

The Intelligent Transportation Society of America

VII White Paper Series
**Technology Evolution: Lessons Learned and their Impact on
VII Applications**

Executive Summary

The Vehicle Infrastructure Integration (VII) program has the potential to revolutionize transportation by creating an enabling communication infrastructure that will open up a wide range of safety and mobility applications.

This paper explores a number of technology introductions in the past few decades and reviews the challenges, success stories, and lessons learned from these examples as they relate to the VII program. We consider such life-altering program introductions as the Internet, the mobile communications device, and the personal computer, and contrast these with other large programs such as the seat belt mandate, the launch of the space shuttle, and the ongoing struggle to develop a strategic defense initiative.

From these examples it is clear that predetermining the value proposition is difficult. Can the core VII network be deployed with the realization that the benefits of a technology are not always determined until after the technology has been put into the market and many applications have been attempted?

To the partners involved in developing the VII network it is probably intuitive that an application that requires everyone participate or that the entire infrastructure be in place will take years to come to fruition. But have the VII program partners fully considered that the successful development of the broad vision of VII applications will require continual interactions among technology developers, application developers, and users?

And of course timing remains a key issue - an application may become useful to some long before the majority of users are connected to it. From these examples it is clear that we should seek to develop the applications that have immediate and large benefits to users who will be the first adopters. The applications should address their specific needs rather than more general ones. The value proposition for early adopters will be immediate and apparent, leading to subsequent applications and new populations of adopters.

History tells us that if we do not take an open-architecture, incremental approach, that if we do not take into consideration that consumer acceptance requires a lot of hard work, we are geometrically increasing the risk that VII applications never get fully implemented and accepted.

Introduction

The Vehicle Infrastructure Integration (VII) program has the potential to revolutionize transportation by creating an enabling communication infrastructure that can open up a wide range of safety and mobility applications. Dozens of potential “user services” (applications) have been identified, broadly categorized within the areas of safety, mobility, and consumer and commercial. The development of applications to fill those user service needs has yet to fully begin, while the partners developing the basic VII network continue to finalize their technical and institutional approach.

But before application development gets underway, it is useful to look at other technology rollouts and at the very least, increase awareness of what challenges and successes they encountered. Shouldn't there be lessons learned from product/service launches in the past that allow us to calibrate our expectations accordingly?

The intent of this paper is to briefly review several examples of technology introduction, and relate such issues as consumer acceptance, government roles and responsibilities, open architecture, and timing to the future deployment of VII applications.

Consumer Acceptance

The partners engaged in developing the basic VII network have focused heavily on safety as their most critical user need, in attempt to significantly reduce more than 42,000 fatalities each year on our roadways. A desire to reduce fatalities and accidents is driving some of the technological development and providing an impetus to navigate through difficult institutional development.

If safety is truly a key application that will define the success of VII, one could argue that near-universal market penetration of safety-focused applications will be necessary to have a significant impact on transportation fatalities. Anything less would result in a mix of vehicles on the roadway with some working in cooperation with the infrastructure and others potentially working against.

The ITS industry's most significant challenge may be to find a way to buck the general trend of technology development and reach near-universal market penetration in the short run. History has taught us that customers fall into one of five categories, each of which tends to adopt technologies at a different rate, defined as the diffusion process. The five customer categories are:

- Innovators – willing to experiment with new technology
- Early Adopters – will adopt because they have special problems to solve
- Early Majority – will adopt once an innovation is considered mainstream
- Late Majority – come late to adoption because they are risk averse
- Traditionalists – may never adopt the innovation

If simply left to market evolution, history shows that the majority of the market will only adopt new technologies after “innovative users” have tried the technology and given their approval. Given the ongoing fatality threat, do we have the luxury of progressing through “the diffusion process” to succeed? If not, can we short-circuit that process?

EXAMPLE: Mobile Communication Devices

The introduction of mobile communication devices - beginning with the cellular phone - has resulted in a near-universal consumer acceptance of such technology. But it did not happen quickly, and in general it followed the diffusion model.

Build-out of the cellular network was funded solely by private investors, but the federal government did play a role in helping organize the licensing scheme. The first system started in Chicago in 1983 and grew to 29 other cities in 1984. When the first applications became available (cell phones), the infrastructure network itself was very primitive and lacked coverage.

In the early years there were technological challenges (analog devices that were large and bulky) and institutional challenges (pricing issues, jurisdictional coverage problems). By 1990, the market had reached a mere one percent penetration and none of the companies had turned a profit. They survived, largely, on huge investments based on the future promise of the technology.

During 1990s, a second generation of applications (digital cell phones) began to roll-out, which solved many of the technological issues, but companies still needed to address network coverage issues and therefore had to invest large sums of money into building out more infrastructure. As a result, almost none of these firms were able to turn much profit in the 1990s, but consumer acceptance was finally experiencing rapid growth, and reaching toward that venerable “tipping point.”

In 2001 the market penetration surpassed 53 percent and a few of the cellular companies began to merge, finally creating a market with profitable competitors. It was estimated at the end of 2001 there were over 128 million subscribers. As this paper is being written in September 2005, there are now more than 195 million subscribers, with the 200 million mark probably only months away from being breached.

The mobile communication device (e.g., cellular phone) took nearly 20 years to reach widespread consumer acceptance. Can VII applications that result in reducing fatalities wait 20 years for universal consumer acceptance?

Government Roles & Responsibilities

As noted, two of the early problems with the cellular phone network were clearly the use of large analog devices and the lack of coverage nationwide. Are there examples where the government has stepped in and helped overcome those challenges to help dramatically increase market penetration of an application?

EXAMPLE: Minitel

In 1981, when the Internet was really a collection of specific proprietary networks, the French government perceived a need for some national role for networked information. They decided to create a closed system and determined the technology and initial application. They turned to France Telecom to provide the infrastructure of telephone lines and to Alcatel to provide the boxes.

The initial application was the national telephone directory. France Telecom gave away the boxes for free and the first three minutes of each call was free. France Telecom eventually asked information providers to offer proprietary content that users would be charged for and billed to their phone lines. These applications needed to fit into the constraints of the system – low speed phone lines and modems. By 1995, 26,000 content services were available that had low-graphics, low speed possibilities.

The system did work well and was ahead of the general-use capabilities of the Internet up until the mid 1990s. But at Minitel's peak in 1997, only 20 percent of French households and about 33 percent of the population had acquired the system. The majority market, however, had not accepted the system. From 1997 to 2003, Minitel revenue declined by 33 percent, usage declined precipitously, and the number of content services was estimated to have declined to 13,000.

The predetermination of the technology by the French government limited further development that would have continued to open up the market. The government plays an important role in VII application development, but the industry must play an equal role if we want near universal consumer acceptance.

EXAMPLE: Seat Belts

Although not a large technology deployment requiring sophisticated and integrated system development, another example to be considered is the deployment of seat belts in automobiles. Seat belts are an example of a usage mandate by government agencies long after the technology had been developed and installed, but a mandate in which users had a choice to comply. And yet, the time lines of acceptance and usage still followed the general diffusion model.

The first US patent for an automobile seat belt was issued in 1885. In 1959, Volvo introduced the first three-point seat belt, which is the basic design of seat belts today. In 1962, car manufacturers made seat belt anchors standard equipment, and then in 1964 they made lap belts standard equipment. Even with this long history and reams of research to support seat belt benefits, however, seat belt usage was estimated to be only 15 percent in 1980.

In 1984, state governments began to step in and mandate seat belt usage. As the mandates became effective, seat belt usage went up to about 50 percent in 1990 when 38 states had created mandates. Since then, more states have added the mandates and these mandates have increased from secondary offenses to primary offenses, and many different programs have been developed to promote seat belt usage. Even with all this, however, seat belt usage was at 79 percent in mid 2003.

Even after seat belt usage first became mandated, consumer acceptance was still not widespread or quick to develop. VII applications that are mandated may not be any quicker to gain near universal market acceptance even with the threat of 42,000 annual fatalities in front of us.

Open Architecture

One could argue - and probably with some success - that the previous examples aren't a perfect match for the conditions present in the VII program. Is there a model that at least comes closer?

EXAMPLE: The Development of the Internet

The Internet began as a collaboration among industry and government entities whose goal was to create a communication infrastructure that would open up the ability to create a number of potential applications. The Internet also required large capital investments in its goal to be ubiquitous.

The initial vision for the Internet dates back to 1962, and generally became ubiquitous and accepted by the majority market around 2000. One should not be discouraged, however, that the vision took 35 to 40 years to become a reality. Instead, we should learn from the steps that occurred along the way. The Internet is now a widespread information infrastructure that serves as a broadcasting medium, as well as a mechanism for collaboration and interaction between individuals and their computers.

In 1965 the first wide-area computer network was created that demonstrated how time-shared computers could work well together. In 1967, the Defense Advanced Research Projects Agency (DARPA) put together a plan for a computer network called "ARPANET" and began building it in 1969. Most hypothesize that ARPANET was being built without a clear

understanding of how the network was to be utilized. There were several potential applications worked on, such as Internet telephony, file sharing, and “worms,” but it took until 1972 for a “killer application” to arise – email. Email became the largest application for the next decade.

But even with that critical application there were several “disconnected” networks by the mid 1970s, and little pressure for them to become compatible with each other. Networks that were developed for specific user communities such as NASA, DOE, UNIX users, as well as those for academic mainframe computer users. Several industry players also developed their own competing networks for the commercial sector – Xerox, Digital, and IBM. These networks were built for closed communities of users who were pursuing their own applications.

Today’s Internet arose out of these networks because the original Internet was an open architecture network. This meant that the individual networks underneath it could be designed any way the user requirements and environments dictated. They were given complete freedom to solve their own problems. So along the way to developing the broad vision of the Internet, specific applications for smaller communities of users were being developed rather than waiting for the entire network to be developed.

The move to an open architecture allowed many companies to develop different aspects of the underlying technologies. New technologies were developed to handle the transmission (from copper wires to microwaves, fiber optics, and satellites), routers, data farms, computers, and packets. The technologies in use today are far different from what was available in the 1960s and 1970s: workstations, PCs, ethernet technology, and fiber optics and cable are now the predominant technologies in use. Likewise, many other companies entered to develop potential applications for the Internet.

An open architecture allowed development of the Internet to progress, while specific applications for smaller communities of users unfolded in parallel rather than waiting for the entire network to be deployed. The development of VII applications will be influenced by state test-beds and operational tests, but as long as the nationwide VII architecture allows for acceptance of “regional” applications then overall rollout of the nationwide system will be facilitated.

While accepting the concept of incremental deployment of VII applications as a positive outcome from an open architecture, this then raises the issue of which parts of the system can be implemented first in order to speed acceptance rather than waiting for the whole system to be created. In other words, what are the individual applications that can be implemented without creating a ubiquitous system?

Studies have shown that innovative users (as defined in the diffusion model) do not need technologies that are fully developed. Innovative users, in fact, will sometimes do their own development of the technology to solve their specific problems. The bottom line, however, is that predicting which applications will lead to a majority market is very difficult.

EXAMPLE: Personal Computer

The way that successful technologies develop when there is so much uncertainty is that an environment is created in which many companies experiment with many different applications in an attempt to discover what the majority market will want. When the personal computer was a nascent technology, over 1000 companies were developing variations in hardware and software, trying to determine what the “value proposition” for PCs was.

Apple Computer was the early leading company in PCs but created a closed system – Apple’s operating system was proprietary so no one but Apple could create applications for their PC. The DOS-based PCs, in contrast, were an open environment – anyone could create programs to run in DOS.

Apple soon ended up as a niche product as new, unforeseen applications were developed for DOS. A similar thing happened for diagnostic ultrasound, in which 300 companies attempted to determine what the diagnostic device was supposed to do. If a new technology does not pique the interest of many companies so that they will come in to try to create a new market, the likelihood that the technology will become widely accepted is low.

An open architecture will spawn experimentation with applications never before considered, and that helped propel the DOS-based PC past Apple Computer. The partners currently developing the core VII network should recognize that decisions influencing the architecture could have a long-term impact on consumer acceptance of as-yet-unheard-of applications.

Timing vs. Technological Development

The past few examples have taken a strong position on an open architecture approach, but it must be acknowledged that such an approach does have implications on safety applications, data security, and data management that shouldn’t be taken lightly.

EXAMPLE: Space Shuttle and Strategic Defense Initiative

The VII network, once populated with applications, will undoubtedly be a large, integrated system. The length of time to reach technical completion depends on the “newness” of the technologies and the breadth of the integration.

The Space Shuttle, for example, took a very long time and cost billions of dollars, yet it was successful because the system did not require any breakthrough technologies – all the

technologies were known to be solvable, but it was their integration that was largely new and untried. The breadth of the integration was also limited – to a space craft.

A counter example is the strategic missile defense initiative (SDI), commonly referred to as Star Wars. Although people have been working on SDI from the 1970s, the system is not close to being usable. SDI is relying on breakthroughs in technology being developed, and the integration challenge is an added burden.

There are several major technical risks for VII. Integrating multiple technologies so that they work is a daunting task in and of itself. But a riskier technical challenge is to rely on technologies that have yet to be developed. An example for VII is that some needed technologies, such as computer hardware and software that can perform the real time, asynchronous analysis of data from thousands of sensors, may be years away from working. An example of an asynchronous system is the guidance system of the space shuttle – dozens of sensors are reporting at once, so which piece of data triggers a response? The problem was solved for the Space Shuttle but not for the more complex problems of Star Wars. Star Wars has been limited because no one knows how to build computer systems that can track and target thousands of incoming missiles all at once.

For VII, the partners developing the underlying core VII network are wrestling with issues that in large part haven't been encountered before - such as the daunting task of performing analysis of data from thousands of sensors and prioritizing which commands need to happen first - all of this of course in real-time. But they are also dealing with technology in DSRC units that are only now being tested in the roadside and on vehicles. Will challenges such as these have an impact on the timing of a ubiquitous network and therefore further delay the launch of some VII applications?

The development of new technical systems not only has the technical risk as described above, but also market risk. Market risk comes in two forms – who is going to pay for the system and who is going to use it. The Space Shuttle and SDI were both paid for by the government and used by the government so there has been no issue of acceptance other than political complaints that the money could be better spent elsewhere. For VII applications, however, it is envisioned that a combination of industry and government entities makes the investment and that the driving public uses and ultimately pays for the system.

This is similar to the developments of the Internet and mobile communication devices, where companies invested because they saw the potential for getting a return on that investment. Users, moreover, were willing to pay for the services because they saw a benefit from using the services.

The timing of technology evolution is influenced not only by the “newness” of core technology, but by the challenges present in large system integration. The core VII network has both new technology and large integration issues to overcome - will this negatively impact the potential timing for VII application launch?

Summary of Lessons for VII

This paper explored only a small number of technological introductions. It should be clearly noted that there have been other highly successful examples of technology introduction that bear lessons for VII, including Electronic Toll Collection in Singapore or the London Congestion Pricing program. However, those applications were limited in scope, limited in geography, and certainly not without significant institutional and political debate.

Can the core VII network be deployed with the realization that the real benefits of a technology are not always determined until after the technology has been put into the market and many applications have been attempted? Although email and file sharing were anticipated for the Internet, the now widely accepted applications of e-trading and e-commerce were not. Similarly, cellular phones are being used today in a very different way from when they first came onto the market. This makes predetermining the value proposition very difficult.

These lessons and others point to a VII application market that will be initially fragmented rather than a mass market. This also means that many companies need to be involved because the potential application space is so large, lest we end up in the Apple Computer example. If the application that someone is trying to develop requires that everyone participate or that the entire infrastructure be in place, then it will take years before anyone can use the application.

Timing remains a key issue - the Internet and cell phones became useful to some long before the majority of users were connected to it. But can the safety applications envisioned for VII be useful to some and not all? Will they be effective without a majority of users having adopted them? If all cars or roads need to have the technology in place for an application to work, it will take decades for that application to be useful.

The successful development of the broad vision of VII applications will require continual interactions among technology developers, application developers, and users. This interaction will be dynamic and develop over time, as we have shown in several other technologies. A dominant design occurs when people begin to agree on what they want out of an innovation. When PCs were in their infancy, there were hundreds of designs. Now PCs are pretty much the same except for some minor variations.

We should seek to develop the applications that have immediate and large benefits to users who are willing to pay to solve their problems either directly as vehicle drivers or indirectly through state transportation agencies. These will be the innovative users who will be the first adopters. The applications should solve their specific issues rather than some more general ones. The value proposition for them will be immediate and apparent. This will be the low hanging fruit and the easiest to justify in financial terms.

It is harder to justify investments in uncertain future markets when investment is needed in the existing market. But as the high return applications are implemented, the incremental

costs of doing other applications decrease. Adding infrastructure becomes easier to justify in a stepwise fashion.

As different user groups have their needs met, the issue is making sure that the various sub networks can work together as happened with the Internet. This requires that the designers set the ground rules or the protocols for the various entities to work within rather than predetermining the actual system. As with the Internet, each subsystem stood on its own but was able to communicate with the others.

For example, if an application is developed that works on its own to help truckers move through congested areas, then it should be implemented in those congested areas. If another application for measuring traffic flow is developed that only requires taxis to be equipped, then that is fine. The technologies used to develop those two applications can be specific to the applications. But at some future point if we want all vehicles to be equipped and all roads to have sensors, then the early applications need to know how they are going to communicate with the later ones rather than be forced now to all use the same technology.

History tells us that if we do not take the open architecture, incremental approach, and take into consideration that consumer acceptance requires a lot of hard work, then we are geometrically increasing the risk that VII applications never get fully implemented and accepted.

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