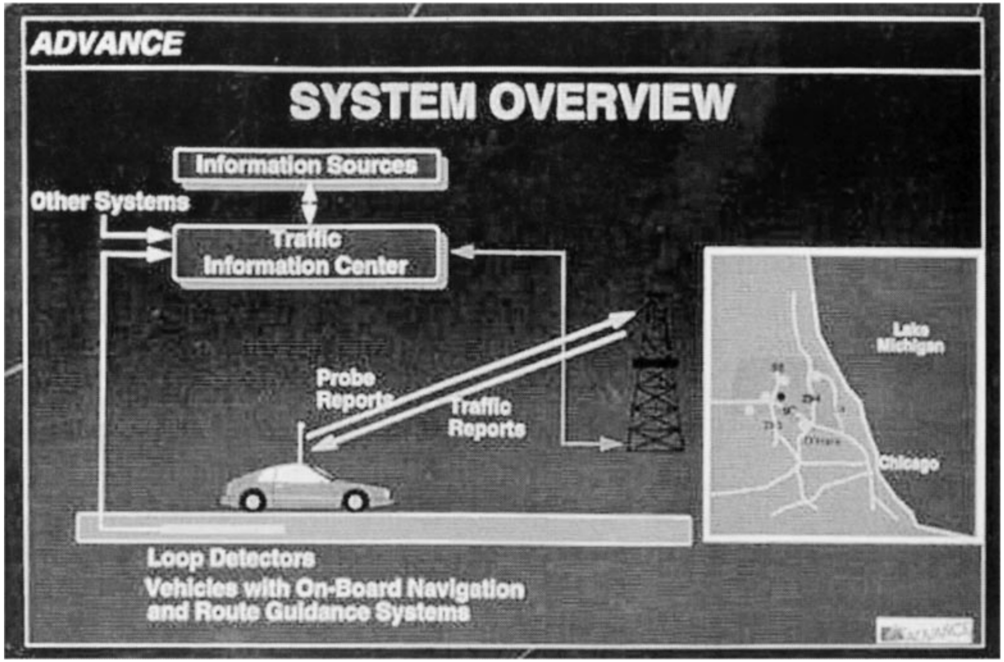

FIGURE 1. ADVANCE System Design Concept.
Source: *ADVANCE* Information Source, available at http://advance.dis.anl.gov

between the TIC and the MNA is an automatic process with no manual intervention required.

- The *Traffic Information Center* (TIC) provides the IDOT operator service and the central computer system. The TIC includes the central computing resource, console functions, communications interfaces, active data storage, archiving, and other services. It also receives probe data from the MNAs and prepares travel time estimates.

  In addition to the MNAs, the TIC communicates with all other external entities: (1) information collected by IDOT's Traffic System Center from roadway detectors on area expressways is downloaded to the TIC and stored; (2) detector data is downloaded from closed loop signal systems with online communication capabilities; and (3) data received from anecdotal sources including weather conditions, incident reports, and lane or road closures.
- *Traffic Related Functions* (TRF) provide travel time estimates and predictions, incident detection, and data fusion.

  An off-line network model estimates link travel times at the detail of intersection turning movements by time of day, and is used to initiate the route guidance system. Future link travel times are predicted dynamically within the TIC utilizing these prior estimates and historical and current data for usual travel conditions. In cases of unusual conditions, a process detects and classifies incidents from two sources: (1) manual detection (incidents by automated or anecdotal sources); and (2) automatic detection. Finally, data fusion performs an in-depth verification of the reasonableness and internal consistency of all traffic-related data across time intervals (probe reports, loop detector data).

NEGOTIATION OF THE IVHS AGREEMENT

In the end, then, the feasibility study became the initial stage in the implementation of the project, a task to be completed in order that negotiations could begin on an agreement to proceed with the actual design work. The concept design was incomplete, and probably flawed, the cost estimate was rudimentary, and important questions regarding the sources of funding and sharing of costs by the primary participants were not addressed.

The final report on the feasibility study (Boyce et al., 1990) was submitted in August 1990. Shortly afterwards, a meeting was held concerning the next steps needed to implement the project. This meeting led to the preparation of an initial budget for the design phase, then estimated as 12 to 18 months, and set the stage for the negotiation of an agreement among the four participants (FHWA, IDOT, Motorola, and IUTRC) to undertake the operational test.

The negotiation of the agreement began only in November 1990, and continued at the rate of about one meeting per month through March 1991. A signing ceremony was initially scheduled for April, but actually occurred on July 9, 1991. The participants in the negotiations were FHWA representatives from the Washington operational field test office and FHWA's regional and state offices, the principal participants in the feasibility study from Motorola and IUTRC, and IDOT staff, mainly from its Urban Programs Planning Branch in Springfield. The meetings were chaired by IDOT staff.

The principal issues considered in these negotiations go to the heart of the public–private partnership that was sought. They are the following:

- objectives of the operational test and responsibilities of the parties including the need for a systems designer/architect;
- governance and project management;
- source of funding and cost sharing by the participants;
- intellectual property rights;
- liability for accidents occurring during the test.

These issues are now discussed in the order listed, which corresponds to their order in the IVHS Agreement.

Objectives and Responsibilities of the Parties

The project's goals and objectives were addressed in the feasibility study and reviewed in these negotiations. They were broad, relatively far-sighted, and uncontroversial. With regard to IDOT, the enhancement of existing IDOT District One operations was emphasized. With regard to ITS, testing the effectiveness of using vehicles as probes was cited as the first of four items. Objectives of IUTRC and Motorola were also included.

The original drafts of the Agreement used the term *partners* to refer to the four main participants in the project. At the insistence of FHWA, this term was changed to *parties*. The reason was that the federal government could not enter into a formal partnership of the type defined in the Agreement. Although this terminology caused much semantic confusion, no substantive effect or change seemed to result.

The discussion of the responsibilities of the four parties began with a design review at Motorola in November 1990. By this time, IUTRC had added a computer scientist to its team, who was qualified regarding the use of engineering work stations for real-time operations, as well as search methods for route planning in various applications. This design review raised for the first time the issue of the need for a systems engineer, also referred to as a systems architect. The issue was raised by Motorola's leadership. It was evident that Motorola wanted to limit its responsibility to the in-vehicle and communications systems, but at the same time wanted to ensure that provision was made for the overall systems design.

In the final version of the agreement, however, the issue of systems design was not addressed, and therefore Motorola did not succeed in placing responsibility for this issue. This issue of systems design was addressed again in procurement of a project management consultant, which ultimately added the role of systems design and integration. The issue was relatively controversial, if only because of the lack of experience of all parties, including Motorola staff, with the design of a complete system.

The responsibilities assigned to IUTRC served to begin to clarify its future role in the project. First, the design and implementation of the Traffic Information Center was assigned to IUTRC, in recognition of its enhanced computer science capabilities. Second, incident detection was identified as part of this design, which was in effect the beginning of the Traffic Related Functions component, not yet identified as separate from the TIC component. Third, additional responsibilities were assigned to IUTRC related to system design, in addition to evaluation. The research program described in the feasibility study report was not included, FHWA being adamant that this project was an operational test, not research.

Although IUTRC succeeded in securing responsibility for the preparation and conduct of "selected components," the primary responsibility for the preparation of the evaluation plan, and its implementation, was reserved to FHWA. The rationale was that FHWA was responsible for a program of operational tests and needed to ensure that the evaluation plan was designed in a manner that would permit the comparison of results from several tests. Because a primary motivation for IUTRC to participate in the operational test was its interest and expertise in evaluation, this issue became particularly delicate. At one stage, the FHWA representative stated that IUTRC was welcome to respond to a likely Request for Proposals for the evaluation contract, much to the consternation of the university evaluation experts. In the end, the issue was not resolved, except IUTRC was assigned responsibilities related to certain evaluation work plans and their conduct. This issue illustrates the difficulties of defining and accommodating the diverse objectives of the parties in a public–private partnership.

Project Management

Responsibility for project management was assigned to IDOT. In addition, a Steering Committee was defined with one representative for each party. A Liaison Committee was also described. The latter was never formed, but some of its functions were performed by the Technical Advisory Committee and its several subcommittees. The Steering Committee definition and functions were not controversial, and it did function well.

Project management functions were described only in terms of administration of contracts. Although there was no reference to contractors, it was implied that the contracts were with Motorola and IUTRC, as well as other participants. This provision placed IDOT in the position of being both the sponsor and manager of the project, as well as a participant in the technical design process. The evident conflict of interest defined by this arrangement was not discussed, if it was even noticed. The implications of this arrangement are discussed further in the following section.

Not discussed in the Agreement under project management was IDOT's role in defining the design and implementation schedule and related work programming activities. However, these requirements were defined in a Request for Qualifications (RFQ) prepared for distribution to IVHS systems engineering consultants. Likewise, the role of the engineer in system design and integration was not noted. These functions were described in the RFQ, but the main emphasis was on project management functions.

Funding and Cost Sharing

The provision for project funding in the Agreement stated that the estimated cost of \$35 to 42 million (taken directly from the feasibility study) "will be split 50% from federal sources, 25% from state sources and the remaining 25% from Motorola, the Consortium and other private sources." Moreover, it was stated that the in-vehicle hardware funding would be divided equally among federal, state, and Motorola and other private sources.

The 50/25/25 division of funding for costs other than in-vehicle hardware was readily accepted by all parties. However, the negotiations lacked detail, and therefore, it was not clear what this division meant. This ambiguity was especially true for Motorola and IUTRC. The participants to these discussions generally understood that Motorola would pay for the design costs of its in-vehicle unit. It was never estimated, however, how large these costs might be, and therefore what part of the

25% private cost share they might comprise. In addition, it was never discussed how these costs would be accounted for and audited, which became a major issue during the design and implementation phases of the project.

IUTRC was never clear until it actually received its first contract in August 1991, what its cost share would be, and how much of its cost share could be provided by other sources. In other words, the 50/25/25 split was only discussed in terms of the entire project, and not as applying to individual contracts between IDOT and the two private parties. However, the agreement did state that support may be solicited by individual parties and applied in support of their responsibilities under the Agreement. What was unclear was how such support would be represented in the contract budgets between IDOT and the other parties. As implemented, IUTRC's contracts required a 25% cost share; third party sources could be used to the extent they are available and represented in the IUTRC budget. In other words, if IUTRC succeeded in raising project funds unrelated to its responsibilities, it had no way to count these donations as part of its cost share. In reality, this did not become an issue, because no such funds were raised.

The split of funding for the in-vehicle hardware was especially contentious. FHWA maintained it could not participate in a major equipment procurement as part of an operational test. Because the cost of the equipment was estimated to be $14 to 18 million, it was clear that Motorola could not contribute this amount. An agreement was reached among FHWA, IDOT, and Motorola in early 1991 to split the costs equally three ways. Motorola believed at that time that it would be able to convince domestic auto manufacturers to contribute all or most of its one-third share of $5 to 6 million. As the project moved slowly toward implementation, this belief was tested and found to be excessively optimistic. As a result the agreement was renegotiated with the federal share increasing to about 70%.

Intellectual Property Rights

The negotiation of intellectual property rights was a perplexing issue, in part because the representatives of the parties, other than Motorola, had little experience with such matters. Moreover, they were not familiar with the federal laws governing intellectual property developed with federal funding. Because this is an issue rife with misunderstanding, the provisions of the Agreement are quoted in some detail.

First, the Agreement defines *PARTY intellectual property* as copyrights, patents, trade secrets, and any other form of information developed by a PARTY with its own funds. Such Party Intellectual Property remains the property of the party.

Second, and more important, the following section of the Agreement describes Intellectual Property Developed with Government Funding:

> In accordance with provisions of 35 USC 200-212, which gives non-profit organizations and industry the right to retain intellectual property rights covering technology developed with government funding, each PARTY shall own and retain all rights to its inventions, discoveries and works of authorship made or created with government funding (referred to below as "Government Funded Developments"), subject only to the following:

1. The federal government and the State of Illinois shall each have a royalty-free, non-exclusive, and irrevocable license under any patents and copyrights covering such Government Funded Developments to use, reproduce, publish, and to authorize others to use the Government Funded Developments on behalf of the federal government or the State of Illinois.
2. Each non-governmental PARTY shall have the right to use other Government Funded Developments only in connection with its work under this Agreement. Use shall be on a royalty-free basis.
3. Government Funded Developments that are made jointly by the non-government PARTIES shall be jointly owned by those PARTIES and shall be subject to all the conditions set forth in this paragraph.
4. A PARTY who makes an invention with government funding shall, within two years after reducing the invention to practice, either 1) make its election to retain title to the invention under 35 USC 202(c), or 2) publish the invention for the purpose of putting it in the public domain.

The federal legislation referred to above is the Bayh-Dole Act (P.L. 96-517), passed in 1980, and amended in P.L. 98-620 in 1984. This law amended Title 35 USC by adding Chapter 18, Section 200-212. The law was a culmination of events since 1945 leading to the decision that the public is best served by a policy that encourages the utilization of inventions produced under federal funding and promotes the participation of universities in the development and commercialization process (paraphrased from Council on Governmental Relations, 1993). The legislation is also implemented as OMB Circular A-124, subsequently codified as 37 CFR Part 401. Moreover, the Federal Acquisition Regulations (FAR) were amended in 1984 to assure that all R & D agencies would implement the Bayh-Dole Act.

The language of the Agreement with regard to this issue was provided by the Office of the Chief Counsel of FHWA. Unfortunately, no representative of that Office attended the negotiating meetings to explain the concepts and application of the Act. Moreover, IDOT and FHWA staff were essentially unfamiliar with these concepts. As discussed later, despite the clear-cut provisions of the Agreement, the intellectual property provisions of the Agreement were largely being ignored, either through misunderstanding of its provisions, or a sincere belief that the public interest is better served by placing inventions made with government funding in the public domain.

Once the language drafted by FHWA was provided and reviewed by Motorola, IUTRC and its member universities, there was no controversy about these provisions of the Agreement during the negotiating period. Whatever disagreements took place occurred before an understanding of the law was obtained.

Liability

Because the design of the ADVANCE Project provided for placing route guidance systems in private vehicles, there was substantial concern about the liability of the parties in the event of accidents involving these vehicles. Other than providing for sensible procedures in screening drivers during the recruitment process, it was concluded that there were no workable mechanisms for limiting the liability of the parties. In the end, each party agreed, in effect, to be responsible for its own liability, and not to be liable to the other parties.

EXPERIENCE AND OUTCOMES

In this final section, comments are offered on the experience of the ADVANCE public–private partnership and the general outcomes of the project from this perspective. These comments are organized in the following way:

- use of operational tests in technology development;
- contractual and cost-sharing issues;
- project management methods and their application in technology development;
- intellectual property;
- project leadership and duration.

Technology Development Research

FHWA embarked on a program of operational tests of Advanced Traveler Information Systems in 1989. The first project under this program was the Pathfinder Project conducted using Etak technology in the Los Angeles–Santa Monica Corridor. Subsequently, FHWA participated in the TravTek Project in Orlando, Florida. In both cases FHWA was responsible for evaluation, and contracted with consultants and universities for the required evaluation studies. Federal funds were not used to undertake the operational tests themselves.

During this period, the Research Division of FHWA at Turner-Fairbanks Laboratories was also engaged in a few projects related to ATIS based on computer simulation. However, to the author's knowledge, FHWA had no basic or applied research program related to ATIS. Moreover, at that time FHWA actively opposed, and effectively prevented, the National Science Foundation from awarding grants to universities in support of ITS research.

As a result, the only external support available to academic researchers desiring to participate in the development of this emerging technology was to become involved in an ATIS operational test. Industrial research units, such as those at Motorola and General Motors, also recognized that they could not undertake the development and testing of this technology without the involvement of a public agency. Unlike other industrial sectors such as telecommunications, the road network is public infrastructure on which experiments cannot be conducted by a private organization. The lack of a research program, or the creation of an appropriate testbed for the use of private developers, meant that they had no recourse but to attempt to create an operational test. The result, almost inevitably, was that research must be conducted during the design process; for this reason, alternative solutions may not be explored as fully, and as objectively, as desirable.

To illustrate this point, the following list of research areas that would have benefited from academic and pre-competitive industrial research in 1989 is offered.

- navigation system algorithms and computational requirements;
- algorithms and fast heuristics for route planning;
- computational requirements for centralized versus distributed (onboard) route planning;
- communication system requirements for centralized versus distributed route guidance systems;
- in-vehicle display methods and associated computational requirements;
- data fusion procedures;
- incident detection algorithms;

- travel time profiles and prediction methods;
- dynamic traffic assignment models for ATIS and ATMS operations.

In various ways, all of these research issues were examined in the course of the ADVANCE Project. In some cases methods were devised as needed, but not reported to the field. In others, the issue was simply ignored, and a pragmatic decision made in support of a party's vested interests or in ignorance of alternative approaches.

As a public–private system, ATIS benefits from the development of a public knowledge base in a way that totally private systems do not. For this knowledge base to develop, some government research funding is required. A portion of this funding should be available on an unsolicited proposal, investigator-initiated, peer-reviewed basis, in addition to procurements such as the System Architecture Study initiated by FHWA subsequent to the commencement of the ADVANCE Project.

Contractual and Cost-Sharing Issues

IDOT's contractual and project management role in ADVANCE placed it at best in an awkward position vis-à-vis the other parties, and at worst in a conflict of interest situation. On one hand, IDOT was purchasing contractor services, sometimes of a consulting nature from its viewpoint, from the other parties. As contract manager, IDOT was also responsible for making and maintaining a schedule. On the other hand, as written in the Agreement, IDOT was one of four parties *jointly* participating in the design and implementation of a very complex system. These dual roles effectively resulted in a conflict of interest, especially with regard to contract budgets, schedules, and even design alternatives. The ultimate result of this conflict was that ADVANCE gradually became less of a public–private partnership and more of a public project with three private contractors: Motorola, IUTRC, and the project management and systems integration consultant.

Whether this result could have been avoided through a wiser design of the institutional framework is unclear. Obviously, it is necessary to have a management function in such a project, and from time to time it may be desirable to hold to established schedules, however arbitrary they may seem. At the same time, as noted earlier, ADVANCE had much in common with applied research, in addition to systems design. Research often requires a creative process, and cannot generally be conducted on a schedule, as much as managers would like to wish to the contrary. This observation is especially true of the conceptual stages of such a project. The experience of similar projects in completely different fields may provide useful insights to ITS in this regard.

In its role as contract manager, IDOT also had responsibility, jointly with FHWA, for administration of the cost-sharing agreement and for audits. These issues are examined next.

For the universities, provision of their cost share effectively means a modification of the usual approach to budget preparation. Universities routinely cost share on externally funded projects by contributing more faculty time than is stated on the project budget. Because faculty do *not* maintain time records under the requirements of OMB Circular A-95, they are generally not even aware of the amount of this cost-shared time. For ADVANCE, this additional time had to be explicitly built into their budgets, requiring a different way of budgeting. Moreover, if contributions of computer hardware and software were secured, these costs also had to be reflected in the budgets, whereas normally they would be simply regarded as academic discounts or outright contributions in support of the university's educational and research programs.

Having learned to make these adjustments in their procedures, the budgets submitted by IUTRC often seemed much larger than IDOT may have been accustomed to. In fact, they *were* larger, because they reflected a fuller accounting of the actual research program costs than is generally provided. After the first year's learning experience, however, this new budgeting process proceeded fairly smoothly. Other questions concerning the application of indirect cost rates were also gradually resolved to the satisfaction of all concerned.

Motorola faced an entirely different problem in contracting with IDOT. Most of Motorola, and in particular its IVHS unit, is not organized to accept contracts from a public agency that requires accounting for expenditures, followed by an audit. In contrast, Motorola conducts its business on the basis of purchase orders for equipment and services at stated prices. Because Motorola desired to accept contracts from IDOT for its responsibilities pertaining to RF communication systems, it needed to find a way to account for its contract and cost-sharing expenditures and to be audited on them. The solution was to establish an independent accounting system within its IVHS unit for these contracts. This accounting system also needed to provide a basis for negotiating and auditing an indirect cost rate.

These two contractual issues, both with the universities and with Motorola, go to the heart of the difficulties of a public–private partnership. To the author's knowledge, there are no better approaches than the ones employed here for passing funds between public and private organizations, short of outright grants, which are a somewhat extreme solution in terms of relinquishing control. As with any administrative process, excellent communication and explicit, even-handed application of procedures can help to facilitate the difficulties of this unusual institutional format.

Project Management Methods

Over its five-year duration, the managers of the ADVANCE Project experimented with various project management methods. Essentially, these methods are drawn from (1) the civil engineering subfield of construction management; and (2) the computer science subfield of software development using the military requirements specifications approach.

Construction management methods ranged from highly detailed critical path analysis methods to more generalized procedures involving milestones. Typically, several hundred specific tasks were defined, related, and monitored through monthly progress reports. Motorola and IUTRC, as well as De Leuw, Cather & Company, the project management consultant, each devoted at least the equivalent of one full-time person to these tasks throughout the project.

The requirements specification approach to preparing a detailed system design developed out of military software procurement processes. The approach may be briefly described as one of first describing the functional requirements for the desired system, and then making a detailed specification of the system requirements. This method envisages that the technology is relatively mature, and the challenge is to design a specific application. As discussed previously, these conditions were not met in the ADVANCE Project.

Several problems were experienced in attempting to apply the requirements specification approach. First, the consultant, who recommended the approach, had very little experience with it. Second, although Motorola staff was generally familiar with the approach, it was unclear whether they took its use seriously, in part because it was taking time and resources from their internal technology development and design activities. Third, the academic transportation researchers were unacquainted with the approach, although their computer scientists had a general familiarity and some experience with it. Finally, and most important, it is highly questionable whether this approach is at all suitable for a system that requires solving many research problems during the design process. In retrospect, the requirements specification approach did not serve the project well.

In a large-scale project such as ADVANCE, nevertheless, detailed management of personnel and budgets are clearly necessary. The time-honored method of dividing large tasks into smaller subtasks and even subsubtasks is clearly one appropriate management strategy. How much effort should be expended in monitoring this system is a difficult and contentious question that tends to bring managers into conflict with the designers being managed.

The general experience with ADVANCE can be summarized by stating that more aggregated techniques were more useful than more detailed techniques. Given a milestone chart that fits on one or two pages, a group of project leaders could at least visualize their tasks and discuss deadlines and progress toward them in a meaningful way. Whether the more detailed description of tasks provided any useful insights or measures of progress is unclear.

A related question concerns budget planning, both for annual work programs and the entire project. As already noted, the budget prepared during the feasibility study was quite incomplete. An attempt was made shortly after to devise a budget for the design phase. The difficulty with this budget-making process was that the budget planners were always in the position of advocating the implementation of a proposal or a proposed solution to an unsolved problem. If they erred on the side of ensuring the successful solution of the problem, the budget could be so large as to be rejected. On the contrary, if they kept the budget low, so as to be more attractive, then the project would be more likely to fail. Budgeting, then, is another conflict-of-interest dilemma faced in such projects. In ADVANCE, the planners often convinced themselves the design problem was substantially easier than turned out to be the case. Variations on these themes occurred each time budgets were prepared.

A different design approach, known as *rapid prototyping* may have helped to avoid some of these problems. In rapid prototyping, emphasis is placed on quickly designing and implementing prototypes of the desired system. The first prototypes are rough and simple, but they prove or disprove concepts and identify design problems. Subsequent prototypes are more detailed and sophisticated. Competing designs may also be explored in prototypes prepared in a parallel manner.

The rapid prototyping approach may be regarded as the opposite of the requirements specification approach employed in the ADVANCE Project. Given the number of unsolved problems identified during the course of the project, it would appear that the rapid prototyping approach might be preferred. Indeed, both IUTRC and Motorola computer scientists did have parallel software development efforts underway from time to time. From the top-down perspective of the project managers, however, such efforts were likely to be regarded as duplication of effort, and therefore wasteful of project resources.

Clearly, the ADVANCE Project was not the first project to face these questions. Because most of the project leaders had no previous experience with this type of technology development effort, they had to rely on the project management consultant, as well as their own best judgment. Although project management itself was identified early by both IDOT and Motorola as an unresolved issue, the interviews with six prospective project management consultants provided no assurance that anyone knew how to manage such a project. Perhaps accounts of positive experiences do exist in the computer science and engineering or in the aerospace field. If so, managers of future projects would be well advised to study them carefully.

No generally recognized methods for this project management can be recommended, based on the experience of the ADVANCE Project. Whether analysis of successful projects would enhance the understanding of these issues is less clear. Undoubtedly, experience and a willingness to keep the whole project in focus and perspective are important ingredients of success.

Intellectual Property

As reviewed in the earlier section on the negotiation of the IVHS Agreement, the intellectual property provisions of the ADVANCE Project were very clear. The creators of patentable and copyrightable property had the right, and were encouraged, to claim ownership of their property, whether it was created with public or private funding. In its implementation, however, the rules of the Agreement were largely ignored, either because they were forgotten or regarded by project managers as inappropriate.

With regard to intellectual property, Motorola and the universities were treated differently, not withstanding their parallel status in the Agreement and in contractual relations with IDOT. When relating to a large, highly successful and very important technology development corporation in the State of Illinois, IDOT readily deferred to Motorola on issues of intellectual property. Design decisions were consistently oriented toward enhancing the prospects of Motorola in bringing its route guidance system to fruition in the marketplace. After all, this was a primary objective of the project. Only when schedules were jeopardized, or when contractual requirements for audits were implemented, did IDOT treat Motorola in the same manner as it customarily treats its consultants.

In the case of the universities, an intention to patent or copyright intellectual property was regarded by IDOT as an effort to benefit inappropriately from the results of a publicly funded project, even though the investigator was doing precisely what was intended by the intellectual property provisions of the IVHS Agreement. In effect, the Agreement was ignored, and IDOT reverted to its traditional stance in procuring consultant services: whatever is produced on the contract belongs to the State. This was true even though the university would own the copyright, and even though one university was a public university of the State of Illinois.

Project Leadership

At the time this memoir was first written in early 1996, seven years had elapsed since the March 1989 meeting that was the genesis of the ADVANCE Project. None of the persons who attended that meeting had been actively involved in the Project for the past three years. Equally important, the supervisors of many of the leaders of the project had changed during this seven-year period.

Technology development efforts require a long time to bring to fruition, and therefore, they require unusual focus and persistence to achieve positive results. Many of the leaders of this project found this length of time to be extremely long in terms of their previous professional experience.

Equally important, supervisors typically evaluate the success of projects under their purview on an annual basis, or less; likewise, their success as managers is evaluated on the same basis. A long-term development effort of the nature of ADVANCE is in conflict with this time scale. Shorter term objectives and successes are needed to maintain the interest of management, both public and private. On the public side, in the course of seven years, the federal political environment of ITS had changed from highly positive to barely tolerated. And in the private sector, ITS had lost much of its glamour whereas other technology developments, such as computer networking, made huge gains.

Finally, it is necessary to address the issue of experience. Almost everyone involved in this project had no prior experience in an effort of this type. By prior experience, I do not mean with ITS, because in 1989 almost no one had significant experience with this concept. By prior experience, I mean experience with a large-scale technology development effort. I am convinced that everyone involved did their best to make wise choices and to learn from other similar experiences. But collectively, this project consisted of learning by doing.

EPILOGUE

At the end of my sabbatical year in late 1996, I made a conscious decision to leave the ITS field and return to my long-term research interests in travel forecasting, primarily in the context of long-range urban transportation planning. I have continued to follow developments in dynamic traffic modeling, however. Now, nearly six years later, I can report that this choice was the right one for me. My research has been highly productive, and I have enjoyed my return to the classroom, especially with teaching of undergraduate and professionally oriented students.

Still, I am very pleased that I was a participant in the ADVANCE Project. It offered me a once-in-a-career opportunity to engage in inventing, and attempting to implement, something rather new. But afterwards, it was clear to me this was not an experience I wanted to repeat. Perhaps this memoir helps explain why.

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