OVERCOMING BARRIERS TO IVHS-
LESSONS FROM OTHER TECHNOLOGIES

FINAL TASK B REPORT

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EXECUTIVE SUMMARY

The conclusions and recommendations here result from an investigation of institutional lessons relevant to Advanced Traffic Management Systems (ATMS) and Advanced Traveller Information Systems (ATIS) learned from the history of technological development and deployment in a large number of industries, including fourteen that were examined in some depth. First some general conclusions and recommendations are presented. Then specific lessons from selected industries are presented.

A. General Conclusions and Recommendations

There are opportunities for the public and private sector to work together to mutually leverage their scare funds in pursuit of common objectives. Many of these opportunities exist as pre-deployment activities involving research and development, operational tests, and early deployment. For its part, early intervention by the government designed to leverage its own scarce funds --inherently a distortion of market forces-- has had an uneven history and unpredictable prospects. Government intervention may be successful in achieving the intended result, may be ineffective, or may be counterproductive. The result achieved depends on the overall investment of effort and funds by both the public and private sectors and may be better than anticipated, may be proportionate to the investment, or may be a poor bargain.

Recommendations:

- ITS policy-makers should approach with caution any potential decision to seek to influence private sector firms and markets. A robust competitive market is efficient at sorting out right and wrong judgments, but government policy might enforce a judgment whether it is right or wrong.

- ITS policy-makers should define their objectives clearly and consider the full range of alternative policies and approaches to realize their objectives.

- If ITS policy-makers decide to intervene in the market, they should consider making the smallest possible intervention and should initially seek to accomplish relatively limited objectives. If experience indicates positive rather than negative results, the degree of intervention can be increased at a later time.

- A shared public and private initiative conceived by the government should include incentives to private firms, however policy-makers should seek ways to limit public sector concessions to the minimum required to achieve policy objectives. It is possible in principle to alter the private sector's risk/reward tradeoff in order to benefit both private and public sectors.

- ITS policy-makers should actively build fallback positions and exit strategies into their plans so that successful policies can be improved and failed policies abandoned quickly. This objective is potentially at variance with the desires of private sector firms for a stable policy environment; this conflict should preferably be resolved in advance under the objective of mutual private and public sector benefit.

Virtually any policy adopted to influence private sector behavior will necessarily create corresponding benefits for a number of private sector firms. Benefits that accrue to strong firms inevitably create strong interests, and strong interests acquire political strength. Thus a policy once adopted is often difficult or impossible to change after it has outlived its usefulness.

Recommendations:

- Policy-makers should build sunset provisions, policy transitions and exit strategies into their approaches from the beginning.

- Where possible, policy-makers should seek to establish conflicting private sector interests, to balance the political equation in advance.

Franchising is a well known and potentially promising approach to compensate private sector firms for the risk they incur by investing in new and untried technologies or services. Usually the request for protection from competition that is inherent in a franchise has come from the private sector rather than from government, and even in these cases the franchise concession has sometimes continued well beyond the time at which it became counterproductive for public policy. In the case of ITS, government may itself seek to induce private sector investment in the service of public purposes, thus placing government in a less advantageous bargaining position.

Recommendations:

- ITS policy-makers should limit their objectives in any effort involving franchising, and thus the risk to private sector firms, to limit the corresponding concessions required.

- Where possible, government should seek to grant concessions having a fixed or identifiable value (e.g., free access to information that government will be collecting anyway for its own purposes) rather than indeterminate and long term concessions (e.g., monopoly rights to provide essential public services).

- Government may be able to find less costly ways to limit private sector risk, and thus limit its policy concessions (e.g., by guaranteeing private sector debt to finance costly but necessary highway improvements, installation of conduit, etc.) rather than including these items in the risk/reward tradeoff.

The principal historical rationale for awarding monopoly franchises has been the presence of economies of scale. The relevance of economies of scale to ITS is limited, and the long term cost of basing policy on the assumption of economies of scale is potentially high.

Recommendations:

- Economies of scale are relevant to policy-making only if essential public services are under consideration. ITS policy-makers should examine their objectives closely to determine if a particular ITS service meets this test.

- It appears likely that ATIS will not exhibit economies of scale, and in any event may not be considered an essential public service. Thus ATIS may not be an appropriate candidate for monopoly franchises.

- ATMS may well exhibit economies of scale and therefore justify a single provider service in any specific area. Thus the potential of franchising for ATMS should be studied carefully.

Protection from competition, plus the investment of substantial amounts of risk capital, creates a powerful incentive for a private firm to innovate slowly and deliberately. Policy-makers should be aware that cost savings resulting from economies of scale may soon be offset by failure to take advantage of the benefits of newer technology.

Recommendations:

- Despite the sometimes strong arguments for monopoly franchises, policy-makers should make a vigorous effort to find ways to maintain some competition in the provision of ITS services. At the least, there is substantial precedent for authorizing a minimum of two competing licenses or franchises, with clearly positive public benefits.

- Monopoly provision of an essential public service necessarily implies regulation of rates charged to the public; without such regulation government would in effect be granting taxation authority to private firms. Policy-makers should consider the proposed regulatory regime in advance, with great care, to balance properly the public interest in low short term rates for service and the long term cost of improvements achievable from innovation.

Government has two very different objectives in seeking to develop ITS with private sector assistance. Government's broad role as the custodian of the public interest is potentially at variance with its desire to realize private sector concessions to reduce budgetary outlays. This dichotomy of viewpoint has led in the past to substantial concessions to private interests (such as grants offranchises) in exchange for limited returns (such as free service for certain government agencies).

Recommendations:

- ITS policy-makers should define their short term and long term policy positions clearly, and avoid mortgaging long term interests for short term budgetary convenience.

- The interests of federal and state/local agencies may diverge on the tradeoff between short term and long term policy benefits. Policy-makers should consider these differences openly and objectively to avoid potentially costly errors.

B. Lessons From Other Technologies

There are important lessons to be learned from the deployment of technologies in other industries. The lessons vary depending upon the history of each industry. Both the public and private sector should carefully consider the successes and failures different industries experienced during their evolution.

Lessons from the Cable TV Industry:

1. Under law, cable TV franchises must be non-exclusive. However in practice, de facto exclusive franchises have proven to be sufficient to foster rapid deployment. For ATMS, where an argument can be made for the existence of natural monopoly conditions, it may also be true that de jure exclusive franchises are not necessary and that de facto exclusive franchises would be sufficient. Non-exclusive, non-discriminatory licenses might also be sufficient as has been argued in the courts, though not successfully, in the cable TV industry.

2. The cable TV industry depends strongly on advertising revenues to cover costs. The cable industry has found that to be in both the cable and telecommunications business, fragmented urban area franchises must be interconnected. This also paves the way for cable systems to interconnect for the provision of personal communication services and alternative access telephone service. The lesson for ATIS is that similar types of interconnects will be required to the extent that ATIS depends upon advertising as a revenue source and requires wide area telecommunications.

3. ITS should develop reasonable expectations for any franchisee. In the cable TV industry franchise commitments made by cable operators in competitive applications were often re-negotiated or ignored. Some franchises have reneged on commitments with the reluctant acquiescence of the franchising authority.

4. Cable franchise agreements normally include quid-pro-quo features such as the granting of the franchise partly in return for provision of cable TV access to government agencies and educational institutions. Government policy makers need to examine carefully whether such conditions would unacceptably retard the pace of deployment of ATMS/ATIS, and whether these are the kinds of conditions that have been ignored by some franchisees.

5. Experience in the cable TV business suggests that it is important to establish procedures to scrupulously avoid unsavory aspects of franchising such as under-the-table payments.

6. The development of a model franchise agreement early in the history of Cable TV had a significant influence on the pace of deployment and helped many jurisdictions strike the proper balance in providing Cable TV service by rewarding the private sector, obtaining compensation for the use of public rights-of-way and satisfying other public service obligations, in addition to providing cable service.

Lessons from Direct Broadcast Satellite (DBS) Industry:

1. Direct Broadcast Satellite Industry requires very large sunk costs ($600 million to $1 billion) per satellite, and constant variable costs which cannot be covered by debt financing. Spectrum

for DBS, which is limited by international treaty and further limited by the Federal Communication Commission's process for allocating U.S. share among potential providers, is one of the factors that provides some degree of market exclusivity, which helps create a profit incentive for deployment. The policy framework is thus a limitation on market entry imposed by limited spectrum rather than by economic or regulatory theory. The relevance to ITS concerns the regulatory forbearance and the resulting market structure, rather than the spectrum issue. Unlike, DBS, ITS will at most be a small user of spectrum and may be able to purchase communication services from firms already licensed to provide them. The important issue for ITS policy makers and the private sector is the market structure for ITS itself for which the DBS market considerations are relevant (i.e. some degree of exclusivity), rather than the spectrum shortage which created them.

Lessons from the Television Industry:

1. The history of the TV industry makes clear the importance of setting appropriate standards and equipment compatibility in successful deployment.

2. In any wireless service relying on a widespread receiver base, adoption of uniform standards is an essential precondition to widespread diffusion of service.

3. UHF/VHF experience in TV broadcasting teaches that for competition to be effective, the frequencies used by each competitor must be equivalent in receivability, and to the extent they are not, standard setting action is needed at the outset to require that receivers be compatible with all competitors' frequencies.

4. TV broadcast experience teaches that while compatibility is vital, flexibility and upgradability in equipment is also important. For example, vehicle equipment standards for ATIS needs to be sufficiently flexible to be upgradable (retrofitted) for ATIS use at relatively low cost. Otherwise implementation of a second generation ATIS, will be stymied by the need to replace the equipment base embedded in vehicles. This problem is already evident in the case of trying to convert the current installed base of signal control systems found in urban areas throughout the United States to systems that provide real-time traffic control.

5. Experience in the deployment of television also shows there is no fundamental tradeoff between standard setting and fostering innovations in the future, provided the original standard setters have the foresight (or perhaps the good fortune) of selecting a standard as adaptable as possible. In setting initial technical standards, one must try to anticipate the whole family of ITS user services and not focus on just a few. However, one cannot wait until an ideal standard comes along because implementation will occur anyway if there are profit opportunities. Standard setting is a balancing act.

6. TV is fundamentally different from ATMS user services as being almost completely an advertising supported service. This conclusion might be less so for ATIS. To the extent that a service relies primarily on advertising revenues, the service provider has a built-in incentive to encourage rapid growth in the size of end-user audience.

7. The emergence of cable TV as competitor to TV broadcasting is an example of a general trend that competition extends across delivery technologies.

8. The public interest of standard television broadcast licenses promotes local content and diversity in programming. This often implies local ownership as well as ownership by minority businesses. These considerations may well apply to ATMS and ATIS to some degree as the legal and regulatory framework for deployment of these technologies evolve.

Lessons from High Definition Television:

1. HDTV provides a lesson indicating the need for forward and backward compatibility of technology. Government adoption of a standard that takes into account the full delivery chain is likely a pre-requisite for the successful introduction of a new technology where individual segments of the delivery chain are under the control of different industries.

2. Where new technology is incompatible with an embedded base, as is the case with HDTV, the role of government in managing and facilitating the transition may be crucially important to the commercial success of the new technology. This is particularly true where the transition can only be accomplished through extraordinary demands on the radio spectrum which is true for HDTV, but does not hold for ITS.

Lessons from the Cellular Telephone Industry:

1. Cellular benefitted from all operators offering consistent basic voice service. Many ITS user services might benefit from offering a basic level of consistent service. Recommended, or perhaps even mandatory, minimum acceptable levels-of-service should be established to which all service providers ought to (or must) adhere. For example, in the case of ATIS, a minimum level-of service might include the availability at homes, business and to people on the move of virtually real time and projected information on the travel time and travel costs between any origin and destinations by different modes, routes and times of day. Additional information such as electronic yellow pages would not be part of the basic level-of-service.

2. Cellular became a mass market product when the cost of equipment declined to less than $200. ITS should be aware of the “barrier price” beyond which widespread market acceptance will occur.

3. Transportation policy makers will have to decide how to award licenses, if they are deemed necessary, to service providers. The experience of the cellular industry makes it clear that comparative hearings of the offerings of potential service providers and competitors are fraught with pitfalls and should be avoided. The FCC and Congress continue to explore auctions and lotteries as alternatives to comparative hearings. Auctions eliminate speculators but favor large firms over smaller players. High filing fees can reduce the number of applications and speculators for lotteries.

4. The cellular telephone industry was deployed under a regime of duopoly licenses in 305 metropolitan service areas and 427 rural service areas. Duopoly licenses or franchises might prove to be an effective way to balance the need for competition with the need for some market exclusivity to induce private investment.

Lessons from the Telephone Industry:

1. As in the history of the telephone service, deployment should be broken into two phases: (1) initial universal service; and (2) service innovation to promote rapid technological advance of second generation technology. This has worked well in the telephone industry.

2. The telephone industry, to reach a critical mass necessary to provide coverage throughout a metropolitan area, responded with mergers and consolidations, resulting in little competition, and little regulatory or antitrust intervention. In the case of ATMS, the public sector through the exercise of its own public monopoly, can provide the critical mass. The public sector can also grant franchises, licenses, and pursue other means to deploy ATMS. In the case of ATIS, where monopoly conditions appear to be absent, consolidation and mergers, or some other means of limiting competition, may well prove necessary to avoid destructive competition and induce the private sector to achieve rapid, region-wide deployment. However, if market failure occurs, the public sector could provide basic ATIS service as indicated above, or take other steps to stimulate deployment.

3. As in telephone service, private sector economics probably dictates that ITS will be most economical and will arise first in the larger urban and suburban areas, developing market-by-market. Unlike telephone service, where government felt a need to create policies designed to promote extensions to rural areas, there may be less of a need to extend ATMS to rural areas. This avoids the need for cross subsidies. Cross subsidies from urban to rural areas could undermine the success of ATMS, and makes little sense because of the tenuous interconnections. The issue of cross subsidies between urban and rural areas for ATIS, is more complex and needs to be studied carefully, but probably should be avoided.

4. The ultimate beneficiaries of ATMS will be-the traveling public (both personal and business) who should see travel time (and thus costs) lowered. But purchases of ATMS will more likely be government bodies. This creates a need for a fundamentally different kind of revenue source for ATMS than exists for telephone service.

Lessons from the GIS Industry:

1. There is a convergence occurring between GIS and ATIS technology. The deployment of GIS therefore offers some important lessons. One of the most important is the difficulty of implementing GIS across jurisdictions for metropolitan or statewide applications, and the necessity of gaining early cooperation and buy-in from all affected parties. GIS implementation can be quite expensive, especially data collection, and each party typically must bear some responsibility for both the costs and the updating of information. The institutional challenges in gaining this cooperation are often large and sometimes prohibitive. Experiences in developing multi-participant GIS's can be very instructive for ATIS.

2. Each implementation of GIS grapples with the problem of how to charge for data, whether it should be free, cover costs, or return a profit. These issues also apply to ITS. Generally public agency systems lean toward making information available for free or at a nominal cost, while private companies seek to make a profit.

3. Spatial data standards are crucial for effective transfer and storage of spatial data. The same is true for ATIS. In fact, because of the convergence of both GIS and ATIS technology, both should conform to nationally (better yet internationally) accepted spatial data transfer standards.

Lessons from the GPS Industrv:

1. The accuracy of a specific technology in determining locations of vehicles and other transportation features is one of the major criteria affecting the deployment of ITS products and services. The history of the development of GPS indicates that the cost of achieving requirements for locational accuracy for different applications and user services is a major determinant of the speed of deployment. Each type of locational technology will have different costs and accuracies (e.g. dead reckoning, map matching, GPS, Loran, etc.). In the civilian sector, the cost of user equipment, more than any other single factor, influences the acceptability and diffusion of the product or service.

2. The current national technology policy enunciates a theology of converting defense technology to civil applications. GPS is a model of dual use (military/civilian) technology and closely fits this policy. The government has no statutory obligation to provide GPS to civilian users. But having done so, it needs to exercise extreme care in operating the system. The fact that the service is provided for free has no legal importance. The government needs to provide a system with maximum reliability and accuracy, consistent with national security interests.

3. The development and implementation of GPS provides a great example of government leadership in the development of technology that provides broad benefits to the commercial sector. While GPS was developed to meet important military objectives, the early involvement of non-military and commercial interests have ensured dual success.

Lessons from the On-Line Services Industry:

1. On-line services significantly benefitted from government investment that led to the establishment of the Internet. Correspondingly, public investment in ATMS and ATIS will most likely spawn private investment and much private competition. The public sector needs to figure out how to capture some of these economic rents in order to recover part of the costs of public investment but without scaring off private investment.

2. Advertising may be a necessary source of revenue, but ITS policy-makers must learn from Prodigy's example that some users may turn away from an ITS service if they must confront advertisements. To the extent that a provider of an ITS service includes advertising, competition comes not just from other service providers but also from television, radio, newspapers, magazines, etc. that may have more viewers, circulation and so on. With users and advertising sponsors having other options, ITS services must remain flexible and updatable in order to retain both users and advertisers since demand will shape the service, as has happened to Prodigy.

3. ATIS services should try to capitalize on the existing Internet infrastructure. However, it will be necessary to carefully select how service will be provided over the Internet, since the Internet has its own culture and, up until recently, a laissez-faire regulatory environment.

4. Prodigy has proven the success of a small flat fee for access to basic services. If ITS policy-makers are to include an access charge for ATIS, it must be determined whether there should be a flat fee, a fee for each service request, or no fee.

Lessons from the National Weather Service:

1. The experience of the National Weather Service indicates that a broad array of products and services will evolve from ATMS/ATIS. It also demonstrates the effects politics and economics can have on the institutional framework for delivering services. ITS policy-makers should pursue an institutional approach that is flexible enough to withstand significant changes in politics and economics over time as well as the emergence of many different products and services.

2. ITS providers may find themselves inundated with vast quantities of data, just like the National Weather Service has. It may be prudent to develop a national ITS information management plan to collect, store, retrieve, and analyze unprecedented quantities of data. This plan may be similar to that of the National Weather Service and incorporate a national reference system, coordination with the National Bureau of Standards or other appropriate standard setting body, and preparation of a coordination plan to manage archived state and regional data.

3. The National Weather Service uses a partnership of public, private and volunteer sectors in order to collect, analyze and disseminate information. The government provides centralized guidance and offers basic services. Private organizations and volunteers augment this as well as provide value-added products and services. ITS information can be handled in a similar way with the government providing centralized information management, traffic management and link travel times and the private sector providing independently offered services, value-added products, and services that build upon the government's basic offerings. Volunteers can serve as probes for gathering link travel times.

Lessons from the Electric Utility Industry:

1. There are strong parallels between the electric utility industry and various elements of ATMS/ATIS. Central power stations can be viewed as the analogue of the traffic management centers, transmission lines the analogue of telecommunication trunk lines, and distributions systems the analogue of the part of ITS that reaches into businesses and homes. Unless wireless technology is used, ITS will require a technology somewhat analogous to substations for local distribution to drivers/motorists/homes/businesses, which may very well take the form of area processors and controllers for managing the information flow to and/or from personal computers, beacons, signals, video cameras, changeable message signs, and so on. Because of the technological parallels, there are likely to be institutional parallels. One of these is the question of whether a central authority or local authorities should have control over distribution.

2. As with electric power generation, economies of scale and the need to avoid excessive amount of duplicative rights-of-way argue for limiting the number of wireless ATMS in a metropolitan region.

3. Ownership of one or more portions of the triad of generation, transmission and distribution confers on the owner potential market power regarding other portions of the triad. The same will be true for ITS.

4. Strategies designed to encourage rapid deployment of ATMS and ATIS need to apply a steady and balanced approach over the long run and avoid swinging back and forth from approaches that emphasize competition one day and government control the next, which marked the early history of the electric power industry.

5. The electric power industry during its middle years addressed the problem of achieving economies of scale and system reliability by establishing Public Utility Districts and power pooling arrangements. While the institutional challenges in doing so are large, ATMS/ATIS deployment would probably benefit from similar arrangements.

6. The concentration of market power in the hands of a few firms can be a significant problem, but it also seems that anti-trust actions did little to mitigate it in the electric power industry. Government needs to pay close attention to the concentration of firms in different elements of ATMS and ATIS.

7. The electric power industry was slow to address rural needs, resulting in remedial action by Congress. ITS America and the Federal government have identified Advanced Rural Transportation Systems as a separate category of ITS, which is sound foresight.

8. The job creation ability of ITS could strengthen its public support and help speed deployment just as the was the case for power systems duringthe 1930's, when the Public Works Administration was established.

9. High rates of return may be warranted given the risks of investment, but if the public comes to see ATMS and ATIS as being a public utility and therefore a right, just as the provision of electricity, there could be a backlash.

10. If the composition of the electric power industry around the year 1990 is a measure of a mature industry, the following can be expected to occur with regards to ATMS/ATIS:

    - By virtue of the large number of municipalities, counties states and regional planning organizations, there will be many more public providers of ATMS/ATIS than private providers.

    - The relative mix of public and private provision of ATMS/ATIS will vary around the country.

11. All levels of government, federal state, regional and local, are likely to exert varying degrees of control over ITS, just as in the electric utility industry. In some cases federal regulations will pre-empt regulations of lower levels of government and so will state regulations. The federal government can exert regulatory powers as a result of the interstate commerce clause of the U.S. Constitution. However, there will be dynamic tensions among 'the regulatory powers of different levels of government, as in the case of the electric utility industry. City councils and local boards, responsible for ITS Districts may very well exert control over local

and regional traffic policies and regulations, provided they do not conflict with state and federal laws and regulations.

12. Equity and fairness may play a major role in the provision of ITS just as it has in the electric utility. Prices charged will have to be just and reasonable and the rate of return to private investors must be fair. While these criteria have specific legal. meaning in the electric utility industry, loosely speaking they will still apply in the ITS industry.

Lessons from the Water Supply Industry:

1. A lesson from the water supply industry is that early and thoughtful development of regulations and standards facilitates instead of impedes technological progress in industries offering public services. In the water supply industry, an absence of regulations and standards created little incentive for technological innovation. Flexible, outcomes-based, and coordinated regulations among all levels of government can bolster safety, efficiency, and creativity within an industry. Also, regulations can be accompanied by implementing grants and loans to address funding shortfalls and to promote restructuring that reduces financial inefficiencies.

Lessons from the Refuse Collection Industry:

1. Transportation infrastructure, to the extent that it serves interstate commerce, must adhere to rigorous federal standards while refuse collection is not regulated by any major piece of federal legislation. As a result the search for technological methods to protect safety has been more intense in the transportation industry than the refuse collection industry. The experience of the refuse collection industry suggests that government agencies must design regulations with care lest they have the unintended effect of retarding technological advances. A flaw in the solid waste regulatory framework is that it is devoted to disposal and does not encourage linkages between collection and disposal.

2. The regulatory framework should specify outcomes but not the methods for achieving those outcomes, i.e. performance rather than method specifications.

3. The regulatory framework should not tilt the economics toward either private or public operators. The question of optimal mix of public and private operators is an empirical question that must be answered differently across the country. Therefore regulations should be flexible to allow the pursuit of a variety of service options. While flexibility is important so is accountability to citizens and stakeholders, without which deployment is likely to be less than satisfactory.

Lessons from the Electronic Funds Transfer (EFT) Industry:

1. The EFT industry, including the databases, secure telecommunication linkages, automated teller machines, and equipment for point-of-sales transactions has developed fairly rapidly overall. Not only can ATIS potentially piggyback, at least in part, on this infrastructure, but the EFT deployment is an instructive lesson for ITS.

2. At every step in service development in EFT there were delays in adoption of service, while customers became familiar with the new technologies. Builders of electronic toll collection systems should be prepared for an extended period of time during which there will be relatively little return on their investments.

3. Customers are quite adept in perceiving where their own self interests lie. For exarnple,when banks seek to maximize their revenues by debiting a customer's account immediately for ATM withdrawals or point-of-sale (POS) transactions, but place a few days' hold on deposited funds, their customers are quick to realize that they lose the "float" they would otherwise have by using paper checks. Customers will pay for convenience, but not in large amounts. In the case of debit card POS, the advantages compared to credit cards or checks are unclear, and may in fact accrue to the bank or the retailer instead of the customer. ITS bears a similar burden of proving its value to customers. If consumers must also incur an up-front out-of-pocket investment, those benefits must be clear and unambiguous, or the service will be ignored.

4. From a policy perspective, the basic financial industry issues of POS have been addressed and largely resolved, but electronic toll collection raises anew some of the most difficult of these. To all of the controversial questions regarding collection and use of personal and lifestyle data in the connection with electronic transactions is added the potential for real-time surveillance and tracking of motorists.

I. CHAPTER ONE — INTRODUCTION

Government and the private sector have often worked together for their mutual benefit, but not always successfully. The key to success is developing an environment of shared risk and mutual reward. This requires policies and objectives that both partners can agree upon.

A. ITS Objectives and Market Structure

Although a national consensus on the main objectives of these systems has emerged, as reflected in the ITS America Strategic Plan and the National ITS Program Plan, the public and private sector are still working on both technical and institutional issues. To many observers the technical challenges are not as great as the institutional challenges. Most of the institutional issues confronted by ITS policy-makers have a long history in the transportation field as well as in many other industries. Institutional approaches to the deployment of many key technologies are directly relevant to ITS, either as models to emulate or as pitfalls to avoid.

The policies that have controlled the deployment of technologies in many industries range from provision by government as a sole provider, to provision by private sector firms under monopoly franchises, to limited competition rationalized by limited availability of an essential resource, to full and free competition. Each of these policies has served important public purposes, and each has brought with it significant disadvantages. ITS has characteristics similar to those of some of these key technologies, and different from others-thus it is useful to examine this policy continuum systematically to help guide the deployment of ITS.

Different policies encourage different results-it is thus essential for government to define its objectives clearly, for it will reap the results of its policies whether it wants the results or not. For example, a policy that encourages the commitment of private capital and rapid deployment of technology may ultimately create an environment in which most of the benefits of the technology accrue to strong private firms rather than to the public. Since it is axiomatic that strong-interests soon acquire political strength, a policy once adopted is often difficult or impossible to change after it has outlived its usefulness. Policy-makers need an “exit strategy” as much as they need short term effectiveness.

The technologies examined in this report are a disparate lot. Some (e.g. local exchange telephone, electric power, water) exhibit economies of scale and have historically been the province of a sole provider, either a franchised private firm or a government entity. Some of these providers (e.g. local exchange telephone, cable television) have recently been subject to a modest degree of competition (from cellular telephone, wireless cable/MMDS, DBS) and have responded by adopting the competing technology in addition to the monopoly technology-most businesses seek to maximize market share, and most seek to leverage market strength into related sectors. Other technologies (e.g. broadcast television, cellular telephone) do not exhibit economies of scale but need access to a scarce public resource, the radio spectrum; private sector providers of these technologies have traditionally been regulated, although subject to limited competition, to assure that the public interest is protected. Still others (e.g. toll telephone) were once ***de jure*** monopolies based on the assumption of economies of scale, but were later opened to competition with spectacular results. [The airlines, not studied here, have in recent years yielded less than spectacular results under a competitive regime.]

Economies of scale as a rationale for market policy are applicable in part to ITS. ATMS installations require widely dispersed sensor facilities, facilities for communications between ATMS and individual vehicles, and centralized traffic management centers. These installations exhibit economies of scale, in the sense that an alternative set of sensors or a separate management center in any particular area would add cost but not increase the capability to manage the particular traffic. Thus economies of scale may be a relevant criterion for adoption of a sole provider policy for provision of ATMS capability in a particular area.

It is worth noting that, in the case of ATMS, it may be unnecessary to appeal to economies of scale to justify a sole provider policy. These systems are intended to control, in an integrated sense, all vehicular traffic in a particular area. Thus ATMS is in this sense inherently a single integrated system, a monopoly because of *function* rather than because of scale.

For ATIS it is difficult to assert economies of scale. Even the nationwide satellite and interexchange telephone systems, very much larger in size and scope than projected ATIS facilities, have been successfully subject to vigorous competition to the benefit of the public. It seems appropriate to regard ATIS as a technology well-adapted to a competitive market structure, and to rely on the market both to stimulate the deployment of the service and to protect the consumer.

B. Market Structure and Technological Innovation

An important corollary of a competitive market structure is technological innovation. Sole providers do not have the incentive of would-be competitors to introduce new technologies-they benefit from innovation only at the margin, and they sometimes view innovation more as disruptive than as beneficial. Given that some innovations can ultimately call into question the very economies of scale on which the sole provider role ultimately depends, it is clear that market structure and innovation are closely intertwined.

Examples are not hard to find. Although for many decades the telephone industry continually took pride in its technological prowess, the rate of deployment of new technologies has accelerated markedly since the introduction of competition in interexchange (toll) telephone service and the divestiture of the local telephone operating companies from the AT&T Bell System. A similarly accelerated development has taken place in computer hardware and software (not studied here) as a result of IBM’s loss of dominance of the personal computer industry. The cable television industry deployed its basic coaxial cable aggressively, to improve market share and cash flows, but only began serious efforts at introducing new technologies when faced with imminent competition from DBS and telephone company optical fiber systems.

As a practical matter, despite the cost characteristics of a technology, it is only appropriate for government to grant exclusivity in recognition of economies of scale if its purpose is essential to the public interest. For example, shopping malls might well exhibit economies of scale, but that does not discourage competitors from building additional malls, and in any event the public interest is well served by more rather than fewer shopping malls (apart from environmental issues).

Even if the purpose is essential, economies of scale should be a guide for policy only if technology is stagnant. For example, even if economies of scale exist for cable television facilities, alternative technologies such as MMDS, DBS and telephone company optical fiber have arisen as competing means to accomplish the purpose of cable television.

Finally, even if the purpose is essential and the technology is stagnant, government mandated sole providership should not be automatic. Even if the aggregate cost of the technology itself would be greater if two or more competitors were permitted, the efficiencies and creativity fostered by competition may well lead to increased public benefits, or to offsetting cost reductions in other aspects of the business or industry.

C. The Public/Private Bargain

Economies of scale are not the only foundation for sole providership. A costly new technology or service for which no market exists is a risky prospect for a private firm. If government desires both the adoption of such a technology and the commitment of private capital, it must consider the ***quid pro quo*** demanded by the private sector, usually the freedom to avoid competition. This bargain may be implicit, as with the ***laissez faire*** policies of government in the early years of the consolidation of the telephone industry, or explicit, as with the later period of regulation of the industry. Either or both approaches might be possible policies to guide the deployment of ITS.

If a sole providership of certain components of ITS is judged desirable, the policies adopted for the deployment of other technologies offer useful experience. A ***laissez faire*** policy is practical only if consumer interest is sufficiently large to induce the private sector to commit its resources to a competitive market. Telephone service grew rapidly under this approach, and except for an appropriate charge for information generated at public expense it may be appropriate for ATIS. Cable television grew rapidly also, but protected by ***de facto*** municipal franchises (federal law prohibits exclusive cable franchises). These franchises were typically awarded competitively, with guarantees of public service channels and other concessions forming a part of the bid package, but in many cases the promised concessions never materialized. Thus government should make reasonable demands on franchisees, consistent with financial viability of their businesses, but should include strict enforcement procedures to ensure that the bargain is kept.

It is important to recognize that concessions to government in exchange for award of a franchise (i.e. a franchise fee and other public interest obligations) in effect position government as a favored customer of the franchise, relative to the private citizen, and in effect constitute a “tax” on the operator that is recovered by higher prices paid by private users of the franchised service. In such cases government should be clearly aware of what is to be paid (the “tax”) and what is to be received (the concession), and to assure itself that the price is justified. This is not an academic matter-a legislative bargain is presently being struck in Washington between government and the telephone companies that propose to build the “information highway.” It is entirely possible that the telephone companies will be granted the right to add many billions of dollars to their rate bases, thus increasing individuals’ telephone bills, to pay for optical fiber systems the companies want to use to compete with the cable television companies, in exchange for connecting certain schools and hospitals to those optical fiber systems. Government would thus be subsidizing one monopoly service provider (the telephone company) via increased telephone rates, to help it compete with another monopoly service provider (the cable television company), receiving in return concessions whose cost might well be recovered from the public anyway. The value to the public of these concessions should clearly be balanced against the “tax” to be paid by the public via increased telephone rates.

Experiences with both the competitive approach and the franchised approach have one common element: a service that is attractive to consumers, for which they are motivated to pay. ATIS is potentially such a service, but it may not be so essential a service as to justify protection from competition. ATMS is quite different, conferring benefits to all travelers within its scope whether they pay for it or not. Thus ATMS will probably be economically viable, absent government subsidy, only if payment is enforced by toll collection or similar means. In this case the consumer will truly be at the mercy of a franchisee or other protected service provider if the franchise is not crafted with great care.

Another mechanism that confers protection from competition is a government license, most commonly applied to grant access to a scarce resource such as the radio spectrum. The licensing approach has been phenomenally successful, giving rise to the television and radio broadcast industries, the cellular telephone industry, satellite communications, and terrestrial microwave radio transmission systems. Licenses typically do not include economic strictures such as rate regulation, although they do sometimes impose limited public interest requirements (e.g., public access to a portion of the channel capacity or equal access for those having different viewpoints). Licenses are an effective approach because they grant access to a resource that has demonstrable value, a value derived from the ability of a private firm to sell a service that consumers are willing to pay for. As noted above in regard to franchises, ATMS may not have a substantial voluntary market. Moreover, if payment is mandatory, a traditional licensing approach without rate regulation and other safeguards could well disserve the public.

Licenses for the radio spectrum have traditionally been awarded on the basis of comparative hearings, in which the Federal Communications Commission evaluates proposals of would-be licensees from a public interest perspective. These hearings were long, complex, costly, and burdensome to the FCC as well as to the private sector. Accordingly, a variety of alternatives have been proposed to avoid hearings. In the case of the DBS industry, when demand for spectrum exceeded supply the FCC simply divided the available spectrum equally among the applicants. For the cellular telephone service and a number of less well known users of spectrum, the Commission adopted a lottery approach. These lotteries were relatively easy to administer, and were fair to all applicants, but they encouraged speculation by individuals and firms that had neither the ability nor the desire to build and operate real communications systems.

At the behest of the Congress, the Commission recently auctioned spectrum, starting with the Personal Communications Service (PCS). The Commission captured for the government large sums as a result of the PCS auctions. This is money that under a lottery approach would go to speculators. While auctions are efficient, and produce significant revenues for the government, they clearly favor the largest firms over smaller firms and individual entrepreneurs. From its operational perspective, government could simply conclude that any approach that maximizes its revenue or minimizes its cost is desirable, but in its broader capacity as custodian of the public interest it should consider issues of fairness as well.

Some of these disadvantages might be avoided by using lotteries combined with revenue sharing, to generate revenue for the government without imposing the barriers to entry for small firms and individuals that are inherent in auctions. Speculators could be discouraged, and the number of applications reduced, by requiring relatively high filing fees.

In addition to the basic desire to achieve deployment of a new technology such as ITS, without assured prospects for profitability, government's objectives often differ in other ways from those of the private sector. For example, private businesses usually seek the most profitable opportunities first, and pursue less profitable ones only when the best ones have been exhausted. Government has broader objectives and is subject to different pressures, e.g. the need to deploy technologies in rural as well as urban environments. Thus the desire to encourage "universal service," as in the initial deployment of telephone technology, may lead government to strike short term bargains (e.g. protection from competition in exchange for internal cross subsidies) with industry that are inconsistent with a mature, risk-free industry. The third-party beneficiaries of a subsidy of this kind, in this case the millions of subscribers to local telephone service and the state regulators that sought to protect their interests, inevitably become the natural allies of the industry in its efforts to preserve the arrangement. It is not easy for government to disengage from such a bargain when it has outlived its usefulness (e.g., when the policy objective shifts from fostering universal service to encouraging technological innovation).

D. Quality of Service

Successful infrastructure services generally offer a basic level of service that is consistent in quality regardless of service provider. This consistency of quality can be enforced by government or by the competitive market. For example, the government can establish performance standards as it has in a number of industries. In the cellular industry, the FCC stipulated the maximum percent of uncompleted calls, and similar performance specifications can be applied to ATMS/ATIS. Government has also frequently defined basic services as in the case of local exchange telephone service, and government could very well do the same for ATIS.

The other enforcer of quality is competition. Firms tend to compete both on price and quality of service. Firms that fail to offer sufficient quality are vulnerable to losing market share. In the past in such regulated industries as railroads and trucking, where price was controlled by the government, competition occurred by varying offerings in service quality.

E. Who Will Pay for ITS?

It is fundamental to decide who will pay for ITS. It seems likely that consumers will perceive benefits from ATIS and will be disposed to pay for this service. The benefits of ATMS are more indirect and are less easily perceived, since the principal beneficiaries (the traveling public) may not notice its benefits and in any event may not be able to choose whether to receive them or not. Unless every ATMS-equipped area is also equipped with toll collection facilities, direct payment by consumers seems doubtful. Thus the actual consumers (or purchasers) of ATMS will probably be local governments or transportation authorities, who may be unable to pay its full cost from their limited budgets.

Regardless of the market structure adopted, it is also fundamental that prices must be kept low if widespread deployment is desired. Unless government is prepared to mandate ITS or to provide service with public funds, consumers will only adopt it if the perceived benefits exceed the perceived cost. Even then, the rate of adoption may be too slow to please either government or private business. Not every new technology can be expected to achieve the market penetration of television, telephone or VCR’s Closely related to this key economic incentive structure are ancillary issues that may send mixed messages to consumers (e.g., the perceived effects on personal privacy).

If consumers do not perceive the benefits of ATMS and if government is not prepared to pay for it directly (or through direct subsidy), only indirect payment (subsidy) options remain. One such option is a cross subsidy from ATIS revenues, managed by a provider of both ATIS and ATMS services: the price of ATIS would be increased to reflect the subsidy to ATMS. Here the history of the regulation of the telephone industry tells us clearly that indirect subsidies are effective only if the subsidizing service is not subject to competition. Thus if cross subsidies through pricing mechanisms are adopted, the sole provider approach that may well be adopted for ATMS would necessarily be extended to ATIS, which might otherwise be a good candidate for a competitive provider approach.

There is of course the possibility of charging all operators of a competitively provided ATIS for information generated by ATMS. Again the users of ATIS would pay disproportionately for ATMS, even though the benefits of ATMS would accrue to all drivers. Too much cross subsidy of this nature could unduly raise the price of ATIS, thus depressing demand for the service and discouraging entry of ATIS providers. Also, the cost of construction and initial operation of ATMS must be incurred before ATIS can use (and consequently help pay for) ATMS-provided information. Thus at least part of the cost of ATMS will probably have to be funded directly by government.

F. Technical Standards

A related issue is the role of technical standards. A sole provider of a technology or service usually adopts standards to serve its own interests; if the mere adoption of a standard is economically more important than its specific elements, this approach is beneficial. The adoption of a single standard for initial deployment of cellular telephone contributed to the early success of this technology, the widespread adherence of a hotly competitive computer industry to the ***de facto*** standards adopted by IBM, Intel and Microsoft have greatly benefitted both the industry and the public, and the refusal of the competitive marketplace to accept the *Betamax* VCR standard (it was proprietary to Sony) doomed this arguably superior technology in favor of the presently used VHS technology.

Essential though nationwide (and possibly international) standards may be for a fixed service such as telephone or television, it is even more critical for mobile services such as ITS. The inconvenience and economic inefficiency that would result if motorists needed different mobile ITS equipment for use in different cities would soon become a national joke.

National standards need not mean standard equipment features. Since the Federal Communications Commission opened the telephone equipment business to competition, telephones have been provided by dozens of manufacturers, large and small, and all are capable of placing and receiving telephone calls anywhere in the country; yet the service features of these telephones range from simple rotary dials to pushbutton sets to advanced phones with answer recorders and hands-free speakers and facsimile capability. In the case of telephone sets, standards were originally established by the AT&T Bell System, virtually a national telephone monopoly, for its own business-no local independent telephone company could conceivably adopt a different standard, even a better one, since its calls would be incompatible with the Bell telephones used in the rest of the country.

The situation is quite different with cable television. These systems are essentially local, and are different in different cities. Even a large multiple system operator (MSO) owns systems that are incompatible with one another. This incompatibility is of little consequence to the cable subscriber, since the cable company typically owns and leases the set top converter to the subscriber. Upon moving to a different city, the subscriber would obtain a converter usable in that city from the local cable operator. Cable system incompatibility is of course more significant to cable operators that might seek to meld their local systems into a nationwide system.

Standards are a continuing process.’ Although the cellular telephone industry began with a single standard (adopted by the Bell System), the transition to digital technology has been delayed by the adoption of different standards that will make mobile equipment more costly and incompatible with different digital cellular systems.

For ITS, it is essential to adopt technological guidelines and interface standards that allow for continuing innovation while maintaining compatibility across manufacturers, service providers and existing consumer equipment. These guidelines and interfaces must be revised and updated as necessary to assure a smooth transition to any new technology that may be adopted in the future.

G. ITS and Telecommunications

It has so far not been demonstrated that the market for ITS services will be large enough to justify separate telecommunications systems to carry its traffic. Also, the capital cost of such separate systems may be too high a burden during the initial phase of development of ITS. Moreover, the private sector owners and operators of existing telecommunications facilities may see ITS as a source of additional traffic for their systems; by using these existing systems, ITS can avoid seeking scarce radio spectrum for separate, dedicated facilities.

The practicality of using existing telecommunications services should be separately evaluated for each ITS application. For nationwide distribution of traffic information, existing satellite and optical fiber networks will probably be the most cost effective method. For distribution of information along a particular highway or within a metropolitan area, existing systems that parallel the highway or serve the area may be competitive with dedicated ITS systems. For highways distant from existing telecommunications routes, or for areas having inadequate facilities, dedicated systems may be a better choice. And for short range transmission of highway traffic data directly to vehicles, dedicated beacons or other wireless systems may be the only practical choice.

H. Policy Stability

The policies that have guided the development of some technologies have been modified as the technologies matured and the deployment became more complete. These changes have for the most part been healthy, but the rapid fluctuations in policy that have sometimes occurred (such as in the early years of the electric power industry) serve no party well. The private sector in particular needs a stable, predictable political environment. Government should adopt an ITS deployment strategy with care and then keep its hands off the policy levers for long enough to give its chosen approach a chance.

II. CHAPTER TWO — PUBLIC AND PRIVATE COOPERATION IN RESEARCH AND DEVELOPMENT -- INSIGHTS FROM OTHER INDUSTRIES

The development of ITS technologies, products and services can be supported by policies designed to mutually leverage scare public and private resources including funding, staff, laboratories and equipment. Examples of many collaborative efforts that may have applicability to ITS exist in other industries. This chapter looks at private sector research consortia or collaborations that are facilitated by public sector policies and offers clues as to how policy-makers could choose to promote ITS in the pre-deployment phase, especially in regards to research and development (R&D).

An important issue affecting (R&D) in the United States concerns the positive externalities in the creation of knowledge and technological innovations. Positive externalities are societal benefits associated with the production of a good. Suppliers or manufacturers produce less than the optimal amount of the good because they cannot charge a price which captures the full value of the good to consumers. For example, if a private company conducted basic research in physics and then published the results, the company probably could not reap the full returns of any theoretical advances since its findings could be widely and cheaply disseminated. Recognizing positive externalities associated with basic research, the federal government has provided substantial funding to universities and research institutes. According to the National Academy of Engineering, the United States spends more on basic research than Japan, West Germany, France, the United Kingdom, and Sweden.[1]

Positive externalities are also present in the phases of research leading to the adoption of new technologies by manufacturing firms. Applied R&D incorporates the theoretical advances of basic research into industrial processes and products. Even if a firm has a patent on a new product or process, it might not be able to realize the full returns on its innovation as knowledge of the innovation is disseminated. Through word-of-mouth and general discussions in trade journals, competitors can learn about innovations and imitate them without obtaining licenses from the patent-holder. According to Geroski, survey evidence indicates that companies cannot effectively use patents to capture full returns on their inventions.[2] Partly because of this, the National Academy of Engineers reports that the U.S. economy as a whole does not invest as much in applied R&D and technology transfer as foreign economies.[3]

A. Federal Policies

During the last few decades, the federal government has provided an enormous level of funding for all types of research and development. In 1986, for instance, federal R&D expenditures amounted to half of total public and private R&D expenditures of $122 billion dollars according to <u>BusinessWeek</u>.[22] In the early 1990's, federal R&D funding increased to around $72 billion dollars annually and its share of total expenditures is now greater than 50 percent as businesses have decreased their R&D funding during the recent recession.[4]

As federal subsidies for R&D remained generous during last decade, Congress tried to leverage more private sector R&D activities through patent law reform. The Stevenson-Wydler Technology Innovation Act of 1980, the Bayh-Dole Act of 1980, the Trademark Act of 1984, and finally the Federal Technology Transfer Act of 1986 facilitated the issuance of patents to private sector entities for inventions created with federal subsidies or through private-public cooperative research projects. Authorized by the Technology Transfer Act of 1986, Cooperative Research and Development Agreements (CRADA's) involve the sharing of research facilities and personnel among federal laboratories and private entities. The public and private partners also agree to share intellectual property rights.[5]

To date, collaborations among federal laboratories and private organizations have not generated extensive technology transfer to industry. Even though the number of R&D agreements between the labs and industry increased substantially from 15 in 1991 to 192 in 1992, a survey done for the Industrial Research Institute indicates that firms searching for new technology seek assistance from universities and other companies first before contacting federal labs.[6] The massive R&D resource at the labs (700 labs consume $20 billion or one-third of federal R&D expenditures) has not yet developed huge quantities of technological products and processes with private sector applications because much of the lab research is driven by the missions of federal agencies rather than market developments. Observers do not criticize the agencies for devoting much of their R&D effort to important national goals such as research in energy efficiency and conservation. They take issue, however, with the slow pace of implementing procedures for transferring technology as mandated by federal legislation. For example, the National Academy of Sciences cites a 1991 GAO study revealing that 31 percent of labs still lacked official guidance for implementing the 1986 Technology Transfer Act and 156 laboratory directors did not have authority to negotiate CRADA' S.[7]

The National Academy of Sciences cautions against broad mandates to increase the amount of federal lab R&D with commercial applications. An example of a global directive is the Stevenson-Wydler Act's requirement that 0.5 percent of each federal lab's budget be devoted to assisting private sector companies to utilize technology developed at the labs. Laudable in their intent, these mandates can nonetheless create inefficiencies by requiring all federal labs to devote a portion of their capacity to technology transfer, despite the varying abilities among the labs to do so. Instead, the National Academy recommends that the federal government direct increased funding to labs specifically structured for technology transfer.[8]

Labs structured for diffusing technology have institutionalized public-private partnerships. The partnerships range from advisory committees guiding lab research to joint business ventures. For example, the Department of Energy's Oak Ridge National Laboratories has an advisory council composed of private sector representatives which offers suggestions for research. Other Department of Energy labs conduct research in super-conductivity at the request of business. The most involved relationships among federal labs and non-governmental organizations are business ventures. Argonne National Laboratories and the University of Chicago, for instance, have established a corporation that licenses inventions by Argonne scientists who receive 25 percent of sales revenues. Sometimes, the government plays a more passive role when agencies contract out the operations of federally owned labs to private companies. Known as GOCO's (Government Owned and Contractor Operated) a number of these labs are regarded as very effective at inventing technology with commercial applications.[9]

The key feature of the various public-private relationships is the utilization of the private sector's knowledge of the marketplace. Many assert that private companies have a comparative advantage over the government of assessing the marketability of high technology products. Also, the private sector has more detailed knowledge of the costs associated with adopting technological innovations or processes to their manufacturing operations. In the past, the federal government, without the extensive involvement of the private sector, invested heavily in R&D for some technologies it deemed to have great societal benefits but which were not being produced due to positive externalities. Unfortunately, a number of the resulting technologies did not fare well on the market.[10] Commentators suggest that while the government should continue to pursue these types of innovations, the private sector should have a major role in the R&D phase in order to reduce the risk that the technological innovations are not marketable.

As well as engaging in cooperative R&D projects, federal agencies award grants for basic and long-term applied R&D to universities and private research organizations and firms. The 1988 Omnibus Trade and Competitiveness Act created several new R&D and technology transfer programs such as the Advanced Technology Program (ATP) administered by the National Institute of S tandards and Technology (NIST). Started in 1990, ATP is enjoying the emphasis of the Clinton administration on technology development; its budget is slated to grow from $68 million in FY 92 to $750 million in FY 97. ATP awards grants for generic or basic R&D, but maintains the link to commercialization of technology through a selection process that involves private sector representatives reviewing the research proposals for their commercial potential. NIST is considered very competent in assessing the scientific merit of R&D proposals due to its own impressive in-house R&D activities carried out by 3,000 scientists operating at labs in Boulder, Colorado and Gaithersburg, Maryland.[11]

The Small Business Administration (SBA) and the National Institutes of Health (NM) also issue grants for private sector R&D activities. The SBA receives funding from eleven different federal agencies for its Small Business Innovation Research (SBIR) program. The SBIR's FY 1990 funding level of $460 million supported awards for over 3,100 R&D projects ranging from bio-technology to energy systems conducted at small and medium-sized businesses. With a considerably larger annual budget of $5.2 billion, NIH supports about 25,000 research and training projects. Many of the NIH subsidized R&D projects have developed into commercially available biomedical and pharmaceutical products.[12]

As we have seen, successful federal subsidy and research programs involve the active participation of the private sector. The federal government has involved the private sector in developing research agendas and in awarding grants to non-governmental organizations. In addition, the federal government has instituted cost-sharing as an integral part of its partnership with the private sector. It is widely felt that cost-sharing is an important indicator of the potential commercial applications of R&D activities. Firms are most likely to request funding from a program like ATP that requires up to a 50 percent match if they think that the research can lead to a marketable product.

B. Lessons for ITS

The lessons the federal government has learned since 1980 about investing in R&D indicate that public investment in ITS R&D should involve public-private partnerships. R&D related to ITS will generate positive externalities just as basic R&D does. Therefore, significant public funding is desirable, but policy-makers also must work to incorporate private knowledge of the marketplace in ITS decision-making. Though federal investment in R&D increased substantially during the early 1980's, the amount of publicly subsidized R&D with successful commercial application did not increase much. However the creation of several policies and programs after 1988 involving private participation and cost-sharing is substantially increasing the amount of commercially viable R&D. Public-private partnerships in the R&D phase can help spur progress in ITS deployment.

C. State Policies

While the federal government provides the great majority of public sector funds for basic or generic R&D, states are more involved in technology transfer and industrial extension activities. Since it is mostly concerned with national economic performance, the federal government channels most of its assistance to basic R&D that benefits many different industries and sectors of the economy. States also fund basic R&D in their universities and private research organizations, understanding that the generic technological innovations of such R&D often flow to companies located throughout the United States. But because states are naturally most interested in promoting economic development within their jurisdictions, they direct most of their subsidies and technical assistance to activities that promote the commercialization and transfer of technologies to companies operating in their borders. They are also heavily involved in industrial extension activities which include general technical assistance to firms in business management and worker training.

The states have adopted the vital role of building institutions supporting R&D activities and technology transfer as the federal government assumed the major funding responsibilities. The National Governor's Association reports that in total, states funded less than 1 percent of R&D activities in 1985.[13] As mentioned above, the federal share of total R&D expenditures has increased to over 50 percent during the last few years. However, the states' contributions to technological innovation should not be overlooked by simply examining inter-governmental funding levels. The states have more knowledge than the federal government of the comparative strengths and weaknesses of their economies. Therefore, they are in a better position to develop local institutional frameworks for technology transfer and industrial extension.

Ohio's Edison Technology Centers illustrates how the states tailor their assistance to the unique capabilities of their economies. Funded with federal and state grants, and fees for services, eight Edison Technology Centers draw on the research expertise of in-house staff and local university academics to offer customized services for regional manufacturers. For example, the Edison Polymer Innovation Corporation located in the Cleveland/Akron industrial corridor conducts applied R&D geared to the technological needs of rubber and synthetic manufacturing companies. Research at the Polymer Innovation Corporation has resulted in 16 patents and the licensing of 3 technologies to member companies. Member companies have established two consortia to commercialize technologies developed at the corporation. Like the Polymer Corporation, the other Edison Centers charge sliding fees for services; relatively low fees for technical assistance and dissemination of R&D results, and higher fees for exclusive licensing arrangements for member companies. Fees for service form a significant part of the budgets of the centers. For example, 40 percent of the budget of Ohio University's Biotechnology Center is generated through contract research for member companies.[14]

Indiana's technology development program is not as regionally distinctive as Ohio's. In 1982, Indiana established a state-wide non-profit organization, now called the Indiana Business Modernization and Technology Corporation (IBMTC), to provide funding and technical assistance for new high technology firms and established manufacturing companies. Although it receives biennial funding from the state, IBMTC is an independent non-profit organization able to build stable long-term programs because it is more insulated than state agencies from changing political priorities. IBMTC has two funds, the Product Development Fund (supporting applied R&D and development of product prototypes) and the Product Commercialization Fund (supporting the commercialization of applied R&D) that make equity investments in young high-technology firms. IBMTC also offers bridge loans and grant writing support that assists small businesses through the two phase process of applying for SBIR grants from the Small Business Administration (see above for description of SBIR program). Also, the IBMTC funds technical assistance offered to business by the Centers of Technology Development located at universities and research institutes across the state. Finally, IBMTC has been designated as the affiliate to NASA's Great Lake's Regional Technology Transfer Center. As an affiliate, IBMTC accesses NASA's and other federal databases on behalf of Indiana's companies for information relating to technological products and processes developed at federal laboratories.[15]

Indiana's non-profit corporation is a provider of technical and financial assistance whereas Ohio's technology centers resemble entrepreneurs seeking to interest manufacturing companies in commercial applications of their R&D activities. Why the states choose different approaches to pursue economic development through technology transfer cannot be conclusively answered without more detailed study. One factor which does differentiate assistance programs is state-level assessments of their unique needs and talents. Indiana, for instance, established equity investment funds for high-technology entrepreneurs out of a desire to diversify its economy to include high technology as well as manufacturing firms. It created the SBIR bridge fund because small businesses were not as successful as their counterparts from other states in receiving awards from the SBIR program. Like Indiana, Ohio provides technical assistance to young and established firms. Unlike Indiana, Ohio also established the Edison Centers as high-technology entrepreneurs that assist manufacturing companies incorporate technological innovations into their production processes.

In contrast to Ohio and Indiana, Massachusetts has concentrated its efforts on financial assistance for high-technology firms. With $2.9 million from the federal Department of Commerce and $5.2 million of its own funding, the state created the Massachusetts Technology Development Corporation (MTDC) in 1978 to make equity investments in high tech start-ups. Although the United States has a well-developed money market, state officials concluded that venture capitalists tended to invest in more mature high-technology companies.[16] When MTDC started making equity investments through stock purchases of between $100,000 to $250,000 per company, it was able to leverage substantial investments by existing venture capitalists in nascent high-technology firms. It demonstrated a commitment to reducing risk associated with these investments by providing long-term (up to ten years if necessary) technical assistance in management and business strategy. To date, MTDC has invested $20.7 million in 63 high-technology companies, leveraging an additional $288 million from venture capitalists. It realizes gains through sales of stock when the high-technology firms go public or are acquired by other companies. Net gains, minus losses associated with bankruptcy, since 1980 total $6.8 million.[17]

California is at an earlier stage than Massachusetts, Indiana, or Ohio in its strategic support of technology and economic development. While the three northeastern states have operating programs, California has launched a strategic planning process that will identify how to utilize its public and private sectors to increase job creation and economic competitiveness through technology development. In 1988, the state legislature established an advisory panel, the California Council on Science and Technology (CCST), that is composed of representatives from business, government, labor, and academia. CCST is charged with conducting assessments of the potential to augment the technological capacities and competitiveness of various industries. For example, a CCST panel on waste management created a ranking system for selecting R&D projects to bolster the technological efficiency of waste management. CCST also created ***Project California,*** a public-private collaborative that combines government and industry funding with the research capabilities of California's universities and computer and electrical industries to develop ITS and other advanced technologies. CCST illustrates how a state undertakes a strategic planning process that directs its economic and technological assets towards unmet social needs in an endeavor to increase employment and competitiveness.[18]

The different levels of government specialize in their areas of comparative advantage in the support of technological development and dissemination; the federal government is the primary funder while the states assume a coordinating or a niche role. Over the years, Indiana and Ohio have cooperated with universities and private sector firms to develop sophisticated research centers that conduct basic and applied R&D and then transfer technology to the private sector. Massachusetts' MTDC, in contrast to Indiana's and Ohio's organizations, does **not** undertake the role of coordinating R&D through the establishment of research centers, perhaps because of the extensive R&D facilities of its universities and established high-technology firms. Instead, it identified a niche role, the funding of high-technology start-ups, that it could assume in order to facilitate the development of technology.

D. Lessons for ITS

Some states have adopted policies and programs to foster particular industries within their boundaries. In adopting technology transfer and industrial extension activities, many states demonstrate successful commitments to public-private partnerships. California's ***Project California*** is a public-private collaboration designed for researching and developing ITS and other technologies. Similar partnerships will be beneficial in other states in order to identify and address many ITS technological challenges faced throughout the nation.

E. Private Sector Consortia and Collaborations

In an era of scarce federal and state resources, it is desirable to leverage as much private sector resources for basic and applied R&D as possible. Theoretically, it might even be possible for the private sector to assume the primary role of funding R&D. The current impediment to increased private sector expenditures for R&D is positive externalities. The Coase theorem of public finance economics suggests, however, that if property rights can clearly be assigned to products derived from R&D, then the private sector would substantially augment their financing of R&D.

The clear assignment of property rights is a formidable challenge. For basic R&D, it might not be possible or desirable. A theoretical advance in electronics or physics could lead to process innovations that benefit a wide range of industries. Private companies in one industry are unlikely to be interested in ownership rights to that type of innovation. Moreover, since the theoretical advances have potentially wide societal benefits, some would argue that they should be publicly disseminated rather than profiting a particular commercial entity. On the other hand, greater possibilities exist for assigning property rights to applied R&D. Because applied R&D leads to the commercialization of technology, its beneficiaries are fewer and hence are more interested in assuming the costs and property rights associated with it. But as mentioned above, patents and licenses do not always work effectively in protecting property rights.

To internalize positive externalities, private sector entities have formed consortia and joint ventures among the users and producers of technology. For basic R&D and some longer-term applied R&D, companies usually do not attempt to distribute property rights to R&D among themselves. Instead, they jointly fund university research and help design curricula and research agenda. For applied R&D, consortia and joint ventures are developing mechanisms for assigning property rights to process and product innovations arising from the R&D.

Of the methods to internalize positive externalities, economists generally favor consortia and joint ventures. Geroski, a British economist, reports that in previous years the British government encouraged mergers among producers of technology. This type of horizontal integration is ultimately inefficient because it creates an oligopolistic or monopolistic industry that faces little competition and hence loses its incentive to innovate. Instead, Geroski advocates vertical relationships among producers and users of technology, such as the consortia and joint ventures being established in the United States. In a vertical relationship, a producer of technology might license the technology to a manufacturer or offer a retailer marketing rights to sell the technology. On the other hand, vertical integration occurs when the producer of technology (a bio-technology firm, for example) merges with the. user of high technology (a pharmaceutical company). Vertical relationships are more desirable than vertical integration because they maintain more of a competitive economic structure (with fewer barriers to establishing or terminating business arrangements) according to Geroski.[19]

Regarding consortia and joint ventures to be economically beneficial, the federal government facilitated their development in the 1980's by a series of anti-trust regulatory reforms. The National Cooperative Research Act of 1984 declared that not all business collaborations or combinations ought to be considered restraint of trade. It also eliminated the possibility of defendants being liable for treble damages in the event of a law suit. In the wake 'of the Act, the Justice Department established "reasonableness standards" or criteria for judging whether collaborative projects restrained trade. The Department ruled that long-term, broad-based research projects on a scale too large for one company to undertake were permissible under the reasonableness standard. It further agreed to review proposed research consortia for compliance with the new standards.

The regulatory reform stimulated private sector partnerships and collaborations. Rahm states that one of the greatest stimulants was the elimination of the possibility of treble damages. With this potential liability removed, tax advantaged R&D partnerships (RDLP's) among companies soared so that by the early 1990's industry had invested $2.5 billion on 218 RDLP's. Also, with authority established by the 1984 Act, the Justice Department reviewed and permitted the establishment of consortia.[20]

The Microelectronics and Computer Technology Corporation (MCC), one of the consortia cleared by the Justice Department, advances R&D by undertaking high-risk research and then assigning property rights to technological innovations to members of the consortia. The board of directors, including computer and electronic companies, aircraft manufacturers, and defense contractors, establish a research agenda for MCC's in-house staff. The staff conducts long-term applied R&D and prototype development that is too expensive or risky for any one member company. For example, MCC's Enterprise Integration Program has been developing electronic and computer networks that perform data exchange among companies while maintaining the security and confidentiality of proprietary or personnel information. Through large scale programs like Enterprise Integration, MCC seeks to establish open architectures or flexible infrastructures that promote standardization yet allow for innovative product differentiation within the microelectronics industry.[21]

MCC internalizes positive externalities through a tier system of property rights. Member companies have differential access to the ownership and utilization of technology developed by MCC depending on their financial contribution to MCC. The most expensive memberships are those of shareholder equity investors, whereas less expensive memberships consist of annual fees. Economically, this system seems efficient since it assigns the highest level of property rights to those companies with the greatest needs or desires for MCC innovations as reflected in their willingness to make the greatest financial contributions with the greatest risk. Before MCC, large-scale and high-risk projects desired by industry could not be developed because it was not possible to assemble the necessary capital resources and assign property rights based on the willingness of companies to invest in these projects.[22]

To facilitate technology transfer, MCC has formed an independent company, MCC Ventures Inc. Ventures Inc. establishes entrepreneurs that commercialize innovations arising from MCC's applied R&D activities. For example, Ventures gave birth to Evolutionary Technologies Inc. whose products includes a device that transfers data among dissimilar computer storage environments.[23] Spinning-off companies increases the efficiency of technology transfer by creating specialists in particular technologies. These specialists develop refined abilities to continually adapt and customize high-technology products to the needs of their users.

On the other end of the consortia spectrum from MCC is the Semiconductor Research Corporation (SRC). SRC is a consortia of private sector companies including telephone, car manufacturing and computer companies. Instead of developing mechanisms for stimulating private sector R&D by assigning property rights, SRC decided that it was more practical to fund and influence the direction of basic R&D at the nation's universities. According to SRC, university research in semiconductors is replacing private sector basic and long-term applied R&D, which has greatly decreased in the last two decades. Private industry, while excited about the increase in university research, felt that it could be oriented more towards the needs of industry. In fact, SRC maintains that without its funding presence, "semiconductor manufacturing would be absent from the academic research agenda.[24] Since its inception in 1982, SRC claims that it has provided $200 million, or about half of all the funding for generic semiconductor research at university facilities. In addition to funding, SRC administers R&D activities of research centers at 33 universities in 15 states. Receiving funding from SEMATECH, a public-private consortia to be discussed below, the research centers undertake basic research of interest to industry.[25]

Consortia such as MCC and SRC tend to be formed by mature and emerging industries. Some mature industries have a need to increase R&D due to a decline in R&D research at private sector labs. Emerging industries form consortia out of a need to increase resources directed towards high-risk, long-term research. Young industries, on the other hand, may not yet have the resources that can be committed to the creation of consortia. Instead, they tend to form joint ventures with established companies in related industries.

The bio-technology industry is a relatively young industry that has yet to form consortia of the breadth or depth of the electronics and semiconductor industries. Bio-technology firms are typically small businesses, some of which were established by academics to commercialize university research. While bio-technology firms possess the scientific expertise to conduct R&D, they lack the resources needed to fund the commercialization of R&D innovations. Rather than establishing consortia, bio-technology firms have been forming partnerships with large companies, such as pharmaceuticals, that can support long-term, risky product development. In exchange for funding R&D, the corporate partner retains marketing rights as well as a share of profits. Since 1989, bio-technology firms have formed approximately 650 partnerships with larger corporations.

According to the Economist, partnerships involve complicated deals over property rights that sometimes terminate in law suits. Some bio-technology firms felt that the initial partnerships unfairly favored the corporate funder. Now, bio-technology firms are negotiating more complex agreements dividing marketing rights and profits with the corporate funders.[26] Specifying and assigning property rights in partnerships internalizes positive externalities and therefore stimulates research that may not have been conducted. However, as the bio-technology example illustrates, such agreements are still in their evolutionary stages and need further refinement in order to realize their potential.

F. Public-Private Consortia

As stated above, recent federal efforts to stimulate consortia included tax incentives and regulatory reform. In addition, some federal agencies have started participating directly in consortia that they consider to be vitally important to the competitive position of the U.S. economy. As members of consortia, the agencies direct their funding contributions to areas of traditional public domain, including the pursuit of technologies to reduce pollution.

In 1987, the federal government, industry, and academia created the SEMATECH (Semiconductor Manufacturing Technology) consortium as a mechanism to revive the semiconductor industry, regarded to be essential to national security and the economy. SEMATECH's promotional brochure states that "semiconductors are vital ingredients of every modem electronics system from microwave ovens to communications satellites. They are the technological base of America's economic strength and defense strategy."[27] The private sector and the Department of Defense's Advanced Research Products Agency each contribute about $100 million dollars annually to SEMATECH's mission of developing and disseminating technologies and processes for the manufacture of semiconductors.

SEMATECH's focus on manufacturing processes and technologies was designed to eliminate the U.S.'s weakness in commercializing and transferring technology. While the U.S. is considered a leading innovator, it lags behind other countries in adopting high technology manufacturing production techniques. As well as developing manufacturing technologies, SEMATECH has established research facilities at universities which are managed by SRC as mentioned above. Not only does SEMATECH regularly communicate with its member semiconductor manufacturing companies, it also consults extensively with the suppliers of material used in semiconductors, who have formed their own independent organization called SEMYSEMATECH. SEMATECH, therefore, carefully guides the public and private investment in semiconductor manufacturing processes by strengthening linkages among all phases of industrial production and academic basic research. Partly as a result of SEMATECH's efforts, U.S. industry was the leading exporter of semiconductors during 1993.[28] In a 1992 report, the GAO affirms that SEMATECH has helped "improve a U.S. industry's technological position" while ensuring that public funds are spent "appropriately."[29]

Another public sector benefit is SEMATECH's research in pollution reduction techniques for semiconducting manufacturing. Congress has mandated that $10 million of the annual federal contribution to SEMATECH be directed towards environmental and worker health and safety R&D activities. As SEMATECH is engaged in developing new technology and processes, specific resources are devoted towards creating processes which are as energy efficient and clean as possible. The environmental R&D has identified opportunities for recycling chemicals during the manufacturing process and replacing ozone-depleting chemicals with less polluting substitutes. SEMATECH has also created industry-wide environmental, safety, and health standards.[30]

The Clinton administration has embraced public-private joint research in energy efficient and pollution reducing technologies as a complement to the traditional regulatory approach of controlling energy usage and pollution levels. In the fall of 1993, the administration and the Big Three U.S. automakers announced an unprecedented collaboration called Partnership for a New Generation of Vehicles. The Partnership is devoted to increasing the competitiveness of domestic automobile manufacturers by developing fuel efficient technologies. It combines the expertise of the private sector in marketing and product development with the technological sophistication of the federal energy and defense laboratories. Ambitious long-term goals include the production of prototype vehicles with three times greater fuel efficiency than today's vehicles, the possible replacement of the internal combustion engine with fuel cells, and the utilization of super-strong, light-weight materials developed by the Department of Defense. The exact funding contributions of the public and private partners have not yet been determined, but it is most likely that the private sector will devote most of its resources to near-term applied R&D and commercialization, whereas federal agencies will fund riskier, long-term basic R&D.[31]

Although there are no guarantees that revolutionary new technology will be produced from this partnership, the collaboration nevertheless has societal benefits. On the research side, it coordinates the basic and applied R&D of the private sector and multiple agencies within the federal government, thereby reducing unnecessarily duplicative research. It also enhances the public sector's capacity to regulate energy consumption and pollution levels by providing federal agencies with more information regarding costs and benefits of regulations as well as the feasibility of environmental technologies. In the most optimistic case, the partnership could make a whole range of regulations obsolete if it is able to produce clean vehicles.

G. Lessons for ITS

Private and public-private consortia and collaborations demonstrate the imperative of marketplace experience in researching and developing products with commercial application. It will be essential for many ITS products to be commercially viable. Both purely private and public-private consortia can conduct R&D for ITS that will result in commercially viable products.

H. Summary

Most observers agree that positive externalities cause the private sector to under-invest in R&D. Public funding of R&D is therefore appropriate, but the government should not, on its own, choose which research to subsidize. Existing and new institutional mechanisms should be utilized for involving private sector firms and academics in allocating R&D funding. This way, the government taps the expertise of the private sector in producing marketable technologies, processes, and services. By allocating subsidies with private sector guidance, government gains more information about how to mobilize and utilize the talents and capacities of the private sector when it undertakes large scale procurements to produce a national ITS infrastructure. Similar large scale procurements can and have boosted the competitiveness of U.S. industry as well by supporting the development of new products and markets.

The emerging consensus has stimulated refinements in federal and state-level interventions in the economy. The Clinton administration has increased coordination among federal agencies so that funding and regulatory activities of the various agencies do not counteract one another. While the federal government will probably continue to fund most of the basic R&D in the United States, it has encouraged and required more private sector funding of applied R&D. This should be reflected in ITS policies as well. Meanwhile, regulatory reform and tax policy has spurred the development of private sector consortia that fund industry-wide R&D and develop relationships among users and suppliers of technology in order to facilitate technology transfer. A positive environment of technology transfer will be essential for efficiently developing the extensive ITS infrastructure. For their part, state governments have developed strategic economic plans and have established various public-private partnerships for conducting basic and applied R&D tailored for industries critical to their economies. Many states will seek to cultivate an ITS industry within their borders and will use public-private collaborations in R&D as one instrument for doing so.

In sum, as the federal government continues its traditional role of funding R&D, recent policy initiatives involve the creation and support of institutional collaborations among the public and private sectors. The new institutions have not yet assumed the role of major funders of R&D. For example, consortia contribute less than 1 percent of the total R&D public-private budget.[32] However, if ITS policy-makers implement public-private partnerships and institutions, it can be expected that private investment in ITS R&D will help leverage scarce public funds and vice versa. It is hoped that as these institutions evolve they can also leverage more funding through continued innovations in the assignment of property rights and the development of new types of entrepreneurs. The challenge is to prevent the new wave of institutions from resembling their centralized predecessors that often stymied the progression to succeeding generations of technology. By promoting decentralized institutions engaged in the development of open architectures and flexible technologies, it is hoped that the government can encourage both necessary collaboration and competition.

III. CHAPTER THREE — CABLE TELEVISION

Cable television technology evolved in three stages. In the early days of community antenna television (CATV) systems, 1950 through the early 1970's, cable systems retransmitted local and distant television station signals to provide television programming to homes that could receive few if any television stations with rooftop antennas. Coaxial cable were strung on telephone and utility poles to connect homes to towers, antennas and microwave relay stations capable of receiving television signals. The technology was crude, simple and effective.

The second stage began with satellite distribution of HBO in 1976 and continued to the late 1980's as virtually all non-broadcast cable television programming was satellite delivered. "Communications satellites are key to success of cable service as a distribution medium." [Owen & Wildman] Cable television became the medium through which the benefits of communication satellite technology reached the largest possible number of American homes, nearly 65 million homes today. Without satellite distribution, cable television would not have emerged from a community antenna service to the dominant multi-channel video provider, and without cable television, satellites would not have been used to distribute television to most homes until the advent of high-powered satellites and resultant small home satellite receivers in the 1990's.

England is one of the only countries where cable television and direct broadcast satellite television (DBS) coexist. In the United Kingdom various economic and government policy factors precluded the development of broadband cable television until the mid 1980's, [The Case for Cable, 1991, 1992] and direct-to-home (DTH) satellite television on the Astra satellite preceded cable television. BSkyB became the first and foremost provider of multi-channel television with its Sky channels offered on a subscription, Pay TV basis to dish owners. In the few U.K. cities where high-capacity, broadband cable television systems have been constructed, however, cable television service has eclipsed DTH satellite television, despite BSkyB's first-mover advantage. Indirect usage of satellites by cable television systems which accumulate signals from many satellites and redistribute them to subscribers' TV sets seems to have competitive, consumer-benefit advantages over direct-to-home satellite broadcasting.

The third stage of cable technology is just beginning with the introduction of fibre optic technology and digital compression. Fibre has been used in portions of the cable distribution plant for the past three to four years, and most cable system rebuilds are installing fibre optic cables closer and closer to the home. New cable system architecture employing ring and hub designs maximize the effectiveness of fibre deployment. Digital compression of television signals allows multiple channels of programming to be carried on one 6 Mghz frequency so that a single cable television channel can provide 4 to 10 24-hour a day program services.. The use of fibre optics and digital compression will turn the dream of a 500-channel environment into reality, and these technologies will enable cable television to provide the full range of interactive multimedia services and telephony services in competition with Bell operating companies. Cable is bidding to become one of the nation's information superhighways to the home.

A. History[33]

By early 1941, uniform technical standards for a new broadcasting service called television had been adopted by the (FCC). Only five or six television broadcasting stations had been built and were in operation by the start of World War II, which brought further development of television to an immediate standstill. By the end of the War, television's enormous potential had been recognized, not only by radio broadcasters and receiver manufacturers, but increasingly by the public as well. Radio broadcasters feared for their commercial lives, while receiver manufacturers perceived an exploding market as the public rushed to purchase new radios with pictures.

Applications for new TV station permits inundated the FCC, forcing it to re-impose the war-time freeze. Since the 12 channels in the VHF frequency spectrum allotted in 1941 for television could not even begin to accommodate demands for new TV stations, the FCC turned to the UHF spectrum, recognizing that it would take time to answer the almost unlimited questions about how many new channels would be needed, and how best to make use of them. Meanwhile, General Sarnoff, President of RCA, initiated the prospect of color TV, and the battle between RCA and William Paley's CBS over color standards stalled the post-war development of TV broadcasting once again. By 1948, there were still only 16 TV stations in operation, and the great majority of people who did not live nearby could only envy those who did.

1. CATV

In December, 1948, a radio station operator and electronics hobbyist in Astoria, OR found a hot spot near his home where he could receive television from KRSC which had just gone on the air in Seattle, 125 miles away. To accommodate his neighbors, he ran coaxial cable from roof-top to roof-top, until the fire department forced him to move his wires to the telephone poles. Thus was born the community antenna television (CATV) industry. Simultaneously, an appliance and service merchant in Mahanoy City, PA wanted to sell a consignment of television receivers. He discovered a place on a hilltop a mile or so out of town where he could get television from Philadelphia, nailed flat twin-lead wires to tree trunks and fence posts and brought the signals into town. The first rainstorm short-circuited his wires and forced him to change to coaxial cable. CATV was underway on the east coast.

The FCC freeze of television broadcasting stations was lifted in April, 1952, and new TV stations sprang rapidly into operation. At first, CATV systems were confined to places, like Astoria and Mahanoy City, where television could be-received only with a community antenna on a remote hilltop or other hot spot. Then, as more and more broadcast television stations were activated, CATV operators began to import the signals of distant television stations, even in places where one or two TV stations were readily receivable. Distant signal importation provided a new service offering which proved to be a critical factor in attracting CATV subscribers. CATV, originally conceived as a means for receiving television where none was available, gained public acceptance as a way to receive any programming not otherwise available and to receive improved television reception. CATV operators reached out farther and farther for distant TV stations that could not be received locally, using elaborate high-gain antenna systems and enormous parabolic reflectors.

In 1953, a CATV operator in Casper, WY leased a microwave channel from the telephone company to relay the signals of a Denver TV station for distribution by cable to subscribers in Casper. After the FCC authorized CATV to use microwave frequencies and to become specialized microwave common carriers, a large microwave network was developed nationwide to provide distant TV signals for carriage by CATV.

In 1965, after the U.S. Supreme Court declined to review the lower court ruling in the Carter Mountain case confirming the authority of the FCC to regulate CATV systems using microwave, the FCC issued its First Report and Order regulating CATV. At the same time, FCC established a new community antenna relay service (CARS) providing for licensing microwave transmitters directly to CATV systems in addition to the specialized common carriers. The CARS authorization included a new multi-channel microwave service, called AML (amplitude modulated link) to facilitate relaying cable TV signals from one main headend to multiple smaller communities too distant to be linked by coaxial cable, and too small to support separate headends. By providing an economical and high quality means for connecting the main headend to a group of secondary headends, or hubs, AML became almost a necessity for franchise areas too large to be served by ordinary coaxial cable from a single headend.

Channel capacity stabilized at 35 channels for several years, with new distant signals limited both by the 1972 FCC Rules (see below) and by the fact that additional signals provided little or no new programming choice. There was little need for more than 35 channels.

2. Pay TV and Satellite Distribution

In 1971, the FCC preempted local authorities from regulating Pay-TV on cable television networks. Previously, the introduction of Pay TV, premium channels provided for additional monthly fees,. was restricted by some franchise agreements which banned Pay TV and by technical limitations. Various scrambling methods were proposed to provide security and billing information for Pay-TV on cable, though none were implemented.. By 1974, Pay-TV began to develop by playing video tapes at cable headend and using traps to deny the program to those who did not wish to pay. Home Box Office (HBO) was formed by Time, Inc. to launch the Pay TV industry, but the use of tape was inefficient and expensive and Pay-TV remained dormant until 1975.

In October, 1975, HBO relayed the Ali-Frazier heavyweight championship fight to a cable operator in Florida, and another in Mississippi, by means of a satellite in geostationary orbit, 23,000 miles above the equator. With technical success and huge public enthusiasm, HBO's satellite transmission of "The Thrilla in Manila" proved that satellite Pay TV over cable television systems was a viable business. The era of CATV ended and cable television emerged as a multi-channel television programming provider.

Ted Turner, owner of a UHF TV station in Atlanta, established the first superstation in 1976 by arranging for a subsidiary company to receive WTBS broadcast signals and relay them by satellite to cable headends across the country. The growth of new cable-exclusive program sources, including Pay TV services such as Showtime and Playboy, and basic cable channels such as CNN, MTV and ESPN changed the nature of the cable franchising process. Whereas cable television operators had previously shunned major metropolitan markets, except for New York City and San Francisco, because providing better reception of local television stations and distant signal programming was not deemed sufficient to attract cable subscribers in cities adequately served by broadcast television, the availability of new cable-exclusive programming made the acquisition of urban cable franchises extremely valuable. The chaotic and in some cases corrupt urban market franchise wars of 1978 to 1985 had begun.

Satellite Pay-TV required conditional access to premium TV channels. Picture scrambling techniques for cable TV were first used about 1975 as a means for denying reception to subscribers electing not to pay for Pay-TV. Descrambling can most effectively be accomplished for any channel transmitted on cable by combining the descrambler with a converter. During the past twenty years, descrambler converters, negative traps and positive traps have been used by cable television operators for conditional access to Pay TV, and addressable decoders/converters have been used by most large urban-suburban cable systems to insure signal security and provide convenient pay per view ordering systems. Over half of cable subscribers currently have addressable converters.

B. Regulation

Federal regulations and Supreme Court decisions have had profound effects on the growth and development of cable television, both in fostering cable's viability and explosive growth during some periods and retarding and constraining growth at other times.

Federal regulation of cable by the FCC was an outgrowth of broadcast television regulation. The FCC's objective in the 1950's and 1960's was to provide local television stations on the UHF band throughout America, including numerous local stations in all major markets and at least one or two local stations in every small city and town. This policy stemmed from the FCC's belief that local TV stations were "instruments for community enlightenment and cohesion, much like the hometown newspaper of an earlier era." [Noll, Peck, and McGowan, "Television Regulation, p. 58-93]

However, by the mid-1960's it was clear that "(t)he 1952 allocation plan has not been successful ... fewer than half of the planned (VHF) stations are now broadcasting . . . many (homes) in outlying areas still have few (television) options and relatively poor quality service." [1977 p. 25] By attempting to provide access to local television programming throughout the country, the FCC impeded the growth of broadcast television stations and opened the door for cable television. CATV systems arose in small towns, fringe suburban areas or isolated cities where off-air reception was either nonexistent or of very low quality.

Official federal government involvement with cable television began in 1960 when the U.S. Supreme Court ruled that the 1909 Copyright Law did not require cable operators to pay copyright fees for retransmission of broadcast television programs. This favorable "retransmission consent" ruling was vital to the economic viability of early CATV systems, which could not have sustained compensatory copyright fees payments. Also in the early 1960's, the FCC refused to assert regulatory authority over the fledgling cable television industry, on the grounds that cable was not an independent medium falling under FCC purview.

From its inception, cable television came under local government jurisdiction. Local authorities provided licenses or franchises, assisted in obtaining rights-of-way and pole attachment agreements, often enforced certain safety standards, and usually collected per-customer franchise fees from cable operators. Some pre-1960 cable systems were devoid of any regulation or government involvement, but most were franchised by local authorities, with varying forms of cable rate regulation written into most franchises.

1. Cable Regulation by The FCC

At the urging of the three national television networks, ABC, CBS, NBC and their affiliates, who formed the core FCC constituency, regulatory authority over cable television was asserted by the FCC in 1965. Though still an infant industry, CATV systems were perceived as a looming threat to the broadcast network's domination of the airwaves. The FCC held that the growth of cable was threatening the viability of UHF stations and limiting the establishment of more local stations. Importing distant signals on cable led to competition with local network affiliate stations for audiences and advertising., or so-called audience fragmentation, which implies less revenue for the networks and affiliate stations and greater variety and program choice for TV viewers. In 1968 the FCC banned CATV carriage of distant signals in the 100 largest U.S. markets and placed a moratorium on building cable systems in the top-100 markets.

CATV systems provided two consumer benefits: (1) reception of local and nearby TV stations to homes that could not receive the signals with a rooftop antenna, or homes that could not receive clear, consistent pictures, and (2) programs from outside of the locality (distant signals) especially sports, older movies and syndicated shows. Since most of the 100 largest markets were not reception impaired, the growth of cable in urban-suburban America depended on distant signal importation. During the five year (1968 - 1972) FCC ban on carrying distant signals, cable's growth was frozen.

After 1972 the FCC began to relax the ban and allowed partial distant signal carriage under various, restrictive circumstances, including black-outs of distant station programs shown on local stations at the same time and limits on the number of distant signals carried. Black-outs became a part of the cable program lineup, and four years of regulatory uncertainty and strife ensued. In 1976 the ban on distant signal importation was struck down by the Supreme Court, and Congress passed a new copyright act significantly revising the 1909 Act. Cable received a compulsory license to retransmit any and all broadcast television signals in exchange for a fixed percentage of cable revenues paid into the newly formed Copyright Royalty Tribunal (CRT). The CRT allocated funds it collected from cable operators to original copyright holders: movie studios, sports leagues, TV program producers, etc.

By the end of the decade, the FCC had ended all restrictions of cable television, except for must carry requirements for cable systems to carry all "significantly viewed" local TV stations in the market. Cable rate regulations remained intact, with guidelines set by the FCC and rate regulation implemented by local authorities. Nevertheless, cable's golden age had arrived.

The Cable Communications Act of 1984 deregulated the cable industry, including full rate deregulation, and removed much, though not all, local and FCC regulatory authority over cable systems. Cable, to its detractors, became an unregulated monopoly, while its supporters looked to indirect competition from broadcast television, video stores and'start-up technologies, such as MMDS, called wireless cable, and direct broadcast satellite television (DBS) to restrain cable's market power.

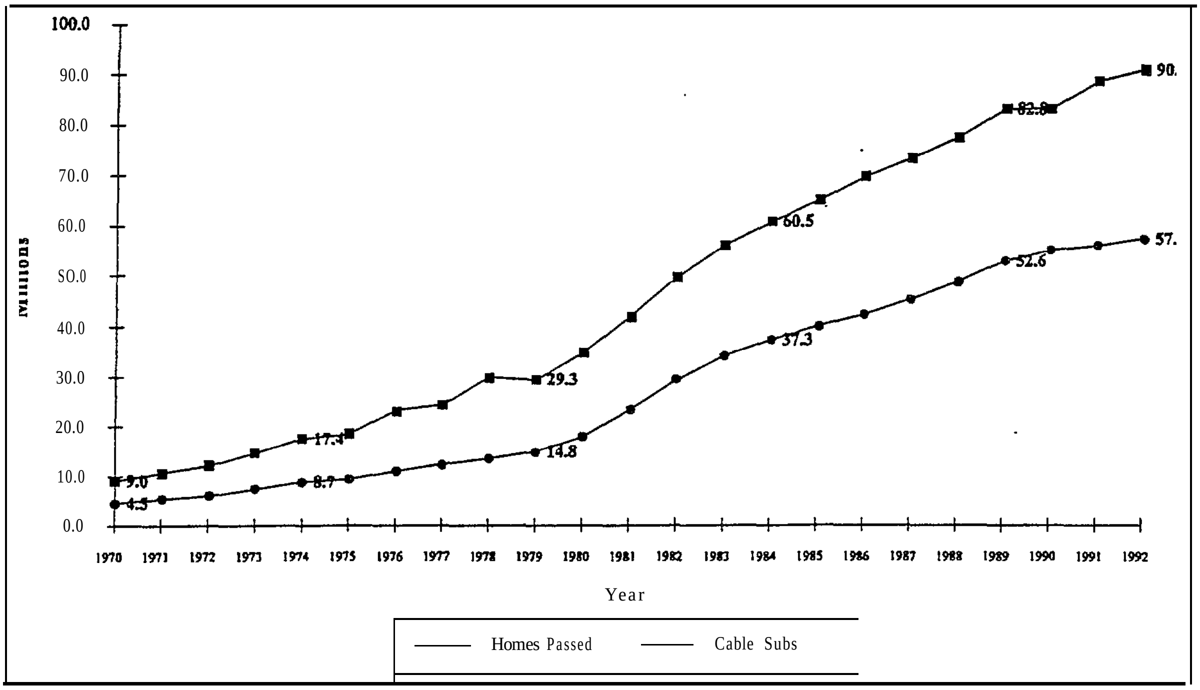
The deregulated hiatus ended in 1992 when the industry was reregulated with a vengeance by the Cable Consumer Protection Act. A discussion of the 1992 Law, which is still being implemented and codified by FCC rulemakings will follow.

2. Regulation and Growth

As shown in the following graphic and table, the growth of cable television was influenced by federal regulation, technological change and economic conditions. Construction and deployment of cable television systems was virtually frozen by the FCC ban during 1968 to 1972. After 1972, new cable systems began construction, homes passed by cable began to grow, and approximately 1.3 million additional homes subscribed to cable television service each year until 1979. The 1978-1980 slowdown in the cable industry was due to the well-publicized collapse of Teleprompter, heretofore the industry leader, due to bribery charges arising from the franchising process, and the resulting refusal of lending institutions to finance cable systems. Inordinately high interest rates in the late 1970's also made debt financing prohibitive.

With financing woes behind it, a newly-friendly FCC lifting the most onerous cable regulations, and the availability of satellite delivered programming on Pay TV and on basic cable channels, cable's growth accelerated during the 1980's. During the decade, nearly 3.8 million new subscribers were added each year, reaching nearly 53 million subscribers by 1989. By 1990-91 cable television was a mature industry.

Cable Television Growth: 1970 - 1992



3. Natural Monopoly and Cable Overbuilds

Natural -monopoly, defined as, “a market in which there is room for only one firm of efficient size,” [Owen & Wildman] characterizes most, though not all cable television systems. Cable television costs per home served or per subscriber decrease as the number of subscribers increase, with fixed cable system size and configuration. Such decreasing unit costs are necessary but not sufficient conditions for natural monopoly, since two or more cable systems could serve a specified geographic area if demand for cable services were sufficient to cover costs incurred by each system operating at efficient sizes.

One study [Smiley] suggested that cable franchises in large cities should be allocated geographically, such as in Philadelphia, where approximately equal sized quadrants of the city were franchised to four different, independent cable operators. Within a few years of completion of Philadelphia’s geographically separate cable systems, the four franchises were merged into two non-overlapping cable systems by acquisition. Smiley’s analysis, most other studies, and historical experience indicate that multiple cable television systems in the same geographic area would be inefficient, duplicative and economically non-viable.

4. Overbuilds

A number of market specific studies concluded that in the vast majority of cases cable television system overbuilds are not economically viable. Few if any communities or franchise areas can support two overlapping cable systems.

A report by Malarkey Taylor Associates, based on Smiley, developed an economic model of costs and revenues generated by two overbuilt cable systems in the same area with equal market shares. The study concluded that four key factors determine overbuild feasibility: (1) housing density; (2) demand for cable services; (3) cost structure of the cable systems; and (4) in situations where a prospective second cable system enters a fully built cable market, the price and service performance of the incumbent cable operator. After assessing various cost, demand, and revenue scenarios, it was concluded that a cable system overbuild could be economically viable only where three or four of the following conditions exist simultaneously: (1) a market with high density of homes per mile of cable plant, (2) a market with high inherent demand for cable television, typically where over the air broadcast reception is poor or where there are few local TV stations, (3) low fixed capital costs relative to the size of the cable system; and (4) poor cable service and/or relatively high cable rates charged by the incumbent operator. Because three or four of these factors rarely co-exist in a single market, a cable overbuild is not likely to be profitable or economically feasible under the conditions that commonly prevail in most markets.

More generally, cable overbuilds are unfeasible mainly because of natural' monopoly characteristic of cable systems. High fixed capital costs and relatively low variable costs lead to decreasing total costs per subscriber, as the customer base expands. Since average cost per subscriber decreases as the number of subscribers increases, two cable systems in one geographic area will each incur substantially higher costs per unit than one cable system.

5. Cable Television Services

Cable television provides improved reception of broadcast television programming; cable-specific, mostly satellite transmitted programming; and, potentially, an array of interactive, non-entertainment services. As discussed above, reception of local and distant broadcast signals was the raisin de etre of pre-1975 CATV systems. Cable was initially a retransmission medium providing better reception of local television stations and distant station programming, especially to smaller cities and towns with only one or two stations receivable with roof-top antennas, and even today, some estimates suggest that 20-30% of cable television demand is based on clear, consistent reception of broadcast television stations, both local and distant.

6. Basic Cable Services

Cable programming is usually divided into basic cable services and premium or pay TV services. Typically, cable systems offer a basic cable service tier of 30 to nearly 100 channels, including local and distant broadcast stations, satellite delivered cable channels, such as CNN, ESPN, U.S.A. Network, The Discovery Channel, Nickelodeon, Arts & Entertainment, Lifetime, Black Entertainment Television, The Family Channel, The Weather Channel, The Nashville Network, Country Music Television, MTV, UH-1, Comedy Central, Court TV, Home Shopping Network, QVC, religious channels and more, and franchise mandated public-educational-government (PEG) access channels. Many cable systems also provide one or more channels of local community programming, referred to as local origination (LO) on the basic service tier. Premium, pay TV channels, such as HBO, Showtime, The Disney Channel, Cinemax and regional premium sports channels (Prime Ticket, Madison Square Garden, Home Team Sports) are offered as optional, add-on services for additional monthly fees. Cable systems do not sell premium channels on their own because the cost of installing a cable television customer and providing in-home converter equipment cannot be justified on the basis of premium channels alone.

If international emulation implies success, it is noteworthy that the U.S. model of basic cable service plus add-on premium channels at incremental costs has been adopted in countries such as the U.K., Israel, Hong Kong and Poland that have recently implemented cable television or are planning to launch cable systems.

During the past twenty years, cable systems have implemented various unbundling schemes for basic cable service. One approach is to offer a limited or broadcast basic service consisting of broadcast stations, PEG access channels, community programming and a few satellite basic cable channels for a modest monthly fee, typically $3 to under $10, and to offer all of the. other basic cable channels on an expanded basic tier. These limited and expanded basic tiers are consistent with and virtually mandated by the 1992 Cable Act, and the approach has been adopted by most cable systems. Fragmentary evidence from markets where broadcast basic and expanded basic are offered indicates that fewer than 2% of full-basic cable subscribers opt for the low-priced broadcast basic tier. Another unbundling attempt, which was tried by a few cable systems in the mid-1980's and may reappear in response to the new regulatory environment, is to offer optional mini-basic cable tiers consisting of four to six channels for incremental fees. This approach represents a tentative step in the direction of a la carte basic cable services.

Basic cable programming services can be categorized into broad-based entertainment channels, such as U.S.A. Network, The Family Channel and superstations TBS and WGN, and special interest or niche services which appeal to relatively narrow segments of TV viewers. The distinction has often been made between broadcasting, which includes the broadcast networks, independent stations and board-audience cable channels, and narrowcasting. A widely held view in the cable industry is that cable television's primary role as an electronic medium and its greatest strength is to provide abundant channel capacity for narrowcasting program services. Cable technology enables TV viewers to pick and choose from among a wide array of programming types and genres, akin to a magazine store customer browsing through hundreds of different types of magazines. Cable operators' marginal cost to provide additional channels is very low on a per subscriber basis, and new technologies, digital compression and fibre optics, will enable even lower marginal costs per additional channel.

7. Premium (Pay TV) Services

Premium, pay TV channels, especially HBO, were once the dominant cable television services. In the late 1970's and early 1980's most people subscribed to cable television in order to receive HBO, along with better reception of broadcast stations. From its satellite launch in 1976 to the advent of video stores and VCR proliferation around 1983, HBO was the first and only way to receive recent movies, without commercials on TV. During that same time period. single channel subscription television stations, referred to as STV, emerged in a few cities where cable television was not available. In Los Angeles, for example, Theta and The Z Channel provided first run movies on a subscription basis over single UHF channels. The deployment of cable television invariably meant the demise of these STV stations.

As the supply of basic satellite cable channels increased in the early 1980's with CNN, MTV, ESPN, etc., and video rentals became a viable alternative for watching recent movies at home, the relative importance of HBO and other premium channels in the cable service mix declined. In the early 80's premium channel revenue equaled or exceed basic cable service revenue in most cable systems; by the mid-to-late 80's, basic service revenue was double or triple premium revenue generated by most cable systems. Of course, rapidly risingbasic cable rates, after the 1984 Cable Act's rate deregulation accelerated the growth of basic cable revenue, while premium channel rates did not increase.

8. Pay Per View and Interactive Services

In the mid-1980's cable systems began offering pay per view, where cable subscribers could order recent movies without commercials and events, such as championship fights and concerts, and only pay for what is ordered. Pay per view required addressable converters and a return-path system for ordering. Most cable systems take pay per view orders on the telephone, while some use store-and-forward systems linked to the addressable converters.

Pay per view has not met early expectations. Fewer than 20% of addressable cable subscribers use pay per view with any regularity, mostly because renting movies from video stores is more convenient and less expensive.

Cable systems are now testing various interactive services, including on-demand movies, sometimes called near video on demand (NVOD). By using file servers, computerized switching and digital compression, NVOD systems enable consumers to order any movie at any time from a menu of hundreds of films. The following is a partial list of interactive television services being tested or already launched on cable systems:

- Near video on demand movies, programs and events
- Play-at-home game shows (The Game Show Channel)
- Interactive video games (The Sega Channel)
- Electronic catalogue shopping
- Interactive advertising
- Interactive program guides and viewer information (StarSight)
- Interactive sports and games (Zing, e.on, Interactive Networks)
- Interactive viewing (ACTV, Videoway)
- Interactive education (Main Street, Mind Extension University)

C. Demand

Economic analysis of cable television begins with establishing determinants of demand among households passed by cable. Given access to the system, a household decides whether or not to subscribe to basic cable television service. The choice will depend on the service alternatives (number of channels of each specific program type) both over-the-air and on cable, reception quality of local television signals, price and demographic characteristics.

Further, once the household has decided to subscribe to basic service, it has the opportunity to subscribe to one or more premium services. The number of premium subscriptions divided by basic cable subscribers, or pay penetration, is influenced by the same factors that determine the demand for typical consumer products: product life cycle, promotion, demographics, competition and price. In addition, since Pay TV services are sold as joint products with basic cable service, the demand for premium services depends, in part, on how basic cable is marketed, sold and priced.

Since 1971, over a dozen econometric studies of demand for cable television have been undertaken. Reliable determination of the quantitative importances of the various factors of demand is somewhat limited by the accuracy of the measurement of the variables, collection of the data, and statistical and modeling methodologies employed. The following list summarizes the principal econometric studies examined in this paper:

1. Comanor-Mitchell, "Cable Television and the Impact of Regulation," Bell Journal of Economics and Management Science, Spring 197 1.

2. Park," Prospects for Cable in the 100 Largest Television Markets," Bell Journal of Economics and Management Science, Spring 1972.

3. Charles River Associates, "Analysis of the Demand for Cable Television," CRA Report #178-2, April 1973.

4. Noll, Peck, and McGowan, Economic Aspects of Television Regulation, Brookings Institute, 1973.

5. Hopkins Cable Project, Lyall, Duncan and DeKay, "Estimation of an Urban Cable Demand Model and Its Implications for Regulation for Major Markets," The Canter for Metropolitan Planning and Research, John Hopkins University, March 1976.

6. Webb, The Economics of Cable Television, 1983.

7. Levy & Pitsch "Substitutability Among Delivery Systems," in Noam, Video Media Competition: Regulation, Economics and Technology, 198.5.

8. Pacey, "Cable Television in a Less Regulated Market," The Journal of Industrial Economics, 1985.

9. Crandall, "Economic Analysis of Market Structure of Cable Television Business", TCI Comments/ Docket 89-600, 1990.

10. Mayo & Otsuka, "Demand, Pricing, and Regulation: Evidence from the Cable TV Industry," RAND Journal of Economics, 1991.

11. Levin & Meisel, "Cable Television and Competition," Telecommunications Policy, 1991.

12. Prager & Salinger, "Effects of Cable Television Deregulation in Price and Welfare," unpublished, 1992.

13. Rubinovitz, "Market Power and Price Increases for Basic Cable Since Deregulation," RAND Journal of Economics, 1993.

These econometric studies use linear regression techniques to model cable demand.[34] Data are gathered from a variety of sources including cross-section system level data published in secondary sources and individual household interviews. When analyzing these studies in light of the data and methods used, substantial areas of agreement emerge.

First, the quantity and quality of over-the-air signals is a key determinant of cable penetration. Park (1972) finds that penetration increases in areas with reception problems (especially UHF reception). Similarly, the Hopkins study measures signal quality directly and finds very significant effects on penetration. In 1983, Webb shows that the most important demand variable is the number, type and quality of signals carried by the system compared to the signals received over-the-air. Pacey's (1985) study finds that reception quality has improved over time and there is little difference between UHF and VHF broadcast signals.

The number of off-air signals received also effects the price a system charges for basic service. Levin and Meisel (l991) find that per channel prices were 16% lower in markets with five or more off-air broadcast signals than in markets with less than five off-air signals.

Second, cable demand matures rapidly to a steady-state level in about a year after the service begins operating. Park (1972) and Noll, Peck & McGowan (1973) find that systems mature within 18 months of operation. Similarly, Pacey (1985) shows that cable systems approach maturity within a year or so.

A few studies show the number of primary unduplicated networks offered on cable television systems has a favorable effect on penetration, and the number of independent stations offered has a modest positive effect on cable penetration. Charles River Associates (1973) find that the number of independent stations have half the effect of the number of unduplicated networks. Noll, Peck & McGowan find that the addition of independent signals is not very important in urban areas. In the early studies, local origination stations were shown to increase penetration to a small extent. However, cable operators provide relatively little local programming except where required by franchise, suggesting that the added penetration is outweighed by the additional costs.

In contrast to the consensus of research on the variables discussed above, the findings on other aspects of demand are mixed. As the following table shows, in the observed range of subscription rates, there is no consensus about price sensitivity.

Study	**Date**		**Price Elasticity of Demand**
Comanor & Mitchell	1971	-0.1 to -0.3	Inelastic
Park	1972	-1.01	Unit Elastic
Charles River	1973	-1.09	Unit Elastic
Noll, Peck & McGowan	1973	-0.75 to -0.90	Inelastic
Hopkins	1976	-1.33	Elastic
Pacey	1985	0.06 (Basic Cable)	Inelastic
Pacey	1985	-1.57 (Pay Cable)	Elastic
Crandall	1990	1.6 to 3.4	Elastic
Mayo & Otsuka	1991	-0.97 (Basic Cable)	Inelastic
Mayo & Otsuka	1991	-1.77 (Pay Cable)	Elastic

The extent to which premium cable characteristics increase cable penetration was first examined by Pacey (1985) who finds that offering premium channels enhances desirability of cable. Other studies, such as Levy & Pitsch (1985) and Mayo & Otsuka (1991), attempt to estimate separate demand equations for pay services. No meaningful conclusions can be drawn from these results, in part, because data on the number of pay subscribers (i.e. unduplicated households) are not available at an aggregate level. The problem is best described in Levy & Pitsch who state, "In the pay case, households subscribing to more than one service are counted more than once. Hence in principle the pay household share (of pay penetration) could be above one."[35] Thus, the extent to which premium services increase cable penetration has not yet been appropriately examined.

Reliable estimates of the importance of other determinants of demand are not available in any of the econometric studies thus far. Specific variables that appear to have no significant effect on demand throughout the various studies include number of color TV sets per household, type of antenna, marketing expenditure per household, number of superstations, presence of a MDS/MMDS operator, topography, and such demographics as, persons per household, vacancy rate, income, length of residence, and occupation of head of household.

However, in a number of market research studies, MTA has analyzed demographic factors across random samples of cable subscribers and non-subscribers. These studies indicate that education levels are not significantly related to the demand for basic cable service or to the demand for premium pay channels, Household size is somewhat greater among basic plus premium cable subscribers, indicating higher demand for premium channels among larger households, especially larger "married households." Marital status is significantly related to the demand for basic cables service. Household income levels are correlated to the demand for both basic cable service and premium channels; affluent households are more inclined to subscribe to basic cable TV and to premium channels than less affluent households. The demand effects of age are very slight. It is expected that older people will be somewhat less likely to subscribe to cable than younger individuals.

In sum, the ideal type cable subscriber would be married, with one or two children at home and moderately affluent, or in the middle income class. The demand for premium pay channels is strongest among more affluent households, headed by married couples in their late 30's and 40's.

D. Public-Private Partnership

Cable television is essentially a private industry franchised by local government authorities and regulated by federal law and the FCC. The franchise is a compact whereby public rights of way are provided to cable operators in exchange for meeting certain public interest requirements, paying franchise fees, and, prior to 1984, agreeing to local rate regulation. Federal regulation stemmed from cable's use of microwave frequencies and from concerns about cable's competitive impact on broadcast television.

There was and is little in the way of public-private partnership in cable television.

However, in the franchising process, some cable television companies entered into implicit partnerships with local governments, usually without success. Two examples are Institutional Networks and Qube.

1. Institutional Networks

One of the innovations first proposed about 1978 for competitive advantage in urban franchising was a geographically restricted second cable called an Institutional Network (I-Net). The typical cable TV system serving mostly residential subscribers is arranged to transmit TV signals from the headend to subscribers (downstream) in a broad band of frequencies, and return signals can be transmitted from subscriber homes back to the headend (upstream) in a relatively narrow band of frequencies. The Institutional Network, on the other hand, is arranged to provide approximately equal frequency bands for transmissions in both directions; I-Net proposals concentrated almost entirely on educational, governmental, and commercial users, to whom it could offer considerably enhanced capacity for two-way data and video transmissions.

Many franchising authorities considered the I-Net a significant public service to be required in return for what was considered a highly profitable franchise. The principal educational uses of the I-Net were for studio-to-headend transmissions of programs produced by students and teachers for cable viewing. City governments would use the I-Net for studio-to-headend feeds for coverage of Council Meetings and for employee training. With few exceptions, the anticipated commercial uses of the I-Net were discouraged, and even prevented by telephone company opposition. While I-Nets were virtually mandatory in franchise proceedings during the period 1977-1985, virtually none are operational today as originally conceived.

2. Qube[36]

Qube was the first interactive television system. The concept was used by Warner-Amex Cable, a partnership of Warner Bros studios and American Express, to bid for cable franchises in the late 1970's, and Warner-Amex obtained a number of desirable franchises, notably Columbus, OH, Dallas, TX, Pittsburgh, PA, and part of Houston, TX. Qube systems were operational in Columbus and Pittsburgh by 1980.

A press release in 1977 described Qube as follows: ". ..two-way medium that allows people at home to participate . . . with programming . . . Five response buttons that allow the viewer to . . . respond instantly to material that appears on his home TV screen . . . Nine channels of premium entertainment . . . Customers will pay per program. . . . Security services, including fire and burglar detection, panic, medical alerts.

In reality, Qube was used for ordering pay per view movies and for audience participation. But HBO offered more movies and more recent movies on a per-channel subscription basis than Qube could offer on a pay per movie basis; most cable subscribers who wanted to watch movies at home opted for HBO. Qube's interactive participation included "voting" on various public issues, calling the next play on local high school football games, home shopping (Qube helped make the Ginsu knife famous), and winning prizes on locally produced game shows.

Like I-Nets, Qube was a public-private partnership in that cities granted franchises to cable operators on the condition that Qube become part of the cable system and that government and educational institutions have free use of and access to Qube. For example, Qube subscribers could be polled on local issues.

By the mid-1980's Qube was abandoned by Warner Cable, Warner-Amex's successor company, with the consent of franchising authorities in Columbus, Pittsburgh, etc. The Qube experiment failed, not because it was a franchise-mandated rather than private-initiative service, but because neither the technology nor the market was ready.

E. Lessons for ITS

Lessons for ITS deployment can be derived from the cable television franchising process and the introduction of new technologies.

1. Franchising

Whereas lotteries and auctions have been used recently to allocate scarce public resources, especially spectrum, among competing applicants for the use of such resources and for the implementation of new technologies, local franchising was the first and only allocation method for cable television. The U.S. cable television franchise model has been adopted in virtually every country that has initiated cable television systems in the past ten to fifteen years, though cable franchising in countries such as The U.K. and Israel was nationally, rather than locally organized and controlled.

Local franchising has been used successfully in the U.S. and other countries in deploying cable television technology. Cable television systems need rights-of-way and other local government compliance and permission which require municipal licenses, though not necessarily franchises. Since federal statute prohibits exclusive cable franchises, the over 12,000 local U.S. cable franchises are de jure non-exclusive, but de facto exclusive in all but a handful of localities. It has been argued [Hazelett, "Preferred v City of Los Angeles"] that cable franchises are unnecessary and counter-productive on economic grounds and unconstitutional on first amendment grounds, and that non-exclusive, non-discriminatory municipal licenses of cable systems would be sufficient to protect local government interests without imposing government into private enterprises. For reasons discussed below, this view has been rejected by most cable television analysts and commentators, including Malarkey Taylor Associates, and by the courts.

Cable television is essentially a local business, geographically bound by a wired distribution plant to a specified area or community and providing services which require local customer service (installation, repair, telephone response) and marketing. One of cable television's main economic advantages over direct broadcast satellite (DBS) is the local presence of cable systems. The importance of localism imparts benefits from local franchising to both the municipality and the cable television operator; regulation and control at the local level coincides with conducting business locally.

Natural monopoly characteristics imply that cable television systems will make most efficient use of scarce resources under regulated quasi-monopoly conditions. Multiple cable television systems serving the same geographically restricted area incur higher costs than one cable system in the area. The franchise approach which grants de facto local monopoly power to cable systems in return for the provision of local public services and benefits, such as public, educational and government (PEG) access to the cable system is economically justifiable and a practical means of obtaining reasonable quid pro quo between the cable television system and the locality.

Local franchising, under federal or state direction and with federal support, may be the most effective method for rapid deployment of ITS technology. The franchise provides security and specified assurances to operators who are likely to need such government certified assurances to finance ITS systems. Insofar as private business and consumer demand for ITS services is insufficient to support ITS deployment or slow to materialize, franchise trade-offs should be weighted in favor of the potential operator; the franchise process can be used to foster ITS deployment, with appropriate safeguards.

Unlike localized cable television franchises, ITS franchises would, in all likelihood be regional in scope, including the total commuter patterns of a metropolitan area. Cable television operators have found that in order to be in the telecommunications business and in the advertising sales business, fragmented urban-area franchise must be interconnected. Advertising interconnects now are used to sell advertising on cable in many major urban markets, and they have pointed the way for cable systems to interconnect for the provision of PCS and alternative access telephone service as well.

There have, of course, been well-publicized problems with cable television franchising which may be instructive for ITS. Franchise commitments made by cable operators in competitive applications were often re-negotiated or simply ignored. Many cable systems in large urban-suburban communities have reneged on at least a few of their franchise commitments, with reluctant compliance by the franchising authority. Institutional networks have never been implemented as originally conceived, regardless of the franchise agreement, and access provisions have frequently fallen short of franchise promises.

The lesson for ITS is to develop reasonable, financially viable expectations for ITS operators and to include strict enforcement procedures in franchise agreements. Moreover, mechanisms must be developed to prevent some of the more unsavory aspects of cable franchising, such as “rent a prominent citizen” schemes and under-the-table payments to local officials.

2. New Technology

Most cable television multiple system operators (MSO’s) pride themselves on developing and introducing new technologies only in response to consumer demand, and the history of cable television has been reactive rather than proactive with regard to technical innovation. Nevertheless, the cable television industry can lay claim to implementing many new technologies and technological advances, including but not limited to the following:

Scrambling technologies
Satellite transmission
Addressable converters
Multi-channel AM fibre
Broadband solid-state technology
Broadband microwave receivers (AML)

Satellite transmission of television signals was a major technological development brought to commercial viability by cable television. Addressable converters and multi-channel AM fibre were virtually invented by cable operators and manufacturers. The other technologies listed above were developed or initially used by cable systems, and other highly-specialized technologies were also implemented by the cable industry.

Within the past year or so, the cable industry began a series of financial commitments to new technologies and sophisticated experiments and tests of new services which would require major technological change. TCI announced a $1 billion commitment to digital converters. Time Warner and Viacom launched technical and market tests of full service networks (video, voice and data) and interactive multimedia television. Continental Cablevision announced plans to link its cable subscribers to the Internet computer network. Cable Labs, an industry consortium sponsored think tank, submitted a number of Requests for Proposal for rebuilding cable systems to provide fixed telephony and personal communications services (PCS) along with high-capacity video channels.

These technological developments are occurring because the competitive and regulatory environments have changed in the 90’s, and because the core cable television business has reached maturity. For defensive reasons and to propel long-term industry growth, new technologies are being introduced in cable systems, prior to proven consumer acceptance.

Lessons for ITS are ambiguous. Within the security of local monopoly power and de facto exclusive franchises, cable television introduced important new technologies to the market and deployed cable technology nationwide. However, the public was not always best served by this technological diffusion and local governments were often disappointed in the benefits they received.

IV. CHAPTER FOUR — DIRECT BROADCAST SATELLITE (DBS)

This chapter addresses selected issues in the nascent direct broadcast satellite (DBS) industry and suggests lessons that might be drawn from the DBS experience for the introduction of ITS. Three topics are covered: (1) history and current status of the industry, (2) economic characteristics and (3) growth projections.

The commercial viability of DBS depends on transmitting clear, consistent television signals to relatively small, inconspicuous, easy to install dishes. The small and preferably self-installable dish is the key. Without it, DBS is relegated to rural areas and isolated towns that cannot receive broadcast or cable television. High-power satellites in the Ku-band which enable the use of small dishes to receive satellite transmissions are only now being introduced in the U.S. and Canada, the U.K. and Asia.

Digital compression of television signals is another technological development fostering DBS viability. When a satellite with 24 transponders could beam 24 channels of programming directly to homes under its footprint, the competitive equation between DBS and cable television overwhelmingly favored cable, with its 50 to over 100 channel capacity. Using ten to one digital compression ratios, a DBS satellite is able to deliver 240 channels, making DBS much more competitive with cable television.

A. History and Current Status

The terms direct broadcast satellite (DBS), direct-to-home (DTH) satellite broadcasting, and just plain satellite television refer to the use of communications satellites in geostationary orbits to transmit multiple channels of video programming to homes equipped with receiving antennas or dishes. The industry is usually called DBS in North America and DTH or satellite broadcasting in Europe. DBS systems encompass both hardware, including satellites, dishes and converter/decoders, and software, or channels of television programming which are usually distributed to homes and residential buildings for monthly subscription fees, per-channel fees and per-view fees, and also supported by advertising revenue.

1. Backyard Dishes

A distinction should be made between DBS and the backyard dish business, sometimes called TVRO (TV receive only). Backyard dishes began springing up in rural America and Canada in the early 1980's to provide television reception to homes that could not receive broadcast television or cable television. There are currently some 4 million backyard dishes in the U.S. [Kagan, 1993], and about one-half million in Canada [CCTA, The DBS Report, 1992]. Backyard dishes receive signals from low-power satellites (2 to 15 watts) in the C-band range. The dishes are large, 8 to 10 feet in diameter, and require professional installation and mounting in one's backyard or other open area with adequate line-of-sight to the satellite. Backyard dishes are used to receive satellite signals of cable television channels beamed to cable headend earth stations and broadcast network signals transmitted by satellite to affiliate stations.

In the early 1980's, most basic cable satellite services (CNN, ESPN, MTV, etc.) were transmitted via satellite "in the clear" to cable system earth stations; satellite signals were not scrambled. Backyard dish owners could receive dozens of cable channels, including HBO and other premium channels at first, broadcast network feeds and various and sundry other satellite signals without paying subscription fees. In 1983 HBO began scrambling its satellite signals, and by 1985 virtually all cable television channels, premium and basic, were scrambled. Backyard dish owners would need an addressable converter/decoder which would be authorized to decode the satellite signals upon payment of monthly and per-channel fees.

For a few years prior to 1985 backyard dishes grew exponentially; from 1985 to today backyard dish growth has been relatively stagnant. Scrambling of satellite signals dramatically changed the cost-benefit equation for potential backyard dish buyers, who would have to spend over $2,000 for the equipment and still pay monthly fees of $25 to $40 for access to the most desirable programming.

The DBS satellites launched in the U.S. in 1994 are high power (100 to 200 watts) operating in the Ku-band, and the signals can be received by small, 18-inch dishes, about the size of a large pizza. The dishes can be mounted on roofs, balconies, sides of buildings or even, perhaps, inside the home, and they will cost under $600.

Moreover, while backyard dish owners picked up satellite signals intended for other uses, mainly satellite transmission of cable television signals to cable systems, DBS and DTH services assemble and distribute programming from various sources directly to their subscribers. It is expected that the low-power TVRO, backyard dish, industry has reached its peak and will decline and be replaced by DBS [CCTA, 1992].

2. DTH/DBS in Europe and Asia

The first medium-power DBS attempt was in the U.S. in 1980 when United States Satellite Communications, Inc. (USCI) launched a DBS satellite and service financed by a major insurance company. The service suffered from two major problems: small, user-friendly dishes could not be used and the DBS company was unable to obtain attractive packages of programming. Cable television program suppliers, such as HBO and Ted Turner (WTBS and CNN), refused to sell to DBS, and Hollywood studios were not interested in aligning with an unproven technology. USCI failed within six months of launch with losses reported at $70 million.

In the mid-1980's Comsat invested in DBS technology and pursued a number of DBS ventures. Comsat exited the DBS business in 1985 with losses of over $100 million.

There are currently two full-fledged DBS services outside of the U.S.: the U.K.'s BSkyB, owned by Rupert Murdoch and other U.K. companies, and Star TV. Star TV, an Asian DBS service operating out of Hong Kong on AsiaSat, was solely owned by the Hutchison family, a leading Hong Kong conglomerate, until this summer when Murdoch purchased a substantial interest in Star TV and became the managing partner. The Murdoch organization now controls the world's only DBS operator, insofar as a DBS operator controls and provides multiple channels of video programming through distribution systems that include satellites and dishes.

BSkyB and Star TV offer 6 to 12 channels of video programming, including scrambled and free-to-air signals. BSkyB has been quite successful in the U.K., with over 3 million dish owners including 2 million subscribers to one or more BSkyB pay TV channels (Sky Movies, Sky Sports, etc.). Star TV subscriber counts cannot be determined since all of its channels have been free-to-air until recently.

The importance of these satellite broadcasting services to the U.S. is to validate the commercial feasibility of DBS, under certain conditions. There is no doubt that Star TV will become the dominant multi-channel pay TV provider in the Chinese speaking Asia Pacific region and perhaps the Indian subcontinent as well, and BSkyB has established itself as the major non-broadcast television program provider to both cable operators and dish owners in the U.K. Though both services are in their infancy, the following factors seem to be instrumental in their success:

- BSkyB and Star TV have established and supported third-party dish distribution channels, which aggressively retail the dishes and provide some customer service.

- The dishes are reasonably small, though still not at the optimum user-friendly size.

- There is little or no competition for multi-channel television from cable television, wireless cable (MMDS) or other DTH/DBS providers. In the U.K, cable television has been slow to develop, passing fewer than 1 million homes prior to 1993, thereby giving BSkyB a clear field to attract early-adopters. In Hong Kong, Taiwan and China itself, dishes pointed at Star TV's satellite are the only way to receive non-broadcast television.'

- Both companies are exclusive providers and rights-holders of film, sports and other programming; they control the programming as well as the satellite distribution systems.

3. DBS in the U.S.

In the mid-1980's the Federal Communications Commission (FCC) authorized the use of a portion of spectrum in the Ku-band for DBS. Eight orbital positions were assigned with thirty-two 24 MHz channels each for a total of 256 satellite channels. The FCC granted 27 channel pairs to Hughes Communications, Inc., 8 channel pairs to Hubbard Broadcasting and the rest to six or seven other groups.

In 1994 Hughes launched a DBS satellite that has 10 to 1 digital compression and offers 150 channels of DBS service through its DirecTv subsidiary. Hughes also leases channel capacity to Hubbard.

DirecTv has the potential to become the first successful DBS venture in the U.S. Its signals can be received with 18 inch dishes, easily installed on roofs, balconies or poles, and the dishes cost about $600, installed. Since the 1992 Cable Law and recent court decisions mandate nondiscriminatory access to cable television programming to any multi-channel provider, DirecTv will is able to obtain the same programming offered on cable television systems, at approximately the **same** cost. In addition, over 100 DirecTv channels are allocated to pay per view movies, sports and other events, with movies available on a near-video-on-demand basis.

DirecTv seems to have the key elements in place for DBS success:

- Access to the best of cable television programming
- Product differentiation via expanded impulse pay per view,
- Virtually total North American coverage (continental U.S. and southern Canada),
- Small, moderately priced dishes,
- Technical expertise,
- Financial resources.

4. Lessons for ITS

Governments were not very helpful to the three most significant current DBS ventures, Star TV in Asia, BSkyB in Europe and DirecTv in the U.S. Star TV was launched despite government opposition in Hong Kong, bans on satellite dishes in a few of the most promising regional markets, Singapore and Malaysia especially, and mostly negative reactions from China. The precursor to BSkyB, Murdoch's Sky TV, was opposed by Parliament and forced to merge with the government's DBS choice, BSkyB.

Hughes' DirecTv will benefit from the 1992 Cable Law which guarantees access to cable programming, and from the FCC's DBS spectrum allocation policies, but there has been little if any government support or encouragement of DirecTv.

In these three cases, DBS technology was or will be deployed regionally to mass consumer markets when and if commercial prospects seem viable and one or more private firms are willing to undertake substantial financial risks to implement DBS. Governments have not and probably should not take an active role.

Unlike ITS and other technologies which governments foster and support, there are no significant, non-recoverable spill-over benefits or public goods aspects of DBS. DBS satellite transmit video signals to homes and buildings which pay subscription fees to receive the programming and pay for dishes and related in-home equipment, and advertisers buy time from satellite broadcasters much the same as from terrestrial broadcasters. The value of DBS output is recouped by DBS operators, unlike, for example, educational broadcasting (PBS) which helps inform and enlighten the public but is unable to charge subscription fees or generate advertising revenues commensurate with costs.

B. Economics of DBS

The economics of DBS are similar to cable television, cellular telephone, utilities and other industries characterized by substantial up-front, sunk capital costs and relatively low and constant variable costs per customer. Capital costs for a DBS service, including the satellites, uplink facilities and organizational costs have been estimated at $900 million to $1 billion (Johnson & Castleman, 1991), all of which are sunk in that they must be expended prior to marketing DBS service, obtaining customers and generating revenue. High sunk costs imply high risk, considerable financial exposure and, typically, absence of debt financing. Banks are not inclined to lend to high risk, high sunk cost ventures, especially when consumer demand is uncertain.

Whereas most DBS capital costs are incurred before, during and shortly after launching the satellites and services, total capital cost can be amortized over the life of the satellites for projecting costs and profitability over time. The annual amortization factor ranges from 15% to over 20% depending on effective life of the satellites, likely obsolescence and interest rates (Smiley, 1987). An 18% amortization factor is used in the following analysis.

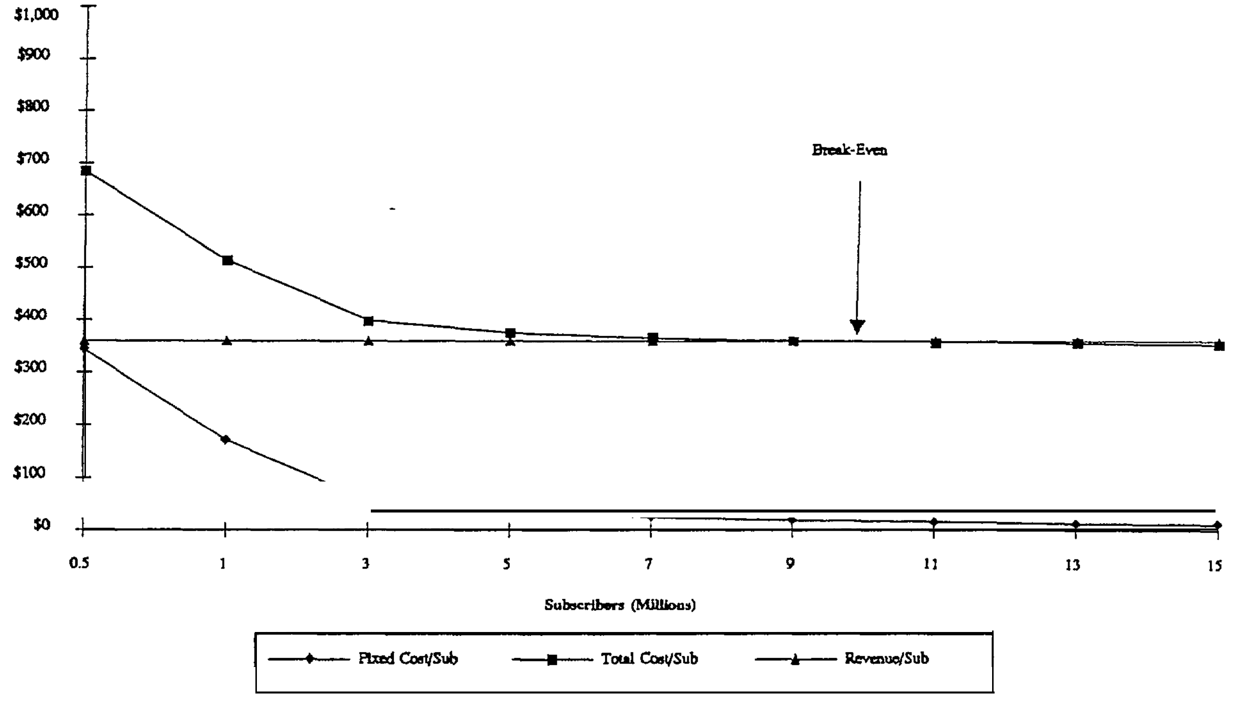
	Cost per Subscriber per Year				
Subscribers	l/2 mil.	1 mil.	3 mil.	5 mil.	10 mil.
Fixed Capital Investment	$342.00	$171.00	$57.00	$34.20	$17.10
Dish & Converter	$132.00	$132.00	$132.00	$132.00	$132.00
Programming	$120.00	$120.00	$120.00	$120.00	$120.00
Operating Expense	$90.00	$90.00	$90.00	$90.00	$90.00
Variable Cost	$342.00	$342.00	$342.00	$342.00	$342.00
Total Cost	$684.00	$513.00	$399.00	$376.20	$359.10
Total per month	$57 .oo	$42.75	$33.25	$31.35	$29.93

Source: Johnson & Castleman, Direct Broadcast Satellites: A Competitive Alternative to Cable Television?, RAND, 1991.

DBS variable cost categories include programming, marketing and administration, and subscriber equipment, mainly the satellite receiving antenna or dish and converter/decoder, which are referred to as the integrated receiver decoder (IRD). For accounting and tax purposes, IRD costs are usually treated as capital expenditures which are amortized and depreciated over the life of the equipment. For economic analysis, IRD costs, estimated at $500 to $600 by Hughes' DirecTv DBS service, are variable with the number of subscribers. The amortization factor applied to subscriber equipment, 22% in the example below, is higher than for satellite related capital costs because the expected life of home dishes and converters is shorter than for the satellites.

Programming expenses depend on the types of program services offered and the quantity and quality of programming. Operating expenses depend, among other things, on customer service provisions and arrangements with third-party providers for maintenance and repair service, and marketing costs are a direct function of anticipated advertising, especially television ads. One study (Johnson & Castleman, 1991) using cable television expenses as a guide suggested total DBS variable costs, excluding subscriber equipment (IRD), at $200 per subscriber per year.

As shown in the following figure, a national DBS service would be expected to break even at about 10 million customers. With fewer than 10 million subscribers, DBS costs per customer, including amortized annual allocation of capital costs, would exceed average revenue per customer, since the high up-front capital costs of launching. satellites would be spread across relatively few subscribers. Conversely, a DBS service that serves to 10 to 12 million homes would earn substantially greater revenues per customer than its total costs per customer.



The above discussion omits critical issues of consumer demand for DBS. Levels of DBS penetration at specified prices depend on the attractiveness of DBS services relative to cable television services and on socioeconomic factors such as household income, family structure, age distribution and consumer confidence. To our knowledge, empirical studies of consumer demand for DBS services have not been undertaken or have not been made public.

C. Growth Projections

Whereas direct satellite broadcasting was first developed in the U.S. by Comsat, USSCI and other DBS aspirants 10 to 15 years ago, and U.S. firms have always been world leaders in satellite technology, DBS/DTH services have been operational in Europe since the mid-1980's and in Japan a year or two later, while the U.S. is still without nationwide, full-service DBS systems. Why has DBS been so slow to develop in the U.S.?

1. DBS Technological Deployment in the U.S.

The most important reason for DBS's slow start in the U.S. is competition. Capital intensive new technologies and services are typically introduced into non-competitive markets. Cable television systems have de facto exclusive franchises, cellular phone systems serve government mandated duopoly markets, local telephone companies have always been regulated monopoly providers.

In Europe and Japan, DBS was the first, and for a few years, the only multi-channel video provider, but in the U.S. cable television preceded DBS. Cable television spread rapidly across the country, especially from 1975 to 1985, passing nearly 80% of U.S. households by 1985 and providing multi-channel video programming to over 45% of homes (NCTA, 1993).

	1975	1985
Cable Passings	18.4 mm	64.7 mm
Cable subscribers	9.2 mm	39.9 mm
Subscribers/TVHH	13.2%	46.2%

Source: NCTA. Cable Developments, 1993.

Early U.S. DBS ventures failed because the technology could not support services and pricing that were competitive with cable television, and because of restricted programming availability. European, Japanese and, recently, Asian satellite broadcasting services seem to be succeeding in part because the vast majority of European, Japanese and Asian households have very limited television choice, usually three or four terrestrial broadcast stations some off which are government controlled, and little or no cable television.

Another related reason for the slow development of DBS in the U.S. is the need for unusually high upfront, sunk capital costs. In the late 1970's, over $50 million was needed to launch DBS satellites and service, and today the capital cost exceeds $100 million.

2. Potential Consumer Demand for DBS

The initial market segments for DBS include homes where cable television is not available (unpassed homes), homes which could subscriber to cable but have opted not to (cable nonsubscribers), and dissatisfied cable subscribers. Though some satisfied cable subscribers might purchase DBS equipment and service, the dissatisfied cable customer segment is undoubtedly a more promising marketing opportunity.

	Households (millions)	(% of total)
Cable Subscribers	56.8	57%
Cable Nonsubscribers (passed)	34.2	34%
Unpassed Homes	9.5	9%
Total	100.5	100%

Sources: Malarkey-Taylor Associates, Inc., Paul Kagan Associates, Inc.

DirecTv's announced marketing strategy will initially focus on unpassed, mostly rural homes. Affiliate agreements between DirecTv and the National Rural Telecommunications Cooperative (NRTC) provide for NRTC franchisers to market, sell and service DBS among unpassed homes in mostly rural counties. The NRTC is selling access to unpassed homes and exclusive distribution rights for DirecTv to its member cooperatives and private organizations for approximately $35 per unpassed home per county.

Estimates of the number of unpassed homes in America range from 5 million to 15 million, or between 5% and 15% of total U.S. TV households. MTA's estimate is just under 10 million unpassed homes. Since cable operators continue to construct cable plant extensions into lower density areas, the unpassed universe continues to shrink.

DBS penetration of unpassed homes should be comparable to cable penetration of passed homes. The two key determinants of demand for DBS among unpassed homes are off-air reception and socio-economic levels. Most homes in small town and rural America receive two or three broadcast TV stations clearly, at best, and just as cable television penetration of non-metropolitan homes-passed exceeds 65% in most areas, the potential market for DBS is likely to approach two-thirds of unpassed homes, as long as the areas are not wired for cable. In other words, where DBS is the de facto exclusive multi-channel video provider its growth and development should parallel cable's.

These semi-rural areas are not served by cable because of low housing density, generally under 30 homes per linear mile, or low income. Rural poverty may inhibit DBS penetration of unpassed homes, just as urban poverty reduces cable's penetration in major urban centers. We forecast 40% to 60% DBS penetration of unpassed homes after two to three years, or some five million unpassed homes likely to subscribe to DBS within three years.

3. Competing with Cable Television

Within the 90% of American homes where cable is available, DBS is likely to be the most effective multi-channel video provider for the remainder of the decade. Growth of DBS in the cabled universe depends **on** programming, operating costs and terminal equipment.

4. Programming

To induce current cable subscribers to shift to DBS and to attract cable nonsubscribers to sign up for DBS service, DBS programming must be comparable to and differentiated from cable. Even dissatisfied cable subscribers are unlikely to switch to DBS in significant numbers if DBS programming is the same as or inferior to cable, since inertia and transactions costs in the form of equipment charges favor staying with the cable company. Nonsubscribers to cable, who, presumably, do not perceive a need for cable programming or are unable or unwilling to pay for television programs, are not likely to subscribe to DBS unless it offers compelling programming advantages over cable.

Lack of access to cable programming, such as CNN, MTV, ESPN, HBO, Showtime and scores of other cable channels, doomed earlier DBS ventures, but the cable law of 1992 and changing economics of cable programming have assured programming access to DBS operators and to any other multi-channel video providers at competitive rates and terms. DirecTv has announced programming contracts with virtually all cable program suppliers, and other DBS operators need only to establish financial capability to obtain full access to programming.

5. Operating Costs

Whereas fixed capital costs, especially for launching satellites and obtaining transponder space, are primary considerations in business planning prior to initiating a DBS service, fixed costs are sunk when incurred and have minimal impact on ongoing DBS business decisions and policies. Variable operating costs, which in relation to operating revenues determine DBS cash-flow profitability, depend mainly on programming costs. Operating cost allocations for cable and DBS operators are estimated as follows:

Operating Costs:	Cable	DBS
Programming	40%	50%
Technical Service	40%	10%
Marketing	10%	30%
Other	10%	10%

Source: Malarkey-Taylor Associates, Inc.

DBS programming costs will be somewhat higher than cable's because cable operators own or control most cable programming channels and because DBS will need to differentiate its programming. DBS marketing costs will substantially exceed cable marketing costs insofar as DBS uses mass-market television and print advertising to attract customers away from cable. Hughes announced a $30 million pre-launch advertising campaign for DirecTv. Conversely, cable's technical costs for plant repair and maintenance and customer service are considerably higher than DBS technical costs, since repair and maintenance is negligible once satellites are operational and customer service and billing will be nationally centralized.

If programming costs are kept in check, DBS operating costs are likely to be comparable to cable operating costs, and DBS providers will be price-competitive to cable.

6. Terminal Equipment

Hughes has contracted with Thompson Electronics to manufacture integrated receiver decoder (IRD) equipment, with production of 90,000 IRD's per month anticipated in 1994. The consumer issues are size and cost. At 18 inches in diameter, or the size of a large pizza, DBS dishes will be small, easy to install and user friendly.

Terminal equipment cost, however, may be a significant barrier to entry. At $500 to $600 including installation, relatively few current cable subscribers will be inclined to switch to DBS and receive comparable programming are comparable monthly service rates. Even fewer nonsubscribers to cable will be willing to pay over $500 for equipment plus the monthly DBS rate. If IRD's are leased to DBS customers, with payments amortized in the monthly fees, equipment costs will add $10 to $15 to subscribers' monthly bills, and the DBS-cable price comparison will favor cable.

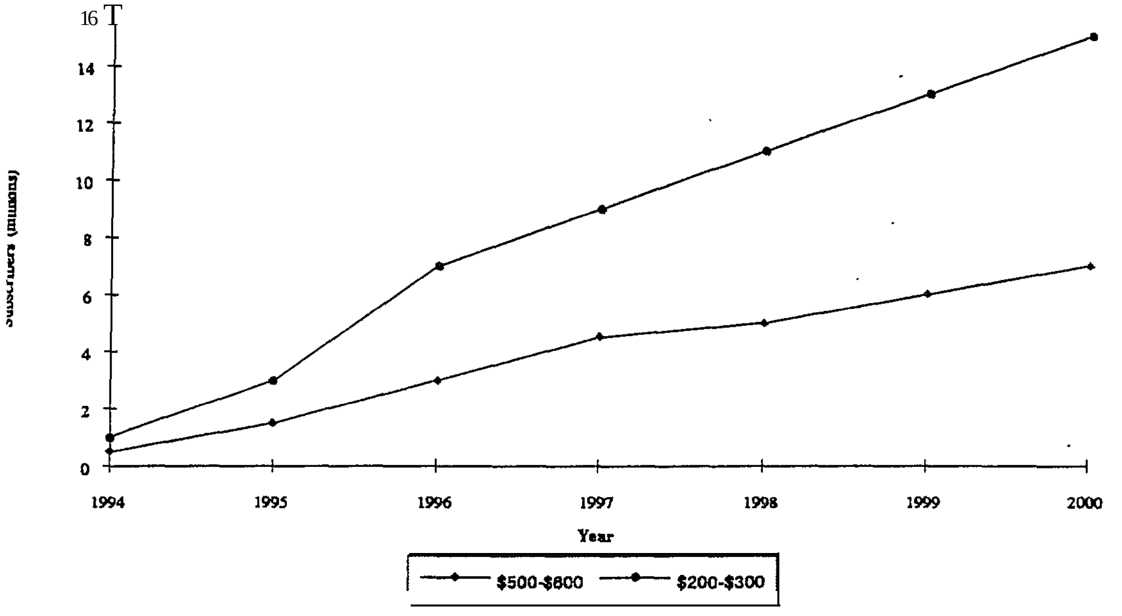
The U.K. experience suggests that consumers will readily pay up to $200 to purchase DBS equipment, but purchases are constrained at higher prices. A drawback of leasing equipment to DBS customers is that they are susceptible to switching back to cable since their transactions cost would be nearly zero.

7. DBS Growth Projections

If DBS service pricing is comparable to cable television rates, DBS customer equipment is small and user-friendly, and DBS programming is comparable to and differentiated from cable programming, the key demand determinant becomes DBS equipment costs. Two demand forecasts shown in the following graphic are based on Malarkey-Taylor DBS penetration projections at alternative equipment price points: $500-$600 and $200-$300.

We forecast 7 million DBS subscribers in 2000 at the higher subscriber equipment costs and 15 million at the lower cost.

8. **DBS Subscriber Projections at Varying Equipment Costs**



Source: Malarkey-Taylor Associates, Inc.

D. Lessons for ITS

There are certain parallels between DBS and ITS that yield useful lessons, but it is important to understand the differences to avoid misinterpreting these lessons.

Both DBS and ITS are highly capital intensive technologies, and the deployment stage of each has barely begun. The operators of each must therefore bear the burden of high initial costs, while their revenues start at zero and build gradually. The high initial capital must be in place well before the time service can begin, because the construction period for the necessary facilities is long (more than three years, in the case of DBS). Clearly "patient capital" is necessary for the development of these systems. It should not be surprising that the first DBS system deployed in the United States is owned by Hughes Communications, an aggressive subsidiary of the largest corporation in the United States, General Motors.

DBS is being introduced into a market awash with major competitors, including the three (or four) television networks, dozens of large cable television multiple system operators (MSOs), large independent television stations, and the ubiquitous video tape rental shops. The large cable MSOs have many interlocking horizontal and vertical relationships with other companies whose products are essential both to cable and to DBS; the most important of these is the programming networks who supply the "software" carried by these distribution systems.

For much of the pre-deployment history of DBS, the tight hold of the MSOs on the limited supply of programming was a major obstacle. The Congress ultimately sought to remove this obstacle with the

Cable Act of 1992, which required that programming networks affiliated with cable companies also provide their product to DBS operators on a non discriminatory basis.

More generally, policy-makers have encouraged DBS as a potential competitor to cable, which dominates the pay television market. The Federal Communications Commission has required much less stringent financial showings from would-be DBS licensees than it has typically demanded from applicants for commercial communications satellites. It has granted DBS operators the flexibility to offer other communications services with their satellites, at least for the initial portion of the satellite lifetime. It has recognized the difficulty of financing these costly satellites, given the very real obstacles of lack of programming and long payback period, and has been generous in granting delays of its construction deadlines.

The FCC has also refrained from adopting any regulatory regime for DBS operators, beyond asking each operator to select the type of business it wishes to conduct (broadcaster, common carrier, or "non-common carrier"). The Commission has given no indication that it intends to impose any form of rate regulation on DBS operators, although of course it retains the authority to do so at any time.

On the other hand, in keeping with its pro-competitive philosophy, the FCC has granted the operators of communications satellites the authority to offer DBS-like services, and it has not restricted cable MSOs from seeking DBS licenses.

The Commission has also gone to great lengths to avoid comparative hearings to choose between competing applicants for DBS spectrum. This has been an important element in the development of DBS, since many of the applicants for DBS spectrum lacked the financial strength to pursue a protracted hearing process, and since the time required to complete such a process would have inordinately delayed the award of DBS licenses. Since the available DBS spectrum is limited by international treaty, the Commission was faced with a dilemma when at one point applications for spectrum exceeded the available supply. It resolved this dilemma by dividing the remaining spectrum equally among the then current applicants. This Solomonic policy mechanism neatly resolved the short term conflict, but left some operators with less spectrum than would make them truly competitive. As a result, a trend toward consolidation of competing operators has begun, even before the commencement of their services.

The result of this policy framework is a limitation on market entry imposed by limited spectrum rather than by economic or regulatory theory. The number of authorizations exceeds the probable number of surviving firms, and the amount of spectrum held by most firms is at the lower limit of that required for economic success.

The relevance to ITS concerns the regulatory forbearance and the resulting market structure, rather than the spectrum issues. ITS will at most be a small user of spectrum, and may be able to purchase communications services from firms already licensed to provide them. The important issue for ITS policy-makers is the market structure for ITS itself, for which the DBS market considerations are relevant, rather than the spectrum shortage which created them.

V. CHAPTER FIVE — TELEVISION

This case study provides an overview of several characteristics of television broadcasting, assessing the extent to which those characteristics might provide useful analogies and lessons for implementing ATMS. The analysis here focuses on the traditional television broadcasting industry. Newer proposed technologies, known generally as Advanced Television (ATV) and, more particularly, High-Definition Television (HDTV), are the subject of a separate paper.

A. Technology

Together with its technological predecessor, radio broadcasting, television broadcasting is perhaps the archetype broadband wireless distribution technology. Broadcasting is itself distinguished from most forms of wireless radio communications as "the dissemination of radio communications intended to be received by the [general] public,"[37] rather than by a specific individual or narrower class of designated persons.

Since broadcasting is designed and intended for receipt by the general public, it creates the need for ubiquitous compatible receivers available to the public. In the case of television broadcasting, compatibility posed special problems because there was a need not only for compatibility between receivers and television broadcast signal frequencies and characteristics, but also among the television cameras used to capture the television images, the broadcast transmitter and the television receiver. Thus, the development and implementation of standards has played a major role in the growth and development of the television broadcast industry.

Indeed, the timing of the widespread growth of television service is directly tied to the FCC's adoption in the early 1950's of a single technical standard for color television. That standard is know as the NTSC standard, for the National Television Standards Committee that recommended it to the FCC. Setting this standard broke the "chicken and egg" problem associated with television broadcast service — on the one hand, broadcasters' hesitancy to invest in broadcast facilities unless compatible receivers were -widely available to receive their signals, and on the other hand, a hesitancy to invest in mass manufacturing of receivers unless television broadcast signals that were compatible with those receivers were sufficiently available to make it worthwhile for consumers to purchase the receivers. The NTSC color standard had the added advantage of being "backwards" compatible with existing black-and-white receivers, so that viewers with black-and-white sets did not have to purchase a color receiver to receive NTSC color signals.

A second salient characteristic of television broadcasting is its dependency on heavy use of the radio-frequency spectrum, with a standard television channel occupying 6 MHz of bandwidth. This relatively large use of spectrum, together with the multitude of competing users of radio-frequency spectrum, created a need for a centralized and coordinated method of allocating spectrum, both among competing broadcast users and non-broadcast users. The federal Communications Act assigns this allocation and coordination function to the FCC.

The FCC has assigned 69 channels, or 414 MHz, to television broadcast use. The channels fall generally into two categories, with channels 2-13 (54-216 MHz) known as Very High Frequency bands (VHF), and channels 14-69 (470-806 MHz) known as Ultra High Frequency bands (UHF). The propagation characteristics of VHF and UHF vary, with VHF generally enjoying superior reach of a quality signal in a given geographic area. As a result, VHF stations generally enjoy a competitive advantage over UHF stations in the same market, although as discussed below, the FCC has taken steps to ameliorate the scope of that advantage over the years.

The FCC has allocated television channels in geographic markets across the nation based on geographic separations of transmitters to minimize co-channel and adjacent-channel interference and on the population size of the geographic market. (Generally speaking, the more populous the market, the more television channels that are assigned to it.) The result is what is known as the "Table of Allotments," which allocates channels (both the number of channels and the frequencies of those channels) in over 200 markets across the nation.

Both the number of authorized television channels nationwide and the number of operating television stations have grown as follows:

Year	Number of Authorized Television Channels	Number of Television Stations on the Air
1946	9	6
1950	111	97
1955	576	439
1960	673	573
1965	676	586
1970	1,038	872
1975	1,010	952
1980	1,094	1,013
1985	1,505	1,194
1990	1,684	1,436
1992	1,688	1,488

Source: <u>1993 Television & Cable Factbook</u> (Warren Publishing)

1. Lessons for ITS

Although television broadcast is a fundamentally different kind of service than ITS, it nevertheless offers two important lessons for ITS. The first lesson is the importance of standard-setting and equipment compatibility. For ITS to be effective, receivers (and possibly transmitters) will have to be widely (preferably ubiquitously) deployed in vehicles. Television broadcasting teaches that, where a wireless radio service depends on widespread deployment of compatible receivers, a uniform standard to ensure compatibility between the signals and the receivers tends to be an essential precondition for the service to develop.

The second lesson is that widespread implementation of any radio-frequency spectrum service presents complicated spectrum allocation questions, both in terms of the allocation within geographic markets and between different geographic markets. The FCC will be the ultimate arbiter of those questions. The allocation decisions it makes will play a large, if not decisive, role in determining (1) whether (and, if so, to what extent) competition will be feasible in the ITS market; and (2) the ITS capacity within each geographic market. If the FCC's allocation pattern in television broadcasting is any guide, greater competition and greater absolute spectrum capacity will exist in larger, urban markets. However, the television broadcast allocation pattern also suggests that, relative to total population, spectrum will be more scarce in larger, urban markets.

B. Services

Aside from variations in programming content, broadcast television is a remarkably homogeneous service: An advertiser-supported video program service delivered free of charge to viewer-provided receivers. There are two exceptions to this general pattern, one relatively insignificant and the other more significant.

First, a very small fraction of broadcast licensees have provided subscription television service, where the viewer pays for service. Second, the FCC has set aside one, or sometimes two, channels in most medium-sized or larger markets for noncommercial use. Noncommercial stations are usually operated by non-profit organizations and/or educational institutions. Noncommercial television broadcasting receives support primarily from three sources: viewer contributions, private grants (i.e., in return for "noncommercial sponsor identifications), and federal government support through the Corporation for Public Broadcasting, created by the Public Broadcasting Act.[38]

Historically, commercial television broadcasting has been dominated by the three major networks — ABC, CBS, and NBC — which provide a substantial amount of programming to their affiliates in virtually every geographic market. The general pattern is that three broadcasters in each market are each affiliated with one of the three major networks. In markets where more than three broadcasters are licensed, the remaining licensees are usually "independents" without a network affiliation. In recent years, Fox has become a fourth network and usually (but not always) is affiliated with the fourth licensee in a market with at least four licenses.

Over its history, television broadcasting has introduced what might be considered two new types of service. The first was color television. As discussed above, the NTSC color standard made implementation of color television possible. The second new service is stereo television, which began to be implemented in the mid to late 1980's. To be commercially viable, stereo television had to conform to the NTSC standard and be "backwards compatible" with non-stereo NTSC receivers.

This is the mirror image of the solution reached with respect to the original color NTSC standard, which had to be "backwards compatible" with the imbedded base of black-and-white receivers. And as with the color television, stereo television was made possible by the FCC's decision in 1984 to modify the NTSC standard to accommodate stereo signals. As a practical matter, the "imbedded base" problem has always placed constraints on the implementation of new, innovative service technologies in television broadcasting.

1. Lessons for ITS

As an almost completely advertiser-supported service available to the public at no charge, television broadcasting is probably a fundamentally different kind of service than ITS. That is certainly true with respect to ATMS. As an end-user consumer service, it is possible that ATIS could be at least partially advertiser-supported. It seems doubtful, however, that ATIS could generate sufficient advertising revenues to be provided free of charge to end users, if no other reason then the entrenched competition for advertising dollars that television and radio broadcasting provide.

The effect on television broadcast service innovation of standard-setting and an embedded equipment base may also be applicable to ITS. There is an inherent tradeoff between, on the one hand, setting standards to promote widespread deployment of customer equipment and, on the other, implementing subsequent service innovations. As a practical matter, subsequent innovations tend to be limited by the technical parameters of the original standard. To the extent ITS relies on the rapid, widespread deployment of remote receivers (either fixed or, more importantly, in vehicles), it will face this tradeoff as well. The television broadcast experience shows that service innovation is still possible, provided that the original standard-setters have the foresight (or perhaps good fortune) of selecting a standard that is as adaptable and flexible as possible.

C. Diffusion/Penetration

Television's broadcasting service enjoyed remarkably rapid penetration. The percentage of total U.S. households with television sets was well over 50 percent within roughly five to six years of introduction of commercial service, exceeded 90 percent by 1965, and has consistently been close to 100 percent since 1975:

Year	Percentage of U.S. Households with TV Sets
1950	9.0%
1955	64.5
1960	87.1
1965	92.6
1970	95.3
1975	97.1
1980	97.9
1985	98.1
1990	98.2

Source: Statistical Abstract of the United States, 1980 and 1992 (U.S. Census Bureau).

The success of television broadcasting is no doubt due in large part to the uniqueness of television: a powerful electronic visual medium that requires no action on the part of the viewer other than to turn on the television receiver. Television's success is also probably due to a considerable degree to the fact that from the viewer's perspective, it is free: other than the cost of purchasing the receiver, the viewer pays nothing to view the service. Economics predicts, of course, that a free good will be overconsumed. But since television is advertiser-supported and audiences are what broadcasters sell to advertisers, audience "overconsumption" is precisely what television's true paying customers — the advertisers — want.

Declining prices of television receivers also no doubt played a role in the widespread diffusion of television service. Between 1958 and 1990, the average price of a monochrome television receiver sold in the U.S. declined from $136 to $70. During the same period, the average price of a color television receiver declined from $425 to $301.[39] Measured in real terms, of course, the decline in television receiver prices is even more substantial.

1. Lessons for ITS

Because of the uniqueness of television broadcasting service, it is hazardous to draw many analogies from it for ITS. Some general conclusions (which are unique to neither television nor ITS) may be inferred. First, in any wireless service relying on a widespread embedded receiver base, adoption of uniform technical standards is an often a precondition to widespread diffusion of service. Second, declines in the price of receivers will spur service penetration. Third, the price of electronic equipment designed to receive a new service tends to decline over time.

D. Private Sector Economics

Television and radio broadcasting are unique among communications services in that they are "free" to the viewer and virtually 100 percent advertiser-supported. As a result, the private sector economics of television broadcasting are also unique and do not provide a very reliable model for any service that follows the more typical pattern of deriving revenues from end users.

Because television broadcasting is almost completely advertiser-supported, viewer demand of television programming is only derivatively important to the industry's economic structure. The relevant market is actually the market for viewing audiences. Television broadcasters sell their audiences to advertisers. Generally speaking, the larger a broadcaster's audience, the higher the price of the advertising time it sells.

A distinctive market trait of television broadcasting is networking. Through affiliation agreements or ownership, broadcast stations in different geographic markets tend to affiliate in the distribution of common programming. The result, of course, has been the three major television broadcast networks, ABC, CBS and NBC, and the recent addition of a fourth network, Fox.

Two economic forces drive the networking tendency in television broadcasting. First, networks take advantage of economies of scale in television programming production and acquisition. Program production is expensive, and it is largely a fixed cost that does not vary with the size of the viewing audience. (For years, FCC rules and an antitrust consent decree limited the major networks' ability to produce programming. But even for the programs they do not produce, the networks nevertheless incur program production costs indirectly through the rights fees paid for programming produced by others.) Networking enables programming production and acquisition costs to be spread across a larger audience.

Second, networks are able to offer advertisers a larger audience by expanding the audience geographically. In essence, by affiliating with a broadcaster in every geographic market, networks offer advertisers the unique product of a nationwide audience. Networks also no doubt reduce advertisers' and broadcasters' transaction costs by eliminating the need for market-by-market negotiation for advertising time.

Historically, television broadcasting has exhibited no natural monopoly tendencies. To be sure, the radio frequency allocated to television broadcasting has generally been considered "scarce" in the sense that fewer channels are available than there are those who wish to use them. And FCC frequency allocations effectively place an absolute limit on the number of stations in a market, thereby limiting entry. The FCC, however, has generally allocated more than one (and usually at least three) television broadcast channels per market. Larger markets, such as the Los Angeles area, have more then twenty channels allocated to them. Thus, head-to-head competition for broadcast television audiences and advertising dollars exists in almost all geographic markets, although smaller markets with only two or three channels tend to be more oligopolistic.

Over time, competition in television broadcasting has increased significantly. In the 1950's and 1960's, the FCC had allocated far fewer channels, and thus each broadcaster in a market had far greater market power. During the period, competition was frustrated by the additional fact that not all channels were equal: VHF channels enjoyed markedly superior signal propagation and reception characteristics over UHF channels, making VHF broadcasters far more attractive to advertisers (and thus the networks as well). The receiver industry's failure to install UHF tuning capability in television sets that was comparable to VHF timing capability compounded this problem. UHF broadcasters' competitive handicap was gradually ameliorated by the FCC's implementation of the All-Channel Receiver Act of 1962,[40] which authorized the FCC to require that all televisions receivers be "capable of adequately receiving all frequencies allocated by the [FCC] to television broadcasting."

Cable television has also provided ever-increasing competition to television broadcasting, especially since the late 1970's when satellite technology provided non-broadcast programming for cable systems to carry and cable penetration grew by expanding into large suburban and urban markets. Cable system operators, as well as advertiser-supported cable networks, now compete with television broadcasters for audience size to sell to advertisers. While television broadcasters in general, and the networks in particular, still enjoy over 60 percent of total television audience time and a commensurate percentage of total advertising dollars, their relative share has declined substantially from virtually 100 percent of the market in the 1970's.

1. Lessons for ITS

Again, since television broadcasting is an advertiser-supported service and thus fundamentally different from ITS, applying television broadcasting analogies to ITS can be hazardous. Nevertheless, a few generalizations are warranted.

First, broadcasting is yet another example of the general rule that some degree of head-to-head competition is usually feasible for wireless-based services. Although spectrum limitations restrict the scope of that competition, multiple (or at least two) licensees can usually exist in a market. The UHF/VHF experience in broadcasting also teaches, however, that for competition to be effective, the frequencies used by each competitor must be equivalent in receivability, and to the extent they are not, standard-setting action is needed at the outset to require that receivers be compatible with all competitors' frequencies. Thus, to the extent that competition is a goal in implementing ITS, it is advisable that standards for remote receivers be set in a way that ensures maximum compatibility with all frequencies used by competing ITS providers.

Second, the emergence of cable television as a competitor to television broadcasting provides another example of the general trend that competition extends across delivery technologies and FCC licensing categories. For ITS, this means that regulators should not necessarily assume that competition will be limited merely to those providers that are licensed to provide a particular ITS service, such as ATIS. On the contrary, other licensed services (particularly PCS, since the FCC has not restricted the types of services to be provided by PCS) may compete with ITS. And ATIS would seem to be the most likely target of such competition.

Third, to the extend a service relies primarily on advertising revenues, the service provider has a built-in incentive to encourage very rapid growth in the size of the end-user audience. ATMS seems an unlikely candidate for advertising revenues. ATIS, on the other hand, may have some potential for advertising support, although not at levels approaching broadcasting. One option might be to encourage "commercial" (i.e., advertiser-supported) ATIS. At a minimum, ITS regulatory policy probably should not discourage advertising.

E. Role of Government

1. Regulation

As with all wireless radio services, television broadcasters are subject to FCC jurisdiction and regulation. Other than zoning regulations, libel and slander and other generally applicable state and local laws, television broadcasters are generally immune from state and local regulation.

The scope of FCC broadcast regulation has waxed and waned over its history, with the general trend toward less comprehensive and intrusive regulation. The FCC remains, however, the ultimate gatekeeper of the market, as a FCC license is a prerequisite to providing broadcast television service. The Communications Act forbids regulation of broadcasters as common carriers, and thus FCC broadcast regulation fundamentally differs from common carrier regulation. Beyond entry, exit and license transfer regulation, broadcast regulation bears little resemblance to common carrier regulation. Unlike a common carrier, a broadcaster is under no general obligation to carry the communications of others and instead is responsible for determining the content of programming carried. The Communications Act forbids the FCC from censoring broadcast content, and thus the FCC has generally refrained from any direct content regulation of broadcast licensees (with the exception of the Fairness Doctrine (since abandoned) and the Equal Time doctrine).

The FCC grants (and renews) television broadcast licenses based on the Communications Act standard of "public convenience, interest, or necessity.[41] All broadcast television licensees are subject to this "public interest" standard. The statutory wording of the standard mimics the common carrier standard- and thus gives no guidance to its application to broadcasting. As a result, the standard has proven amorphous, and the FCC's interpretation of it has changed over time.

The FCC has implemented the broadcast public interest standard through policies such as "localism" (a broadcaster's obligation to be responsive to local community needs and interests) and "diversity" (the public is best served by receiving a diversity of programming and viewpoints). The FCC has enforced these policies through requirements and preferences that indirectly affect content, such as giving competing applicants preferences for local station ownership or management (which the FCC believes promotes programming responsive to local community needs) or for minority ownership (which the FCC believes will promote ownership diversity, which in turn will promote programming diversity). In addition, the FCC has placed a variety of additional requirements on broadcast licensees over the years (ranging from general requirements such as limits on contests and requiring licensees to obtain a public file, to specific prohibitions such as forbidding broadcast of siren sounds). Some, but not all, of these requirements have been loosened or eliminated in the last decade.

Underlying broadcast licensing is the fundamental notion that the spectrum used by licensees belongs to the public, not the broadcaster. A broadcaster's public interest obligation flows from this notion, as does the statutory requirement that to receive a license, a broadcaster must acknowledge its lack of property interest in the license.

Like all forms of government regulation, broadcast regulation imposes administrative costs. Historically, the primary source of administrative delay and costs in broadcast regulation has been the comparative hearing process, which the FCC has used to award or renew licenses among competing applicants. The FCC has recognized the problem and has been engaged for some time in an ongoing effort to streamline and simplify the process, with mixed success.

2. Standards

As noted above, standard-setting has played a major role in television broadcasting, and the FCC has been the primary standard-setter. Television broadcasting is perhaps the archetypical example of the inherent tradeoff in standard-setting: on the one hand, standards are needed to break the "chicken and egg" cycle of coordinating and promoting simultaneous investment in broadcast facilities and privately-owned receivers, while on the other hand, setting standards tends to freeze technological advance (or at least constrain or slow future technological development).

Overall, most observers would probably agree that setting the NTSC standard, and the subsequent implementation of the All-Channel Receiver Act, were critical and necessary steps to the rapid deployment of television service and the development of competition in that service. However, many observers would also note that the versatility of the NTSC standard was more the result of historical accident than foresight: In the late 1940's, the FCC had previously approved a far inferior, less versatile color television standard, but got a second chance when the War Production Board delayed production of sets using the inferior standard. Moreover, adoption and implementation of the All-Channel Receive Act occurred only after a decade or more of political battles.

3. Incentives, Subsidies, Externalities and Other Public Policy Issues

There are three principal government "subsidies" or incentives involved in television broadcasting, two of which benefit the broadcaster and one that benefits political candidates. The first is that broadcasters are not required to pay money for use of federally-owned airwaves. This, of course, substantially lowers the broadcasters' costs, thereby making free over-the-air broadcasting more economically feasible. At the same time, however, it results in a significant transfer of wealth from the public to broadcast licensees — in essence, a public subsidization of broadcasting and broadcasters. This is reflected in the fact that the market value of television broadcast stations generally far exceeds the replacement value of the facilities associated with the station. A major, if not the primary, component of a television broadcast operator's value is the authority given by its license to use a channel to broadcast to the public.

The second form of government incentive given to broadcasters is what is known generally as the "renewal expectancy." Generally speaking, when a television broadcaster's license comes up for renewal, the incumbent licensee is given a preference over competing applicants, and the incumbent licensee is normally renewed absent unusual circumstances. The FCC's renewal policies have the general effect of promoting licensee stability and investment. However, the policy also dulls the incentive to perform that a more competitive renewal process might promote. It also eliminates the FCC's opportunity to recapture the value of the license at renewal.

The third form of "subsidy" in broadcasting is embodied in the FCC's political broadcasting rules, particularly the Lowest Unit Charge rules. Those rules prohibit a broadcaster from charging a qualified political candidate more than its lowest unit advertising rate in the period preceding an election. In essence, these rules require a licensee to subsidize a class of programming -political programming — that is deemed in the public interest during certain time periods.

At bottom, public policy with respect to television broadcasting has reflected an effort to balance, on the one hand, the goal of placing an obligation on broadcast licensees, as the privileged users of a valuable public resource (the spectrum), to serve the public interest, and on the other hand, the goal of not intruding on broadcasters' First Amendment rights as members of the press. That balance is an inherently uneasy one, and one that distinguishes broadcast regulation from most other kinds of regulation.

4. Lessons for ITS

The uniqueness of television broadcasting yields few clear lessons for ITS. One clear lesson, however, is the importance of standard-setting and the role it plays in the pace of development of any radio service relying on widespread privately-owned receivers. The television broadcasting experience suggests that, to the extent widespread deployment of ITS will depend on widespread deployment of receivers and/or transmitters in vehicles, adoption of standards ensuring compatibility between vehicular receivers/transmitters and the fixed receivers/transmitters used in ITS is essential. Standards will also enable different manufacturers to produce the equipment, thereby promoting competition and lowering the cost of implementing ITS.

At the same time, the broadcast experience teaches that, while compatibility is vital, flexibility and "upgradeability" in equipment is also important. For example, the vehicular equipment standard for ATMS needs to be sufficiently flexible to be upgradeable (or retrofitted) for ATIS use at relatively low cost. Otherwise, implementation of ATIS — perhaps a second generation service to ATMS — will be stymied by the need to replace the embedded ATMS vehicular base.

This means that, in setting initial technical standards, standard-setters must try to anticipate the technical requirements of the whole family of future ITS services, rather than focusing merely on a simple ITS service, such as ATMS or ATIS. On the other hand, awaiting the development of an ideal standard that meets all needs could also greatly delay the standard-setting process and thereby delay implementation of any service at all. Standard-setting involves a balancing of these concerns, and there is no magic formula that will identify when the balance is right. But standard-setting — and wisely implemented standard-setting — will likely be essential to ITS success.

VI. CHAPTER SIX — HDTV

This case study[42] analyzes the forward and backwards compatibility implications of technical standards in the context of advanced television (ATV) generally and high definition television (HDTV) in particular.[43] HDTV is of additional interest because of the overshadowing issue of international compatibility of standards.

The anticipated conversion from NTSC transmission standards[44] adopted by the FCC in the 1940's and early 1950's to ATV presents acute transitional problems arising out of the large embedded base of NTSC television transmitting and receiving equipment, which, oftechnological necessity, will be incompatible with a new HDTV standard. The earlier transition from black-and-white television to color television had been much easier because black-and-white sets could receive NTSC color transmissions[45] and NTSC color sets could receive black-and-white transmissions. HDTV transmissions cannot access the NTSC-equipped audience, because that audience cannot receive the new HDTV transmissions. Until HDTV penetration reaches a critical mass, HDTV transmissions will not be economically viable. At the same time, NTSC transmissions will no longer be viable after NTSC-compatible receivers fall below a critical mass. Prospectively, there is the additional issue of making HDTV displays compatible with a large population of personal computers in homes of the future.

The Commission's jurisdiction over ATV standards is largely limited to specifying over-the-air transmission standards. The Commission's influence on standards for television cameras ("production standard") or for receivers ("receiver specifications") is largely indirect. The reason is that, with the exceptions of the 1962 all-channel receiver law, the 1990 Television Decoder Circuitry Act, and the law regarding electromagnetic compatibility (EMC), Sections 302 and 330 of the Communications Act, 47 U.S.C. §§ 302, 330, the Commission has no jurisdiction over television receivers.

In 1983 the television industry formed the Advanced Television Service Committee (ATSC) to coordinate and develop voluntary national technical standards for terrestrial ATV systems. In the Commission's November, 1987, Notice of Inquiry in Docket No. 87-268, 2 F.C.C. Rcd 5125, the Commission established the Advisory Committee on Advanced Television Service, comprised of industry leaders from diverse sectors, including the broadcast, cable, computer, and manufacturing industries. At various stages in Docket No. 87-268, the Commission has provided guidance to, and has acted on recommendations of, its Advisory Committee.[46]

A. Technology

ATV is the generic term applied to refinements of the technology for the transmission of television broadcasts — more specifically to enhancement of the television picture to approach 35-mm film equivalency (HDTV) or to improve the existing NTSC picture, i.e., enhanced definition television (EDTV)[47] By "refinements," the FCC means improvements over the NTSC standard as last adopted by the FCC with the advent of color television broadcasting in 1953. Color Television Transmissions, Docket No. 10637, 41 F.C.C. 658, 10 R.R. 150 (1953). A recent example of such a refinement would be the FCC's adoption of the Japanese ghost-canceling system. See Vertical Blanking Interval, 8 F.C.C. Rcd 3613, 72 R.R.2d 1018 (1993).

Some ATV refinements are designed to be backward compatible with NTSC-standard receivers, even though these receivers lack the circuitry to take advantage of the ATV improvements. HDTV, however, will not be compatible with NTSC. Thus, HDTV confronted the Commission with specifying a transition or "conversion period." The FCC's proposed solution is a relatively lengthy period of dual operation of the prior NTSC standard and the new HDTV standard. To accommodate the interim period of dual standards, the FCC has proposed a transition period under which television broadcasters will have the simultaneous use of two different parts of the spectrum — one for NTSC television and one for HDTV. 7 F.C.C. Rcd 6924, 71 R.R.2d 375 (1993). This double-channel occupancy will be fairly expensive spectrum-wise, but there seems to be no economic alternative until a commercially viable HDTV receiver base is established.

1. Lessons for ITS

The lesson for ITS from HDTV is that incompatibility of a new technology with the embedded receiver base creates expensive and awkward transitional problems 'that should be avoided if at all possible. To a certain extent, of course, completely avoiding transitional problems is impossible, since current standard-setters cannot possibly foresee all future, underdeveloped technologies. However, the expense and disruption of transition strongly suggests that the initial standards should be a flexible as possible, designed to accommodate as many foreseeable future technological developments as possible,

B. Diffusion/Penetration

Public acceptance of HDTV will be the key to its economic viability and, perhaps, the greatest unknown factor bearing on its ultimate success. While there is a great deal of program material on 35 mm. film, the question of whether there will be enough programs in HDTV format to motivate large numbers of viewers to buy HDTV sets will determine whether HDTV proves viable. The lack of forward compatibility of NTSC receivers makes the chicken-and-egg problem here far more acute than with color television, where (i) color programming could be received in black-and-white by the embedded receiver base and where (ii) the vertical integration of some of the major set manufacturers, e.g., RCA, provided an economic incentive for "force-feeding" color programming at the network level.

There is fundamental uncertainty in the television industry as to the rate and extent of HDTV acceptance by the public. Until (and unless) HDTV reaches the stage where simulcasting of programming in both NTSC and HDTV gives way to HDTV-only telecasting, it is unclear that greater picture definition alone will draw people to buy HDTV receivers. The price of those receivers, in turn, will reflect manufacturers' anticipations of sales. A further factor is perceived to be the availability of "flat screens.[48] It may be that a predicate to HDTV's viability in the marketplace is the general availability of flat screens. Thus, unless it is "force-fed" HDTV by elimination of NTSC signals, public acceptance — and hence the commercial viability of HDTV — may prove to be highly dependent upon the development of optimal standards.

The effort to arrive at a single U.S. transmission standard for HDTV has been time-consuming and arduous. Indeed, it provides a good example of the difficulties in setting standards in today's environment where the technological distinctions among various communications services have become blurred. First off, the Americans and Europeans could not even agree on all parameters for a production standard. Second, the Japanese rushed in with an analog system (MUSE) in the 1980's. The FCC established an ATV Advisory Committee to select the U.S. standard in the late 1980's, and by the time the Committee was ready to begin testing alternative (and incompatible) analog systems, several digital systems had been proved workable. Ultimately, proponents of various alternative systems joined together in a "Grand Alliance" to present one composite, digital system to the FCC.

Just as this was occurring, the computer industry belatedly appeared on the scene to demand an HDTV standard that would embody a sequential scanning standard that would be more compatible with computer displays than the interlaced scanning traditionally used by the television industry. Because sequential scanning imposes impractical demands on currently available cameras and certain cost penalties, market observers anticipate that the HDTV standard will begin with interlaced scanning and then transition to sequential scanning some years out.

The ultimate outcome is still in doubt, since the Europeans have given no sign of voluntarily accepting a U.S. standard. Moreover, the Society of Motion Picture & Television Engineers (SMPTE's Motion Picture Expert's Group) has not acceded to the Grand Alliance's proposal to the Advisory Committee. 7 F.C.C. Rcd at 6969, 71 R.R.2d at 396.

1. Patented Standards

HDTV is analytically interesting because of the embedded- base problem and the evolution of the technology during the process of adopting a standard. It, in common with standard broadcast television (the subject of another case study), also presents the issue of "patented standards."

The principal international implications of standardization are three in number. First, international standardization permits manufacturing economies of scale and facilitates price competition among providers. Second, international compatibility minimizes the user's investment in duplicative equipment as he moves from one geographic area to another. Third, international compatibility minimizes the inevitable loss in quality that accompanies conversion from one standard to another as the service crosses a border.

The FCC has announced that it will apply its usual patent licensing requirements to proponents of the HDTV standard.[49] The uneasy tension between patents and regulatory imposed standards has often surfaced elsewhere in Commission deliberations over new technologies and new operating relationships among regulated competitors. For the Commission unconditionally to adopt a patented technology as a standard or to prescribe an operating relationship that would require the use of a patent, raises a substantial risk that would-be competitors would be forced to pay the patentee monopoly charges in order to participate in a Commission-regulated market. That, in turn, would reduce or eliminate the benefits of a competitive marketplace for receivers that standard-setting is presumably intended to provide.

The Commission has solicited advice from NTIA, DOJ, and other government agencies on this point. The Commission's recent order does note the patent policy of the American National Standards Institute (ANSI), which requires that proponents of standards certify that their patents are available on reasonable terms, free of any unfair discrimination.

The Commission traditionally has required non-exclusive patent holders to grant non-exclusive licenses as a condition of allowing or specifying the patented system in its rules.[51] Examples are standard plugs and jacks (1976-79), the comparable television tuning rules (1973) FM stereo (1961), and facsimile (1982). The Commission largely avoided this problem by failing to specify a standard for AM stereo in 1982,[52] until Congress acted in 1992 to required such a standard.[53]

2. Lessons for ITS

The principal lesson for ITS that HDTV teaches is that, where the market admits of only a single standard and transition between standards is difficult because of incompatibility between or ‘amongst successive standards, one should not prematurely standardize. The United States was almost stampeded (“HDTV sets are being loaded on boats in the Japanese harbors”) into standardizing on Japan’s analog Narrow-MUSE system. Ultimately, only digital systems made the Advisory Committee’s final cut for adoption. The danger of premature standardization is that the industry either (i) will be saddled indefinitely with a technologically inferior system or (ii) will be put to the risk and expense of making obsolete the significant embedded base of transmitting and receiving equipment.

Against the risk of premature standardization, however, is the risk of “bottling up” new services that results from delay in standardization. HDTV demonstrates this latter risk only inferentially, i.e., it has not yet evolved to the point of being “market-ready.” Two other entertainment products do offer analogies showing the market risk of non-standardization. In both the absence of standardization doomed the superior technology. AM stereo is an example of the total failure of an improved technology in the absence of standardization. There, after eleven years without standardization, less than ten percent of the AM broadcast stations had installed stereo transmission equipment. Ultimately Congress, in an attempt to rescue AM broadcasting, had to legislatively mandate the FCC to adopt an AM stereo standard.[54] By the time the Commission acted, it considered that its ability to adopt a technologically superior system had been foreclosed by the marketplace’s “acceptance” of the technologically inferior system sponsored by a dominant supplier.[55] It is doubtful that the belated governmental imprimatur on the inferior system will lead to commercial success of AM stereo.

Similarly, BETAMAX failed as a video format in the absence of standardization, although it was arguably a technologically superior system. The inferior format nonetheless was commercially successful. In the case of video recordings, however, the failure to adopt the superior standard was mitigated by subsequent compatible improvements in the competing VHS system that arguably closed the technological gap between the two formats, and the quality recording role was assumed by newer videodisc technology.

C. Services

The primary service that ATV offers is improvement of the picture and sound presented to the television viewer. As noted in the television broadcasting case study at 11, the saleable product is the viewing audience attracted by the transmission-a function of programming as much as picture quality.[56] The end product, of course, results from a chain, starting with the quality of the picture signal generated by the studio camera and the processing of that signal (the production standard), the transmitting, propagation, and receiving of that signal (the transmission standard), and the receiver’s display characteristics. There are many opportunities for degradation along the chain, and various systems will react differently to such potential degradations. The ability of the signal to resist or conceal degradation in the propagation segment of the chain, for example, is a function of its “robustness.” Certain visual distortions will be more apparent on large-screen displays than on the small screens of “personal” television receivers. A standard ultimately represents a compromise among the differing interests of providers and users in achieving the common objective of a superior viewing experience.

1. Lessons for ITS

The ATV experience teaches that standards must be set on an overall basis, rather than by segments of the chain from origination to termination. Uncoordinated choice of a standard for one part of the system, independent of the impact of that choice on the overall performance of the chain, will inevitably result in a sub-optimal total system.

The further lesson for ITS is that, to the extent a vehicular service depends on mass acceptance for economic viability, compatibility is a significant factor in whether a critical mass will be achieved. The absence of a governmentally adopted standard introduces the risk of market failure. On the other hand, ultimate success of a service can be prejudiced by the premature. adoption of a standard that is incompatible with future technological enhancements. Certainly, a standard should not be adopted that is technically inferior to that necessary to make the new service economically viable. This last point is essentially a marketing judgment.

D. Private Sector Economics

The private sector economics of HDTV are exceedingly complex. The production end of the chain is not fully determined by HDTV, since the production function has other media outputs besides television broadcasting, such as motion picture theaters, cable television and, possibly in the future, computer information services as well. The economics of the transmission segment of the chain depend on HDTV receivers in the hands of the public achieving a critical mass, which in turn will depend on the amount of HDTV-only programming, the price of HDTV receivers, the improvements in display technology, e.g., flat screens, and the cross-utility with other services, e.g., computer-compatible display. Because the various segments of the chain are controlled by different industries and forces, the marketplace unaided will not necessarily achieve an optimal confirmation of the chain, i.e., there are externalities to each segment.

1. Lessons for ITS

The lesson for ITS is that governmentally adopted standards are likely a predicate to achieving a technologically optimal and economically viable system. Standards should be adopted early enough to support the development of the market but not so early as to freeze system configuration at a technically inferior level as to not be economically viable. To the extent practicable, standards should be adopted to be compatible with neighboring technologies so as to derive the benefits of increased volume and lower costs i.e., economies of scope and scale.

E. Role of Government

As previously noted, the FCC's jurisdiction is largely limited to the middle (over-the-air transmission) segment of the HDTV chain. The standards of the production segment are controlled by the MPE (Motion Picture Experts) Group, and the final, receiver segment is largely controlled by standards adopted by the receiver-manufacturer members of the Electronics Industries Association. The FCC, of course, lacks the in-house expertise to select an optimal HDTV system. So it is dependent on the ATV Advisory Committee, formed under the Federal Advisory Committee Act, 5 U.S.C. app. 2 §§ 1, et seq. The competing HDTV systems are being tested by the Advanced Television Test Center and the Cable Television Laboratories. These centers, in turn, are being funded by diverse segments of the respective industries, in addition to testing fees being collected from the proponents of the competing systems.

Thus,, the Commission is getting the benefit of the best brains in the country and a consensus among the interested parties — all at a relatively insignificant cost to the taxpayers. The government has provided relatively little in the way of financial incentives since some early grants by DARPA, now ARPA.

Beyond the area of standards, as the transmission segment of the HDTV chain is activated, the FCC will presumably receive user fees from the telecasters approximating the cost of regulation, pursuant to 47 U.S.C. § 8.

A by-product of the FCC's involvement in the HDTV standards-setting process will likely be fostering exports of the HDTV technology. Successful exports will in turn likely reduce the cost of the new technology by permitting economies of scale in manufacturing.

The FCC has a key role to play in facilitating the transition from NTSC to HDTV by reason of its full control of spectrum allocations. As presently contemplated, there will be a substantial overlap period during which existing NTSC telecasters will be permitted to simulcast over two channels — one using the NTSC format and the other the HDTV format. See Second Report and Order in Docket No. 87-268, 7 F.C.C. Rcd 3340, 70 R.R.2d 1102 (1992), and Second Further Notice of Proposed Rulemaking in same, 7 F.C.C. Rcd 5376 (1992). Such dual operation will be necessary until a critical mass of HDTV receivers in the hands of the public is achieved and, presumably, sometime after there ceases to be a critical mass of NTSC receivers.

1. Lessons for ITS

Government adoption of a standard taking into account the full delivery chain is likely a prerequisite for the successful introduction of a new technology, where individual segments of the delivery chain are under the control of different industries.

Where the new technology is incompatible with an embedded base, the role of government in managing and facilitating the transition may be equally important to the commercial success of the new technology. Particularly is this so where the transition can be accomplished only through-extraordinary demands on the radio spectrum.

VII. CHAPTER SEVEN — CELLULAR[57]

The ITS industry will face industry development issues similar to those faced by the cellular industry. Technology, offered services, diffusion patterns, industry economics, and government regulations all will have an impact on the success of ITS. This report examines these issues for the cellular industry to provide insights on how ITS can mirror the successes of cellular and avoid the pitfalls.

A. History

Technological, economic, and institutional factors all shaped how cellular radio was developed and ultimately implemented.

Cellular is a combination of technical developments in both telecommunications and radio technologies. Vehicular application of mobile radio service began back in the 1920's with two-way radio services available for many police and public safety institutions in the 1930's. The first commercial mobile telephone service was introduced by AT&T in 1946, but did not have direct dial service or was not interconnected to the public telephone network. The first full service interconnected direct dial service, known as Improved Mobile Telephone Service (IMTS), was introduced in I965 and was the pre-cursor to cellular radio service.

These systems were not cellular as they relied on powerful transmitters to broadcast radio waves over as many miles as possible, usually 25-35 miles radius. Thus, a user of a specific radio channel tied up that channel throughout the entire area that the transmitter was broadcasting.

The concept of cellular was introduced by the Bell Labs in the 1940's. Cellular represented a very different approach to structuring the radio network by using smaller cells and lower power transmitters. This approach re-used spectrum and provided for an exponential increase in capacity.

The impetus for introducing cellular technology grew largely out of the shortcomings of IMTS. In most areas of the U.S., IMTS systems became saturated with customers and new customers could not be added. In any one area, only 800 - 1000 customers could be accommodated. This was because only a limited amount of spectrum was allocated to the service by the FCC.

The FCC has direct responsibility for making decisions of frequency allocation of spectrum. Because spectrum is limited, the FCC always is making decisions that take spectrum away from some areas and award it to other areas. In 1949, the FCC made the decision to award over 400 MHz of spectrum to television broadcasters and none to mobile telephony. This allocation of spectrum effectively precluded the possibility of large scale mobile telephony systems.

After years of lobbying by AT&T, the FCC reconsidered its frequency allocation and transferred some television frequencies to mobile radio service in 1968. FCC Docket 18262, known as the Cellular Docket, opened up the real possibility of cellular telephone service.

This milestone, however, was followed by political wrangling regarding who should be licensed to provide cellular service, how many operators there should be, how licenses should be allocated geographically, and the terms and conditions of interconnection with the public telephone network. These issues hampered the introduction of cellular as interested parties battled for potentially lucrative cellular licenses.

AT&T believed that by virtue of its market position and pioneering status in cellular technology, it would be granted monopoly rights for the service. The FCC, under pressure to provide competition in the marketplace, instead granted two licenses for 728 regions of the U.S. AT&T formed a subsidiary in 1980 to secure one of the licenses for the entire U.S. The ability of AT&T to offer cellular service, however, was taken away by the divestiture of AT&T in 1982 which separated the ability to offer local telephone service and cellular service from the ability to offer long distance service.

In the early 1980's, after the FCC established final licensing rules; the FCC formally began the process of licensing cellular geographic areas of the country. The first cellular system came on-line in 1983 in Chicago. The largest 306 metropolitan markets were licensed over the next four years, and 422 rural areas were licensed beginning in 1988. Currently, every one of the 728 licensed areas in the country has at least one cellular system in operation, covering approximately 95 percent of the U.S. population.

B. Technology

Technological innovations and compatibility of the technology have played important roles in the creation of the cellular industry and the services available to cellular carriers and end-users. This section provides an overview of the components of cellular technology, and the technological factors which have impacted the development of the industry.

1. Basic Components for Cellular

Cellular service developed from a new concept rather than from a new technology. The actual technological components of cellular do not differ much from those of its predecessor, Improved Mobile Telephone Service (IMTS). The innovative concept behind cellular is that by using available resources in a new way, a completely new service is provided. The principles of cellular are:

- low power transmitters
- frequency re-use
- cell-splitting to increase capacity
- hand-off from cell to cell

Cellular's uniqueness comes from using low-power transmitters that serve only a small geographic area. Prior to cellular, mobile communications was engineered to broadcast using powerful amplifiers from a high elevation to as much geographic area as possible. This meant that one user would tie up the spectrum he was using for the entire geographic area. In New York City in the 1970's, only 12 users could talk simultaneously at any one time. By using smaller cells of coverage, the radio spectrum can be re-used in another cell, which increases the capacity tremendously. Each 50% reduction in the cell radius quadruples of the number of channels per square mile. A system based on l-mile radius cells would have 100 times the channel capacity of a system with 10 mile radius cells.

In addition to smaller cell sites, cell splitting, and frequency re-use, the final element of cellular technology is hand-off of calls from cell to cell as a user moves through an area. To accomplish this a system-wide switch is used for an overlay network that links all of the cell sites. Calls are handed off by monitoring signal strength and switching the call from one cell to another.

By utilizing the concept of frequency re-use, cellular has been able to evolve radio telephony to a truly mass market product.

2. System Infrastructure Equipment and Roaming Capability

Currently, the dominant industry players supplying infrastructure equipment (system **switch** and cell sites) to the industry are Motorola, AT&T, Ericsson, and Northern Telecom. While all cellular systems use a standard analog system, differences in proprietary technology mean that switches from different manufacturers cannot communicate with each other. These communication problems became more problematic as roaming became more prevalent in the industry. Roaming is defined as a cellular user going from his home market to another market and using his cellular telephone.

Because switches from unlike manufacturers have historically been unable to communicate with each other, these switches could not identify whether a roaming cellular user is a valid subscriber or not. Fraud became a large problem in the industry as criminals took advantage of the industry's inability to effectively validate roamers. Because of the rampant roaming fraud in the industry, many cellular carriers dropped roaming agreements with other carriers, thus requiring users to use a credit card if they wanted to make a call in a non-home market.

The historical inability of switches to communicate with one another also made it difficult to complete a call to a cellular phone if the user was not in his home system. The goal of a seamless network has led some carriers such as McCaw to establish their own compatible system and promote seamless roaming as a competitive advantage.

Due to the communication difficulties associated with incompatible switches, cellular carriers pressured the manufacturers to devise a system to allow switches to communicate with each other. The result, IS-41 protocol technical standards, allows switches from one manufacturer to communicate with another manufacturer's switch. IS-41 is now being implemented throughout the U.S. by most major cellular carriers. IS-41 aids in seamless roaming and reduces roaming fraud.

Currently, the cellular industry is devising a national overlay network using IS-41 protocols and SS7 technology to allow nationwide seamless roaming and other carrier and end-user features, The completion of this network will finally create the seamless network that the cellular industry has had as its goal for over 10 years.

The establishment of an inter-switch communications protocol earlier in the industry's development would have improved the quality of roaming service to customers, reduced network development costs for carriers, while still permitting product differentiation by the switch manufacturers.

3. Digital Cellular

Digital cellular is the next large technological advancement that will provide enhanced services and greater capacity to the industry. Digital cellular will be deployed in a dual mode status to cellular's current analog standard (AMPS). The industry has delayed implementing digital technology due to alternative choices of standards, and advancements in analog cellular which have made increased capacity less of a priority. There are three digital standards and one advanced analog standard vying to be chosen by operators:

- Times Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)
- Enhanced TDMA (E-TDMA)
- N-AMPS - an advanced analog technology

The confusion over digital standards began soon after TDMA was chosen as the industry standard in 1989. Qualcomm, which developed CDMA, began promoting its digital technology on the basis that it would provide l0-15 times the capacity of analog, versus TDMA's ability to offer only 3 times the capacity of analog. As a result of Qualcomm's entry into the marketplace, cellular carriers delayed their decisions as they waited to see whether CDMA was feasible. While the industry was debating TDMA versus CDMA, Hughes Communications introduced E-TDMA which offered twice the capacity of TDMA. Motorola also began offering N-AMPS analog technology which could increase capacity to three times that of traditional analog. While these developments were underway, many carriers used advancements in cell splitting and microcell technology to increase capacity and network efficiency further delaying a final decision on digital technology.

In 1992, when carriers began announcing their choice of technologies, it became evident that instead of one standard for the entire industry, different carriers were choosing to implement different technologies. Thus, the industry will be digital incompatible between carriers and systems. As of now, most of the wireline carriers are choosing CDMA, while non-wireline carriers are choosing TDMA. Many carriers still have not decided.

While the competition between digital technologies has likely led to more rapid technological innovation, there is a substantial likelihood that consumers will face multiple incompatible digital standards in the future.

4. Lessons for ITS

The cellular industry benefitted in the early years from having one compatible technology (AMPS) for all service providers. Even with the standard AMPS technology, however, cellular switch equipment will not be compatible across manufacturers without full implementation of the adopted protocol standards. The transition to digital technology has been delayed by the confusion over technology. The industry is adopting different digital technologies, rendering end-user equipment more expensive and incompatible in the digital format across different system operators.

. The ITS industry must be alert to the transitions from technology used at the inception of service to technology that will develop later. Guidelines should be drawn that will allow the industry to adopt new technologies, while still preserving compatibility between old and new technology across service providers and manufacturers. A smooth transition from one technology to another is crucial if consumers are to believe that the equipment they buy will not become obsolete in the future.

C. Services

1. Basic service offerings

Cellular service is differentiated from other mobile radio services by the following service provisions:

- interconnected voice service using car phones, transportables, and portable phones
- compatible coverage that reaches 94% of the U.S. population
- sufficient capacity for everyone desiring service
- automatic roaming service to other markets - basic level now, enhanced level in future

Before the advent of cellular, mobile radio services were classified as private radio and were severely restricted by capacity constraints and equipment incompatibility. The primary form for communication systems was businesses operating their own private communication network solely for inter-company communications. Almost all communications were in dispatch mode - originating from a central control site to all vehicles in the system. Service was rarely connected to the public switched telephone network due to both capacity constraints and technology. Due to incompatible equipment, users could not travel to other cities and use their service on other operators' networks. Privacy was also a concern as the systems had no safeguards against eavesdropping.

The greatest benefit of cellular service is that it provides a private interconnect service to anyone desiring the service and the service is compatible across different operators in cities across the U.S. Both businesses and private individuals can enjoy a new level of service previously unavailable and feel secure in knowing that the same compatible service offerings are available in other cities as future operators start new systems.

All cellular operators engineered their systems to meet minimum voice standards, as mandated by the FCC. Cellular systems were required to be engineered so that not more than 2% of attempted calls in the peak hours were blocked or unable to dial out. This insures that once a user signed up for service, he would have acceptable levels of service in the future, and also from other systems across the country.

2. Future services

The cellular industry has slowly expanded its service offerings as advancements in technology have led to greater capabilities and has begun reflecting consumer desires. Other services that cellular currently offers or is planning to offer include:

- mobile data service over circuit switched network
- mobile data service over packet data network - planned for 1994
- paging service, one-way and two-way - will be expanded by digital technology and packet data technology
- enhanced services such as call waiting, call forwarding, etc.
- electronic Yellow Page services
- personal number services

The cellular industry is currently in the midst of evaluating and implementing advanced mobile data networks using packet data technology. Packet data allows data to be sent in short increments and has built-in error detection algorithms to ensure the data is sent error free. The packet data technology that is currently seen as the leading candidate is called CDPD. McCaw, the largest cellular operator, says that it will begin implementing CDPD in all of its markets by 1994.

According to FCC regulations, data services can only be offered by cellular operators where the data does not interfere with voice service. This regulation ensures that voice service is the primary service offering of cellular operators.

Many cellular operators see mobile data as a significant source of revenues and one that over time will off-set decreasing voice revenues per subscriber. EMCI has found through primary survey research that 18% of all cellular users are interested in mobile data services either over their laptop computers or portable fax machines.

CDPD also offers the opportunity to offer two-way messaging services over dedicated data-only terminal devices that may be only slightly larger than a pager. This type of service will result in more direct competition between the cellular and paging industries, especially in the future as paging offers its own version of advanced two-way paging.

Other ancillary services such as electronic Yellow Page information services, personal number services, and enhanced features have been offered by certain cellular operators on a competitive basis as a way to differentiate themselves from competitors. These ancillary service offerings will increase as digital technology becomes available, allowing for a wider range of services, and as cellular operators must compete against future types of voice services such as digital SMR and personal communications services (PCS).

3. Lessons for ITS

Cellular benefitted from all operators offering consistent basic voice service. FCC requirements insured that all cellular operators would build their system to meet basic minimum standards and that voice would be the primary service offering of cellular carriers. Enhanced ancillary services can be offered by cellular operators as long as they do not interfere with compatibility of the basic service.

ITS should have a basic level of consistent service that is offered by all service providers. Minimum acceptable levels of service should be established to which all service providers must adhere. Standardization will allow consumers to gain confidence that satisfactory service levels will be maintained over time and that basic service will meet basic standards and will be compatible across different markets and service providers.

D. Diffusion/Penetration

1. Success Factors

Cellular has enjoyed tremendous success since its inception in 1984. Cellular has over 11 million subscribers as of the end of 1992. By comparison, paging has over 15 million subscribers, and has been operational since the early 1940’s. SMR has approximately 1.3 million subscribers and has been operational since 1974.

The success of cellular is largely due to two factors:

- phones have decreased in price substantially and become more lightweight and smaller
- consumers are more aware of the benefits of mobile communications.

Cellular started out as a communication service primarily for business purposes. Initially, mobile phones cost over $3,000, and the perception was that only business people needed a cellular phone.

The cost of cellular phones has declined dramatically since inception of service. Industry wide analog AMPS standards encouraged manufacturers to enter the industry and be assured of an open market. Many manufacturers began making cellular phones and the resulting competition drove cellular phone prices down. In addition, cellular carriers began indirectly subsidizing the cost of cellular phones by paying agents large commissions for each new subscriber they signed up. Commissions were sometimes as high as $800 in the 1980’s. Agents would use these commissions to reduce the price of cellular phones far below the wholesale cost in order to attract potential customers. Thus, cellular phones declined in price from over $3,000 to virtually free if a consumer signed up for a one year service agreement.

As cellular phone prices declined, equipment pricing was no longer the major barrier to subscribing to cellular service. EMCI consumer surveys found that in 1990, cellular phone price accounted for the primary reason that consumers resisted cellular service. In 1992, however, phone price was mentioned by only 21% of consumers as the primary barrier to purchase, while service price was mentioned by 45% of consumers.

In addition to lower cellular phone prices, phones are more portable and lighter. The Motorola MicroTac became the first truly portable cellular phone when it came out in 1989. Soon afterwards, other manufacturers vied to have the smallest, lightest weight phone on the market.

Retail distribution channels began to be used by cellular carriers as the price of cellular phones fell. With transportables and portables, the installation of phones in one's car was no longer necessary. Mass retailers such as Sears, Circuit City, and other large nationwide chains started carrying cellular phones, increasing consumer awareness of cellular.

Over time, the perception of cellular changed from that of a trendy toy for business or rich people, to a real benefit to anyone. Consumers became more aware of mobile communications in general and how a cellular phone could add convenience and safety to their lives. Media reports of people using their cellular phones to call for help in emergency situations recognized cellular phones as a real benefit for safety reasons. A survey conducted by Motorola found that 91% of cellular phone users feel that having a cellular phone makes them more safe and secure.

Currently, cellular is used almost equally for business reasons and for personal reasons. The typical profile of new users is a person who uses his phone primarily for personal use, has an average income of approximately $65,000, and has a college degree.

2. Lessons for ITS

Cellular became a mass market product when the cost of equipment declined to less than $200 retail, and consumers became more aware of the benefits of cellular through retail distribution channels and media reports. ITS should be aware of the "barrier price" represented by the price to initiate service. The majority of the barrier price for this type of service is typically in equipment costs. In addition, ITS should have as wide a distribution network as possible in order to generate awareness and competition for the equipment.

E. Private Sector Economics

Cellular is a capital intensive industry with a generally long term payback period. Many cellular operators that began operations in 1985 are just beginning to show profits. The lack of profits, thus far, however, does not imply that cellular service is not profitable. The primary reason why cellular operators have not shown profits is that they have pursued an aggressive growth strategy of acquiring additional markets, expanding their subscriber base, and investing in wide area coverage and improved technology. These activities require large cash outflows that will be paid back in several years. While many are not showing profitability, cellular operators do generate very good cash flows from their operations. Typically, cellular operators show operating margins of approximately 50% on gross revenues.

Cellular licenses have always been valued more for their long term potential rather than actual operating results to date. Because licenses are valued on potential versus actual results, cellular licenses are usually sold and valued on a per population (pop) basis, instead of a subscriber basis. This was very evident in the early days of cellular when unbuilt licenses sold for hundreds of dollars per pop.

While cellular has achieved spectacular success since its inception, there were many skeptics in the beginning who did not think cellular would ever take off. In the early and mid 1980's, many industry players and analysts doubted whether cellular would be economically feasible in markets other than the largest metropolitan markets. Even in the mid and late 1980's, many industry analysts doubted that the rural markets would ever be feasible.

Cellular carriers have been criticized for making excessive operating margins and charging too high prices for service. Cellular operators, however, point to the fact that they took a high risk by investing millions in an industry which many did not think would succeed. Thus, their return on investment should reflect the risk inherent in the venture.

1. Sources of revenues

The average monthly bill of cellular subscribers has been declining over time from $98 in 1988 to $68 in 1992, primarily as a result that new users are more likely to be low usage customers. Cellular carriers derive their revenues from two main sources:

- home subscriber
- roamers

Home subscribers are those subscribers who sign up with the carrier and use cellular service while in their home market. Roamers are customers from other markets who use their cellular phones while away from their home market and in another carrier's market.

On a national level, approximately 85% of a carrier's revenues are derived from their home subscribers and 15% of revenues are derived from roaming customers. Rural markets, however, can deviate substantially from the average. Rural markets with a major interstate highway running through them can derive more than 50% of their revenues 'from roaming customers.

The two sources of revenues have very different profit margins associated with them. Home subscribers must be signed up by the carrier. The average cost of acquiring a customer is $500-$700. This can be almost evenly split between direct costs in the form of commissions and general marketing costs. Commissions that are paid to an agent are typically composed of an up-front fee and a long term percentage of the customer's bill. The up-front fee is generally $200-$400, depending upon the number of subscribers an agent signs up. Residuals are usually 3%-5% of a customer's monthly cellular bill.

Roaming customers, by contrast, have no marketing costs associated with them. A cellular customer driving through a non-home market sees by a roaming indicator on his phone whether he is in cellular coverage or not, and can make a call automatically, assuming the foreign carrier has a roaming agreement with his home carrier. Revenues from that call are passed directly to the foreign carrier. In addition to having no marketing costs associated with the roamin g revenues, roaming prices are much higher than home rates.

Because of the acquisition costs of home subscribers, it can take more than one year for the carrier to make a profit from a new subscriber. A carrier makes a profit immediately from a roaming customer.

2. Cellular Service Pricing

Cellular service pricing has not changed dramatically in nominal terms since the beginning of cellular service. In real terms, however, cellular pricing has declined due to the effects of inflation. Cellular carriers usually have three to six pricing plans that are various combinations of:

- fixed monthly fee
- price per peak minute
- price per off-peak minute
- number of free peak minutes
- number of free off-peak minutes

The total cost per minute to a subscriber, including both the fixed monthly fee, price per minute, number of free minutes, and usage patterns, typically ranges from $1.00 for low usage customers to $.30 to high usage customers.

Roaming prices typically have a per day fee plus a per minute fee. Roaming fees are usually much higher than home based fees. In 1992, the average per day fee was $3.00 and the average per minute fee was $.99.

3. Lessons for ITS

Cellular can be characterized as a high risk, capital intensive industry. Accordingly, returns expected by investors are higher than many other industries. ITS will also likely be perceived as a high risk industry. In order to attract investors, ITS must be perceived such that expected returns are commensurate with the risk of the investments. Artificial constraints on profits, price caps, or other fiscal restraints will be a disincentive for investors and may stop the industry from developing to its potential.

F. Role of Government

1. Regulation

Regulations have played an important role in the cellular industry’s development. The largest regulatory factors shaping the industry are:

- regulated duopoly structure
- licenses broken down into 305 MSA and 327 RSA markets
- licenses set aside for local exchange providers
- lottery system for licenses
- no restrictions on the sale of licenses
- analog communications standard of AMPS

a. Regulated duopoly

One of the largest decisions regarding the structure of the cellular industry was how many licenses should be awarded per geographic region. Some felt that the market could not support more than one license, while others argued that competition was necessary. The FCC decided on a duopoly structure, which it felt would provide competition, while not jeopardizing the feasibility of cellular operations.

b. Small geographic licenses

The FCC adopted a licensing scheme which divided the country into 305 metropolitan statistical areas (MSA's) and 427 rural statistical areas (RSA's). MSAs were licensed first, while RSA's licensing did not start until 1988. As a result of the small geographic area licenses, the cellular industry has been consolidating markets to form regional clusters. These larger market areas provide for economies of scale in network design and marketing.

c. Licenses set aside for local telcos

When creating the duopoly structure, the FCC set aside one license (the wireline B band) exclusively for local telcos. The other license was the A band for non-wireline service providers. In many cases, there was only one telco eligible for a license, so no lotteries were necessary. In other cases, where more than one telco was eligible, settlement agreements were usually reached between the potential licensees before a lottery took place. Because the telcos did not have to go through the lottery process, they usually had a head start on the non-wireline licensees of several months to several years. In order to negate the head-start advantage, the FCC required that operators allow reselling of their services. Thus, the non-wireline licensee could resell services from the wireline side before they built their own system.

d. Lottery system for licensees

One of the major factors affecting the structure and growth of the cellular industry was the FCC decision to move from a comparative hearings process format of awarding licenses to a lottery system. The FCC awarded the first cellular licenses on a comparative basis. This process proved very cumbersome and resulted in lengthy delays. Potential license holders would submit voluminous amounts of back-up data in support of their applications. The FCC would be put in a position of deciding the best company when there was very little substantial difference among applicants. In addition, once a determination was made, the losing side would appeal the decision, creating additional delays in the final awarding of the license.

The FCC stopped comparative hearings after the first 30 markets were awarded, moving to a lottery system for the remaining MSA and RSA markets. Application mills sprang up that processed thousands of applications for cellular licenses. The result was that cellular licenses was awarded to individuals who had no knowledge of the business. Many of the lottery winners sold their systems for millions of dollars before ever beginning construction. Others hired cellular management companies to construct and run their systems.

While the lottery system did speed up the process considerably, the flood of applications along with appeals and lawsuits over winning licenses delayed the licensing of many markets for months and often years.

e. Analog communications standard

The FCC required all cellular systems to operate on a standard AMPS technology. This insured that service would be compatible across all operators, providing economies of scale and reducing risk to manufacturers to provide equipment.

The FCC also requires that all future digital systems continue to support AMPS. Thus, users will not be left with obsolete equipment when operators change from analog to digital technology.

2. Incentives

There were no explicit incentives for investors to invest in cellular systems. The FCC did, however, promulgate rules which removed most of the potential disincentives. One such rule was that -cellular licenses, which were granted for 10 years, would have an expedtancy of renewal associated with them unless there was just cause for terminating the license. Thus, cellular operators could invest in expensive infrastructure and new technology without the fear that their licenses would be taken away before they received adequate returns for their investment.

Because the FCC did not require payment for licenses, either up-front or as an ongoing percentage of revenues, cellular investors did not incur any additional unnecessary expenses, and received the full value associated with their licenses.

There is also no restriction on the sale of licenses. Thus, cellular licenses can be easily bought and sold in an unrestricted manner, making cellular licenses more valuable than if restrictions were placed on them.

3. Public Policy Issues

The FCC's primary goal is to-manage the radio spectrum in the public's best interest. Spectrum is a very valuable commodity because the demand for it has traditionally exceeded the supply. Because spectrum is a scarce commodity, the FCC has encouraged the most efficient use and discouraged holdings of unused spectrum.

In the cellular industry, the FCC mandated that cellular license holders must begin operations within 18 months of receiving the construction permit. In addition, cellular license holders have five years to build out their system. After five years, the uncovered geographic areas can be awarded to other interested parties.

4. Lessons for ITS

ITS will have to decide how to award licenses to service providers. The experience of the cellular industry makes it clear that comparative hearings are fraught with pitfalls and should be avoided, if all possible. Lotteries are relatively easy to administer, but encourage speculators.

The FCC and Congress are actively talking about auctions or other revenue producing measures for future spectrum use. Auctions have the benefit of eliminating speculators from the process and providing revenue to the government. Auctions, however, clearly favor the largest firms over smaller firms and entrepreneurs. A possible idea for future lotteries is to have revenue sharing arrangements built into the process so that the government can generate revenue without imposing barriers to entry for small firms and individuals. High filing fees would also help to decrease the number of applications and speculators.

ITS will also need rules governing spectrum use which discourage inefficient use of spectrum and idle spectrum. Rules similar to those imposed upon the cellular industry, for example time limits on when commercial operations must begin and re-licensing uncovered areas, will aid the ITS industry in a rapid, efficient buildout of systems.

VIII. CHAPTER EIGHT — TELEPHONE

This case study concentrates on the traditional telephone industry and the implications that its history, structure and characteristics have for ITS. By "traditional telephone industry," the study refers to the switched transport by wire of communications (usually, but not always, voice communications) from one point to another. In the past two decades, technology has seen the telephone industry grow beyond this traditional definition both in terms of the delivery mechanism used (use of wireless technologies such as cellular and Personal Communications Service ("PCS")) and in terms of moving beyond the telephone network's traditional "conduit" function into providing content over that conduit (such as information services, of which Sears/Prodigy is but one example). But this study focuses primarily on traditional telephony, largely because some of these new technologies are the subject of separate case studies.

Because traditional telephony is a purely wireline and conduit (i.e., transport and delivery) service unrelated to the content of the message delivered, it is fundamentally different from both ATMS and ATIS, which are defined more in terms of the type of information delivered and manipulated than the technology used to carry out those functions. As a result, direct analogies between telephony and ITS are inappropriate. Nevertheless, a study of telephony can yield some useful lessons for ITS, particularly in terms of the relationship of intergovernmental jurisdiction over the industry, the balancing of regulation and competition, and the role of governmental policies designed to promote universal access to the network ("universal service"). These three issues have a long history in telephone and, in many respects, have come to define the industry.

A. Technology

By modem standards, the technology of the traditional telephone industry is rather simple. It essentially involves the delivery of electromagnetic impulses from point to point, through the use of a two-way wireline network. Through dispersed switches, the network is able to route messages from one point on the network to any other point on the network.

Thus, the telephone network comprises two basic components: the transmission component (the wire distribution system) and the switching component (switching centers that route messages). The relative cost attributes of these two components drove the initial development of the telephone network. The transmission component was relatively more expensive than the switching component because of the need to deploy and maintain wires and telephone poles. Since telephone service began in the late 19th century, in many cases the telephone company was the first to deploy a physical wire network along streets and rights-of-way, thereby making deployment relatively more expensive than it would be today, since an infrastructure of poles and rights-of-way is already in place.

The high cost of transmission relative to switching resulted in a network design with several local switching offices, organized in hierarchical fashion, to minimize the distance of the transmission path required to a complete a call. Over time, this structure has yielded the added advantage of greater network flexibility to add capacity in terms of access lines. Because the traditional telephone network was designed largely for voice only transmission, it is also characterized by narrow bandwidth — the ubiquitous copper wire pair.

Changing technology has had an effect on the traditional telephone network, but the pace of change has been relatively slow. There are two primary reasons. First, because the telephone network is made up of a huge imbedded base of wires, implementing any new technology that would require any significant modification of that imbedded base is extraordinarily expensive. Second, government regulatory policy has played a major role in the pace of technological change in the telephone network, and that role has been largely to lengthen the period over which telephone company investment could be recovered, thereby lowering regulated rates, but also slowing the pace of investment in new technology.

Technological change has nevertheless come to the industry, especially in the last two decades.[58] That change is the result both of technological advances and the competitive impetus furnished by some loosening of the regulatory reins on the industry. Switching technology has changed dramatically as telephone companies have gradually moved from electromechanical to analog and then to digital switches. These switches have substantially improved the speed, reliability and switching capacity of the network. But perhaps their most dramatic impact technologically is that they have added "intelligence" to the network. Since advanced analog and digital switches are essentially computers, they can do much more than route traffic. They can manipulate and analyze the information carried over the network and, indeed, add additional information to be carried over the network. Services such as call waiting and message store and forward services are examples of some of the new services this technology allows, but the pace of introduction of these new services has itself been slowed somewhat by regulatory constraints.

Technology has also enabled telephone companies to effectively expand the capacity of the traditional copper wire pair. Using multiplexers at each end of a communications path has allowed telephone companies to offer more services to the home without installing additional lines, enabling both data and voice to be sent over the same wire.

1. Lessons for ITS

The traditional telephone industry is perhaps a classic example of a dilemma faced with the introduction of any new service or technology in an industry characterized by a large imbedded base: An environment (or regulatory policy) that is designed to promote rapid deployment of a service to everyone at a reasonable price (what might be termed a "universal service" policy) is inherently at odds with an environment (or regulatory policy) that is designed to promote rapid technological advance (in the form of "second generation" technology) of that same service (what might be termed a "service innovation" policy). ITS (both ATMS and ATIS) will undoubtedly face a similar dilemma. Generally speaking, the telephone industry followed a path of pursuing an initial policy of universal service and then, as the industry became mature, supplementing (but not replacing) that policy with a service innovation policy.

Although there might be some dissenters, the general view is that this approach has worked very well. Most would agree that the United States has the most reliable, widely used and affordable telephone network in the world. Whether it makes sense to pursue such an approach with ITS, however, is a much more difficult question.

Unlike ITS, telephone service is primarily a physical transport (or "pipeline") service. ITS, in contrast, is primarily an information gathering and analysis service. Moreover, telephone service, unlike ATMS (but perhaps more like ATIS), is a mass communications service, intended to be purchased by all of the public. ATMS, in contrast, is intended for a narrower class of end users -traffic departments and management services. This might suggest that ITS (or at least ATMS) is more susceptible to a joint universal service/service innovation policy at the outset.

B. Services

Due in large part to the historical dominance of AT&T and to regulatory policy, telephone service has evolved into two basic classes of service: local exchange service and interexchange (or "long distance") service. (There is, of course, also international service.) As the names suggest, these classes are defined by the geographic location of the initiating and terminating points of a call. Since traditional telephone service is purely a transport function, some sort of geographic distinction in classes of service is hardly surprising.

The boundary between local exchange and interexchange service was originally technology-based, defined by the end-office level at which a call was routed to the pre-divestiture AT&T Long Lines service. Over time, however, technological change in switching and the post-divestiture growth of competition in interexchange service have made the boundary largely the product of the regulatory policy of state public service commission ("PSC's"). From the end-user's perspective, local exchange service is probably best-defined as service to the immediate surrounding geographic area for which a flat rate (or perhaps a per-call rate) is charged, and interexchan e service is service to more distant locations for which a toll rate (based on minutes of use) is charged.[59]

The exchange/mterexchange distinction is similar, but not identical, to another geography-based distinction in telephone service that was created as part of the AT&T divestiture in 1982. The basic tenet of the divestiture was to separate what was assumed to be the competitive aspects of AT&T's business (equipment, information services and long distance services) from what was assumed to be the non-competitive aspect of its business (local telephone service). AT&T retained the competitive lines of business, while it divested the seven regional Bell Operating Companies ("BOC's"), which were in turn restricted largely to providing local telephone service. To implement the decree, the divestiture court had to draw a boundary between the long distance service that the divested BOC's could not provide and the local service that they could provide. The court settled on the concept of Local Access and Transport Areas ("LATA's"). The decree prohibited the BOC's from providing interLATA telephone service, restricting them to service within each LATA (intraLATA service). The court drew LATA boundaries based on a loose amalgamation of disparate factors, such as socio-economic communities of interest, switching costs and state PSC certificate boundaries.[60] Generally speaking, LATA's are at least equal to and, in some areas, larger than local exchange service areas, thereby allowing BOC's to provide intraLATA toll service in some areas.

The AT&T divestiture (as well as the earlier advent of long distance carriers such as MCI) also gave rise to a new type of service provided by local exchange telephone companies: exchange access service. Instead of just providing telephone service to end users, divestiture placed local telephone companies in the business of providing other carriers — primarily long distance service providers — access to the local exchange to initiate and complete the long distance calls of the long distance carriers.[61]

Beyond the traditional geographic distinction in classes of telephone services, additional types of services have developed over time. The network has evolved beyond the transport of voice communications into a data transport network as well. This is the result both of technological advances and end user demand. In addition, private line service has evolved. In essence, private line service involves facilities dedicated to a particular user to carry heavy traffic (voice and/or data) between particular locations. Because of the dedicated nature of the facilities, private line service is frequently non-switched and can bypass the traditional switched network. Both data and private line services arose largely to meet the needs of large, high volume users, typically large businesses.

Finally, telephone companies have begun to offer new services beyond mere transport — service that provide additional information, or manipulate or analyze the information carried on the network. These services — known as "enhanced services" under FCC rules and "information services" under the AT&T decree — are more logically considered separately from traditional telephone service. Sears/IBM Prodigy is an example of an enhanced service, and is the topic of a separate case study.

1. Lessons for ITS

There are three primary lessons to learn from the nature of telephone service that might be relevant to ITS. The first two involve potential analogies to ITS. The third lesson is not so much an analogy as it is a suggestion of how the telephone network may be directly used in implementing ITS.

The first lesson relates to the geographic scope of service. It seems likely that ATMS will be primarily a local service, at least if "local" is defined to include regional metropolitan areas. There would seem to be little demand for coordinated traffic management across very large territories (nationwide or statewide, for instance). ATIS, on the other hand, while perhaps also predominantly local, may well have broader applications because it is more of an end-user oriented service. Customers may well wish to plan a trip to a more distant location ahead of time, or receive routing information while en route but before they arrive in a particular regional metropolitan area. This suggests that, much like telephone service, ITS should begin with "local service" in the form of ATMS, with ATIS appearing later as a service built on ATMS.

The second lesson is a related one. The history of telephone service is of placing initial emphasis on widespread deployment of the basic platform (in the case of telephone, basic message transport) before proceeding into more enhanced services built on the platform. In the case of ITS, this might mean placing initial emphasis on getting ATMS up and running on a widespread basis before proceeding with ATIS.

There is one major difference between telephone and ITS, however, that suggests this "ATMS first" approach might not be advisable. Virtually all telephone services are end-user, mass appeal services. Thus, initiation of just the basic platform service produces substantial and fairly immediate revenues. Unlike telephone service, however, ATMS is not likely to cater to mass consumers and thus not to generate the revenues of an end-user consumer service. As more of an end-user service, ATIS may be much more lucrative from the point of view of private service providers than ATMS. Thus, the potential revenues of ATIS may be the "carrot" to induce investment in ATMS — the basic backbone on which ATIS will depend. If so, in order to speed payback and private capital, it may be necessary to deploy ITS — ATMS followed quickly by ATIS — on an individual market-by-market basis, rather than devoting resources to widespread national deployment of ATMS in several markets and then subsequently proceeding with ATIS in those markets.

The third lesson is that the telephone market itself may be the ideal infrastructure, or "platform," on which to build ITS. The local telephone network is unique in that it tends to be both ubiquitous (located alongside most streets) and common carrier in nature. In other words, it is primarily a local electronic transport system. ITS will, of course, require considerable local transport of information. To the extent that the "content" function of ITS (monitoring and analysis of traffic data) can be separated from the purely "conduit" function of ITS, and the conduit function assigned to existing carriers and infrastructure, the up-front investment required to implement ITS may be significantly reduced. That, along with the inherently non-discriminatory nature of common carrier transport service, may make competitive provision of ITS more feasible.

C. Diffusion/Penetration

Telephone service, which began in the late 19th century, followed a classic S-shaped curve in diffusion to the public. Since the telephone industry is a mature industry, however, the top portion of the curve was reached some time ago. Telephone penetration has consistently exceeded 90 percent of households nationwide for over a decade:

Year	Percentage of Households with Telephone Service
1970	87.0%
1980	93.0
1984	91.8
1985	91.8
1986	92.2
1987	92.5
1988	92.9
1989	93.0
1990	93.3
1991	93.6
1992	93.8
1993	94.2
1994	93.9
1995	93.9

Sources: Statistical Abstract of the United States 1995; Telephone Subscrrbership in the United States (FCC, 1995)

The history and growth of telephone service penetration is a product both of the peculiar cost' characteristics of the industry and of government regulatory policy designed to offset somewhat the incentives created by those cost characteristics. Traditional telephone service — wireline telephone service — exhibits classic public utility cost characteristics. Fixed costs are very high relative to variable costs. Fixed costs are largely in the form of a massive investment in a comprehensive, street-by-street local wire distribution network and switching centers. Moreover, since the costs of the network are largely fixed, cost per subscriber is inversely related to subscriber density within the geographic area served by the network. The more subscribers per mile of distribution plant, the lower the per-subscriber cost.

As a result of this cost dynamic, local telephone service initially arose primarily in more dense urban and suburban areas, with many rural areas left unserved. Since telephone service became subject to first state, and then federal regulation in the early 20th century, one of the primary goals of telephone regulatory policy has been to promote extension of telephone service to less populated, rural areas. This policy, part of a larger governmental regulatory policy of providing "universal service" (making telephone service widely available at affordable prices so that everyone is on the network), has been promoted through a variety of different regulatory mechanisms,[62] which are described below in the sections of the paper addressing private sector economics and regulation.

1. Lessons for ITS

The primary lesson for ITS is that, to the extent that ITS is wireline-based or exhibits strong subscriber density-related cost characteristics, ITS will be commercially viable, at least initially, only in more densely-populated urban and suburban areas. Absent governmental regulatory intervention, ITS will come to more rural areas much later, if at all.

Unlike telephone service, however, there may be little need to promote "universal service" for ITS. At least in the case of ATMS, there would seem to be much less need for traffic management in less densely populated, rural areas for the simple reason that, at least in most cases, traffic congestion is much less of a problem in those areas. ATIS, on the other hand, as a more retail end-user oriented service, may present universal service policy issues. Rural residents, for instance, may well need access to traffic and routing information, as many of them often commute to more dense urban areas.

D. Private Sector Economics

The telephone industry is a capital intensive industry exhibiting considerable economies of scale. With respect to local exchange service, it also exhibits considerable economies of density, as noted above. As a mature industry, telephone service demand — in terms of number of subscribers — has peaked at over 90 percent of potential subscribers. Demand growth in terms of number of subscribers is essentially limited to growth in numbers of households and businesses.

However, demand in terms of volume of use (number of calls and minutes of use) is growing rapidly, and has accelerated dramatically in the past decade. Volume demand growth has been a function both of general economy-wide performance and of the growth of new competitive service options, particularly in long distance service.[63] At the same time, telephone service demand also exhibits some unique recession-resistent characteristics, as it can become a partial substitute for business and personal travel during an economic downturn. As a result, the demand curve for telephone service in terms of volume of use tends to be relatively inelastic at high price levels, and relatively elastic at low price levels.

1. Revenue Sources

Telephone service providers derive their revenue from three primary sources: (1) local service; (2) exchange access service; and (3) toll service. According to the FCC's Common Carrier Statistics, in 1990 local service accounted for approximately 33% of industry revenues from these three sources, while access revenues accounted for approximately 23%, and toll service represented 44% of the total. It is important to keep in mind, however, that both local service and access service (as well as some intraLATA toll service) is provided by local exchange carriers (LEC's). Thus, LEC's account for more than 56 percent of total industry revenues from these three sources, while long distance (or interexchange) carriers (IXC's) account for less than 44 percent of the total.

2. Pricing

Generally speaking, telephone service pricing falls into the same three basic categories as revenue sources: local exchange service, exchange access service and interexchange service. Local exchange service, in turn, can be divided into residential service and business service. Historically, business service rates have exceeded residential service rates. This differential is not based on costs, but on regulatory policy. Business rates have historically been set higher to enable residential rates to be set lower to promote universal service. This differential, however, is coming under increasing market pressure as competition has begun to develop for providing service to large business users (see competition discussion below). In recent years, prices for local service have increased at a rate that is below the general consumer price index.[64]

Historically, local exchange prices were flat rate. For most of the history of telephone service, flat-rate pricing for local service was a technological necessity, as early switches lacked the capability to measure local calls. The advent of computer-based switching, however, enables usage-sensitive measurement of local calls (either on a per-call or minutes of use basis). Nevertheless, there has been considerable resistance to usage-sensitive pricing of local service by state PSC's and certain consumer groups. As a result, in most jurisdictions, flat-rate pricing of local residential service remains, although in several jurisdictions subscribers have the option of choosing a lower flat-rate for a fixed number of calls, with a per-call charge added for any calls above the fixed number allowed. Usage-sensitive local service pricing has also become more common for local business service.

Exchange access prices are charged by LEC's to IXC's for interconnection to the local network. Exchange access rates are primarily volume-based, measured by minutes of use.

Rates for interexchange service, historically known as "toll service," also tend to be based on minutes of use. Unlike the markets for local service and exchange access, however, the market for interexchange service is populated by many competitive providers. Thus, prices for interexchange service tend to be set by marketplace forces, while local service and exchange access rates are set almost entirely by regulation. Rates for interexchange service have declined both in real and, in most cases, even nominal terms since the AT&T divestiture. Total interexchange revenues, however, have increased, as increased volume has more than offset price declines.

3. Competition

Competition in telephone service has a checkered history. In the late nineteenth century, telephone service began as largely a local service free from regulation. Competition was present in a few markets but was rarely, if ever, sustained. Instead, consolidation through merger and acquisition characterized the industry. Eventually, AT&T came to dominate all aspects of the industry, providing the majority of local exchange service across the nation and virtually all of the interexchange service. While eliminating what little transient competition for'local service that existed, the consolidation of local service providers also no doubt facilitated the development of widespread interexchange service.

A combination of technological change and regulatory policy in the 1970's led to the emergence of competition in the market for interexchange service. The technological change was the advent of wireless microwave transmission of long-haul traffic as an alternative technology to AT&T's largely wireline-based interexchange facilities. This wireless technology made interexchange competition more feasible, as a competitor would not need to duplicate AT&T's interexchange wireline facilities.

The opportunity provided by wireless technology was made still more attractive by regulatory policies that existed at the time. Generally speaking, long distance rates were set at non-cost-based levels to subsidize lower rates for local service. The theory was that business users and the more affluent were the heaviest users of long-distance service, and could afford to pay a premium to provide revenues to enable local residential service rates to be set at lower levels. These artificially high long-distance rates, however, also served to attract competition.

Efforts by competitors such as MCI to enter the interexchange service market led to protracted legal and regulatory battles,[65] the history of which need not be recounted here. The result was a market for interexchange service populated by scores of competitors.

AT&T, however, retains over 50 percent of the interexchange market, and MCI and Sprint hold most of the rest. Thus, while the market is competitive, it is fairly concentrated and somewhat oligopolistic. Moreover, some believe the market will become less competitive in the future. The reason is again shifting technology. The introduction of fiberoptics into interexchange networks offers significant capacity and reliability improvements over wireless, microwave technology. Because of their potentially immense capacity, fiber networks offer significant economies of scale, which in turn could lead to increasing market concentration in the interexchange market in the years to come.

In contrast to the market for interexchange service, there has been little competition in the market for local exchange service throughout its history. Indeed, the 1982 AT&T Consent Decree centered on the assumption that unlike interexchange service, local exchange service was, and was likely to remain, a largely monopolistic market.[66]

Since the AT&T Consent Decree, however, limited competition has begun to emerge on the fringes of the local exchange market. One of the primary sources of competition is in the narrow class of exchange access services for large business users. In essence, competitive access providers offer large business users the ability to link directly to the IXC carrier of their choice for long distance service, thereby enabling the user to "bypass" the local exchange network entirely for their incoming and outgoing non-local calls. While competitive access services have grown since the AT&T divestiture, they still represent a relatively small proportion of total access traffic. It is also important to keep in mind that competitive access offers competition to only a small segment of the local exchange carriers' total market. Large business users, like small business and residential users, still rely almost entirely on LEC's for local calls.

Two other forms of local service competition have also emerged. First, the separation of customer premises equipment (CPE) from the network, and the deregulation of CPE, has enabled large multi-line users to install PBX's, which are in essence privately owned switches at the user's premises. In essence, PBX's enable large users to move the demarcation point between the local network and CPE one switching center upstream. PBX's have been a particularly effective form of competition to a narrow line of local service commonly known as Centrex service. Centrex is a service offered by LEC's to large, multi-line users for the switching of traffic between the different lines within the single-user's premises. A PBX essentially privatizes this on-site switching function. In the process, it enables the large user to aggregate its traffic, lowering the number of trunks it needs to obtain from the LEC. As in the case of competitive access, however, PBX's are at best only a partial substitute for local exchange service. The PBX user still must connect to and use the local network for all local calls outside the user's premises.

A final form of potential competition to local exchange service is wireless service — cellular service and, eventually, PCS. In theory at least, cellular service and PCS could be far more complete competitors to LEC's than competitive access and PBX's because each service could be used to complete local calls completely outside the local wireline network (for instance, a local cellular call made to another local cellular phone). In practice, however, cellular has been only a partial and imperfect competitor. Because local wireline service enjoys almost universal subscribership and a widespread imbedded base, cellular systems (and presumably PCS systems in the future) must interconnect with the local wireline network in order to provide cellular subscribers with the ability to communicate with most of the local population. Until or unless cellular service (or PCS) attains the virtually universal subscribership of local wireline service, cellular and PCS will remain heavily dependant on, and thus not fully competitive with, the local exchange network.

Over time, the combination of wireless alternatives (such as cellular and PCS), coupled perhaps with local cable systems, together with competitive access and PBX's, will gradually erode the scope of the LECs' revenue base and monopoly power. This erosion will occur primarily in higher density suburban and urban markets. But whether competitive alternatives will dissipate the local service monopoly entirely — or even as effectively as monopoly power has been eroded in the interexchange service market — seems doubtful, for two reasons.

First, while wireless technology has far fewer economic barriers to entry and thus spurs competition, it suffers from a shortcoming that will be difficult to overcome: capacity constraints related to spectrum use. Although cellular and PCS technology have progressively advanced towards increased efficiency through greater spectrum re-use, it is far from clear that wireless local networks could ever match the call-carrying capacity of the wireline network. And capacity is critical to local telephone service. While the percentage of total telephone network minutes of use accounted for by local service has continuously declined since 1980, local calls still account for 74 percent of total telephone network minutes of use, nearly tripling the amount represented by long distance toll calls.

Second, local telephone service is a unique type of service in the sense that much of its perceived value stems from the fact that it provides universal access to the rest of the local population. To be truly competitive, a competing provider also would have to offer universal access. That, in turn, would require shifting virtually the entire population base to a competing technology, an unlikely event in the foreseeable future.

4. Natural Monopoly

Views about the natural monopoly characteristics of telephone service have changed over time. Until the late 1950's and early 1960's, virtually all aspects of telephone service — local service, interexchange service and CPE — were generally viewed monolithically as a paradigmatic natural monopoly. Prompted by technological and regulatory changes in the 1960's and 1970's, however, most observers began to view both the interexchange service and CPE markets as being fully capable of supporting competition. On the other hand, the market for local exchange service continued to be viewed as a classic natural monopoly throughout this period.

The 1982 AT&T Consent Decree essentially embedded this bifurcated view of the telephone industry into law: the Decree deemed the markets for CPE and for interexchange (or interLATA) service to be competitive, while it deemed the local exchange market to be monopolistic. While few if any markets can be neatly categorized as competitive or as natural monopolies, this bifurcated view probably remains largely, albeit imperfectly, correct today. Some, however, have predicted that over time, the economies of scale of fiber optics will make the interexchange service market more concentrated and less competitive, while wireless technologies will make the local exchange market more competitive.[67] Although these predictions no doubt will have some validity, it nevertheless seems likely that for the foreseeable future, the interexchange market will remain workably competitive, and the local exchange market will remain "naturally" monopolistic, at least for all residential and small business users and for all who need access to those classes of users.

5. Lessons for ITS

Because telephone service is a purely transport service, while ITS is more of an information service coupled with a transport function to gather and transmit data, the private sector economics of each are likely to be significantly different from one another. The differences are amplified in the case of ATMS since ATMS, unlike telephone service, is not an end-user consumer service, but a service that presumably wilI be used by a very limited group of institutional users such as transportation authorities and local or regional governments.

Nevertheless, the private sector economics of telephone service do provide some lessons for ITS. Like telephone service — indeed, perhaps more so than telephone service — ITS will require a large up-front investment and there will be a 'considerable time lag before that investment can begin to be recovered. ITS will have little utility — and thus no prospect of revenues from consumers — until the basic infrastructure of remote sensing devices (both on highways and in vehicles) and transport facilities between the control centers and remote locations are in place and working throughout a given metropolitan or regional area. In other words, ITS must reach a "critical mass" of coverage within a given geographic area before the service has much utility at all. Telephone service (particularly local service) also possesses this trait, and in the laissez-faire environment of the industry's developmental years, the industry responded to the problem through mergers and consolidation. Thus, the "critical mass" trait tends to result in a concentrated industry with little competition, at least absent regulatory or antitrust intervention.

As in telephone service, private sector economics probably dictate that ITS will be most economical, and will arise first, in larger urban and suburban areas, developing on a market-by-market basis. Unlike telephone service, where government felt a need to create policies designed to promote extension of service to rural areas, there may be less need to extend ITS (or at least ATMS) to more rural areas. Moreover, avoiding the need for creating subsidies to promote extension of ITS into rural areas may be critical to the success of ITS. This is because the potential revenue sources for ITS would appear to be far narrower than for telephone service. Indeed, since ATMS would not seem to be a mass end-user service, a serious question arises as to what the revenue sources for ATMS will be. (End users will presumably be the revenue source for ATIS.) The ultimate beneficiaries of ATMS will be the travelling public (both personal and business), who should see travel time (and thus costs) lowered. But the "purchasers" of ATMS will more likely be governmental bodies, such as transportation authorities. This will create a need for a fundamentally different kind of revenue source for ATMS than exists for telephone service.

Finally, the history of telephone service suggests that at least one part of ITS — the local information transport function — is likely to exhibit natural monopoly characteristics. To the extent that this local transport function represents a high percentage of the total cost of ITS, then ITS too will likely exhibit natural monopoly tendencies. One way to minimize this problem would be to separate the local transport function of ITS from the information analysis aspects of ITS, and to rely on preexisting local common carriers (such as the telephone company, but perhaps others as well) to perform the transport function under regulated tariffs. This could reduce the up-front investment required for ITS and make competition in the ITS market more feasible.

E. Role of Government

Government has played a major, if not dominating, role in the domestic telephone industry since the early part of this century. It is important to note, however, that from its inception in the late 19th century until the early 20th century, the telephone industry was largely unregulated. Left unregulated, the industry was characterized by selective provision of (primarily local) service to more densely populated areas, with rural areas left largely unserved, and by widespread industry consolidation over time. Since the industry was entirely wireline-based at the time, such consolidation should hardly be surprising. The value of telephone service stems from the connectivity to others that it provides. Thus, the more universal the connectivity, the more valuable the service. Universal connectivity, in turn, requires interconnection among carriers. To the extent interconnection among carriers in different geographic locations is necessary, consolidation is likely to occur, for it offers the potential of reducing transaction costs. Scale economies also no doubt contributed to the tendency to consolidate.

1. Scope of Regulation

Telephone service is a classic public utility and, since the 1910's and 1920's, has been regulated as such. Public utility regulation typically involves:

- Entry and exit regulation (certificate required to provide service; regulatory approval required to withdraw service or to transfer ownership or merge).

- Rate regulation (usually tariff regulation, requiring carrier adherence to rate schedule published in tariff and carrier application and approval for all rate changes).

- Geographically defined service areas (usually defined in certificate).

- Obligation to serve and not to discriminate (carrier must make service available to everyone and not unreasonably discriminate among classes of customers in terms of rates or terms or availability of service).

Public utility regulation rests on two basic premises: (1) that the service is in some sense '"essential"; and (2) that the marketplace for the service tends structurally toward monopoly. The first premise has been and remains true for telephone service. As noted above, the second premise has greatly eroded for certain aspects of telephone service (interexchange service and CPS), while it has remained largely (but not completely) intact for local exchange service.

For the most part, government regulation has changed to accommodate shifts in the validity of the second premise, although regulatory change has tended to lag considerably behind marketplace reality.

CPE has been deregulated. Many of the traditional regulatory requirements for IXC's have been relaxed, although not eliminated.

The persistent struggle with competitive issues in the telephone industry is the source of yet another form of regulation of the industry: the antitrust laws. Antitrust enforcement has played a major role in the history of the industry — ironically, both in facilitating the growth and dominance of AT&T, and then later causing the breakup of AT&T. The federal government sued AT&T on antitrust grounds in the early 20th century, and the suit was settled in 1919 under what is known as the Kingsbury Commitment. The settlement allowed AT&T to keep control of most telephone facilities nationwide, subject to utility regulation. The government sued AT&T again in the 1970's, and the suit culminated in the 1982 Consent Decree, which required the breakup of AT&T into its competitive components (interexchange service, information services and CPE) and its noncompetitive components (local exchange service).

2. Locus of Regulation

Over its history, telephone service has been regulated at municipal, state, and federal levels. Before the advent of state public service commissions (PSC's) in the 1910's and 1920's, telephone companies, to the effect they were regulated at all at the local level, were regulated through the municipal franchising process. (The process was similar to the process under which most cable systems are locally regulated today.)[68]

In most states, PSC's ultimately displaced municipalities as local regulators of telephone service.[69] At the federal level, the Interstate Commerce Commission originally had jurisdiction over telephone service, but the FCC gained jurisdiction when that agency was created in 1934.

The jurisdictional boundary between PSC and FCC regulation of telephone service is simply stated: PSC's have jurisdiction over intrastate service, while the FCC has jurisdiction over interstate (and international) service.[70] In practice, however, the boundary has proved to be difficult to define and has been the subject of considerable dispute over the years between the PSC's and the FCC. The boundary disputes stem from the fact that, for the most part, the same physical telephone network facilities are used both for interstate and intrastate traffic.

To ameliorate the problem, Section 410 of the Communications Act authorizes the creation of a Federal-State Joint Board (composed of FCC and state PSC members) to formulate recommended decisions on matters involving the rates, accounts, and other matters of carriers subject to both state and FCC jurisdiction. The FCC, however, has the ultimate power to accept or reject the recommendations of the Joint Board. The Joint Board mechanism has certainly played a role in promoting compromise on jurisdictional disputes, but it has not eliminated the problem.

3. Administrative Costs

The administrative costs associated with state and federal regulation of telephone service are considerable. They are relatively small, however, relative to the multi-billion dollar size of the industry.

4. Standards

Throughout most of the telephone industry's history, standard-setting was purely private. The reason is the dominance of AT&T and its equipment manufacturing arm, Western Electric. At its peak, the pre-divestiture AT&T provided almost 100 percent of nationwide interexchange service, and approximately 75 percent of local exchange service. As a result, AT&T was able to set virtually all technical standards for the industry.

The eventual emergence of competition in the interexchange and CPE markets, however, changed matters. It created the need for a governmental role in setting standards for the interface between the newly competitive segments of the telephone service market and those segments that remained non-competitive (chiefly, the local exchange network).

The FCC has played the role of standard-setter in virtually all of these instances. Standard-setting has been important in three areas: (1) standards for the interface between the network and deregulated CPE; (2) standards for interconnection between the facilities of competitive IXC's and the non-competitive LECs, known generally as "equal access"; and (3) standards for unbundling network services and for interconnection between the network and providers of "enhanced" or "information" services (these standards are known generally as "open network architecture"). Generally speaking, the FCC rulemaking process has proved to be an effective tool for setting and implementing standards for the CPE interface and for equal access. It is probably too early to predict the effectiveness of FCC standards in the "open architecture" area, as the FCC's rules in this area remain a work in progress.

5. Incentives and Subsidies

Government incentives and subsidies have played a significant role in telephone service in one primary area: promoting "universal service." Universal service originally involved promoting extension of service to high-cost rural areas. In later years, it has expanded to the policy of promoting an affordable low cost local service option to keep low-income subscribers on the network.

Historically, regulators attempted to achieve the goal of universal service through interservice subsidies. To varying degrees, interexchange service rates (before the AT&T divestiture) and exchange access charges and local business service rates (after the divestiture) have been set at levels intended to subsidize the rates for local residential service. In rough terms, the scope of the subsidy is revealed by the fact that, as noted above, local traffic accounts for approximately 74 percent of total network minutes of use, yet local service accounts for only approximately 33 percent of industry revenues.

A second, more direct form of governmental incentive has also played a role in promoting extension of service to rural areas. The Rural Electrification Act, 7 U.S.C. §§ 901 et seq., empowered the Rural Electrification Administration (REA) to grant low-cost loans to eligible utilities — including small telephone companies — to provide service to rural areas. Over the years, small, independent LECs in rural areas have made extensive use of REA loans to expand and upgrade their networks in rural areas.

These two forms of government incentives — interservice subsidies and REA assistance — have come under increasing pressure in the last 10 years. In the case of interservice subsidies, the primary source of pressure is increased competition in the market for the subsidizing services, such as interexchange service, competitive access services and local business services. As competition has placed downward pressure on the rates of these subsidizing services, they have furnished less revenues to be used to offset the subsidized service, local residential service. This trend is likely to continue.

REA assistance has come under increasing political pressure, being a frequent target of federal budget cutters. As a practical matter, the original mission of REA telephone loans — to promote the extension of telephone services to rural areas — has been accomplished. The continuation of REA assistance in this area will depend largely on the strength of proponents' argument that the mission of REA loans should be extended to promote the upgrade of rural telephone networks to offer the more sophisticated information services that are being offered in urban and suburban areas.

6. Other Public Policy Issues

Although it has historically been viewed as an essential public utility service, the telephone industry has always been privately owned. This is the traditional American model for regulated utility industries: providers are privately owned, but subject to government regulation. . Interestingly, the U.S. is the exception to most of the rest of the world, where until recently, telephone service has usually be provided by either a government department or a government-owned company. 'The worldwide trend, however, is toward the U.S. model, with the privatization of government-owned telephone companies and the emergence of competition.

Telephone service presents an interesting externality issue. Indeed, the externality issue is really the counter-argument to the view that interservice subsidies to promote universal service frustrate allocative efficiency in telephone service. One of the unique values of telephone service to consumers is that it provides a means of communicating with everyone on the network. Thus, the argument goes, the more universal subscribership becomes, the greater the value of telephone service to each user on the network. To the extent this is true, spreading the cost of service extensions to high-cost areas among all network users is not a "subsidy" at all, but is instead a means of preventing free-riding by low-cost subscribers. Absent cost-averaging, low-cost subscribers would be able to make and receive calls from high-cost areas without contributing to the cost of extending service to those areas.

Viewed from this perspective, interservice subsidies to promote universal service are arguably nothing more than a means of capturing externalities in telephone service. While this externality argument certainly has some validity, tailoring interservice rates to compensate precisely for this externality, while avoiding the market distortions of over-compensating, is a difficult task. And there is little, if any, in the way of empirical analysis that suggests that the long history of interservice subsidies in telephone service has been so carefully tailored.

7. Lessons for ITS

As in the case of telephone service, government regulation will undoubtedly play a major role in ITS. Perhaps more to the point, as with telephone service, government's role in ITS will be multi-jurisdictional. Since ITS will inherently involve use of the radio frequency spectrum, FCC regulation will be required. Because ITS will involve use of local streets and rights-of-way and because it will include (if not center upon) traffic monitoring, control and management in regional and metropolitan areas, local and/or state government involvement also seems assured.

The type of role played by government in ITS, however, would seem to be quite different than its role as public utility regulator of telephone service. With respect to ATMS, for instance, local government's role will most likely seem to be as a consumer of ATMS rather than a regulator. Moreover, to the extent that ATMS serves an institutional market rather than an end-user consumer market, telephone's traditional public utility regulation model would seem to be ill-suited for ATMS. While ATIS will be more of an end-user consumer service, ATIS also would not seem to be a likely candidate for the public utility regulation model typical of telephone service. In the communications field, that model has historically been applied only to basic transport, or conduit-type services like telephone service. It has never been applied to content-oriented services such as cable, broadcasting and information services, and ATIS appears to fall into this latter category.

To the extent that the transport functions of ITS can be separated from the information aspects of the service, common carrier regulation nevertheless might have a role to play in ITS. If regulated carriers can perform the transport functions of ITS, the platform they provide could actually foster competition in the information service aspect of ITS by lowering the likely economic barriers to entry arising from the transport function of ITS.

Telephone service can also teach important lessons to ITS about government subsidy mechanisms and externalities. Indirect subsidies through pricing mechanisms are effective only to the extent that the subsidizing service is not subject to competition. Thus, the end-user revenues generated by ATlS are unlikely to provide a funding mechanism for ATMS if the ATIS market proves to be competitive — a seemingly likely occurrence. If so, support for ATMS, to the extent it is not self-supporting, will have to come through more direct government subsidies.

This raises the potential externality for ITS. Presumably, the travelling public will be the primary beneficiary of ATMS. The actual consumers (or purchasers) of ATMS, however, are likely to be a much narrower class — local governments and regional transportation authorities, a group that is unlikely to be able to provide all of the funds needed for ATMS. The issue becomes how to make the ultimate beneficiaries of ATMS — the public — pay for it. Two mechanisms come to mind. One is direct government subsidy of ITS, funded through taxpayers. Another approach is a bit more market-oriented: Since ATMS will presumably collect and analyze the traffic information on which competitive ATIS providers will rely, ATMS could generate revenues by charging ATIS providers for the information. Even this approach, however, will not capture all externalities, because some travellers will benefit from ATMS (through reduced traffic congestion) without the need to purchase ATIS. This externality, together with the inherent time-lag problem of relying on ATIS revenues to fund ATMS, will probably necessitate some level of direct government subsidy for ATMS to be financially viable.

IX. CHAPTER NINE — GEOGRAPHIC INFORMATION SYSTEM (GIS)

A Geographic Information System or *GIS* consists of computer hardware and software designed to allow users to acquire, retrieve, manage, and analyze geospatial data and their attributes. GIS's are now being widely used by government agencies, the private industry and the academic community for handling spatial data and for solving a variety of geographic problems. Information systems in ITS such as ATIS perform some of the capabilities of GIS including map displays and route identification. The development and commercialization of GIS products and services present important lessons for ITS in terms of the role of government and the private sector in collecting, maintaining and distributing geographic data, the importance of standards in data communications, and the institutional issues pertaining to accuracy, privacy, pricing and partnerships.

A. History

Computer-based GIS's were first used in the late 1960's. Previously most processes and operations involving geographic information such as map preparation and feature analysis were carried out manually. The introduction of a wide variety of powerful computer hardware in the late 1970's, such as the *super-*mini, enhanced the rapid growth of GIS along with other information systems. Development and commercialization of relational database management systems boosted GIS's ability. to handle spatial relationships and perform various forms of spatial analysis. By the late 1980's, GIS had become widely accepted in North America as the number of systems, projects and facilities continued to grow. Many government agencies and private entities became involved in developing GIS applications.

Today, GIS's operate on various platforms including PC's and large mainframes, and a wide range of software architectures, from simple raster systems to large database managers. Some vendors focus on a single platform, while others offer a single product that runs on several platforms and operating systems. GIS users represent an extraordinary variety of disciplines, resulting in as much variety in the definitions of the field. GIS's are described as "spatial decision-support systems", "systems for input, storage, analysis and output of geographical data", and "geographically-referenced information systems", to name a few.

GIS has been very successful in capturing and inventorying the earth's surface features as represented on maps, and likewise in summarizing and reporting spatial information. Sophisticated analysis and modeling applications have been quite limited.

B. Technology

Most GIS's are capable of associating and manipulating diverse sets of spatially-referenced data on a common referencing system. A GIS understands how elements contained in the data base are spatially related, and it can perform spatial manipulations on these elements. It contains two general types of data - *geocoded spatial data and attribute data.* Geocoded spatial data defines objects that have an orientation and relationship in 2- or 3-dimensional space (topology). Each object is classified as either a point, a line, or a polygon and is tied to a geographic coordinate system. In addition to the topological information, a GIS contains the same attribute data that is found in traditional databases. Attributes associated with a street segment, for instance, might include its width, number of lanes, construction history, pavement condition and traffic volumes. What distinguishes a GIS from traditional database is that this attribute data is associated with a topologic object that has a position somewhere on the surface of the earth.[52]

1. System Components

The generic GIS has three major components: *(1) data, (2) software,* and (3) the *locational referencing schema.* Each of these components can range from the most basic to the most sophisticated, representing a varied and complex set of geo-processing capabilities. The data can consist of a simple flat file containing a locational key, or a more sophisticated, relationally-structured database with multiple indices maintained in multiple formats. The software could be a simple system for selecting, displaying and reporting, or it could allow for interactive query and editing, real-time update and feedback, and knowledge-based decision-support capability. The locational referencing schema could be a simple classification by district or a complex combination of raster imaging, object-oriented entities and vector-based topological referencing.

2. Functional Components

A GIS can also be broken down into the following functional components:[72]

- User Interface
- Database Management
- Database Creation and Data Entry
- Data Manipulation and Analysis
- Display and Product Generation

The user interface consists of software capabilities that simplify and organize the interactions between the human operator and the GIS software through the use of menus, help screens, and graphic displays.

The database management component provides the environment in which the GIS functions and the means by which the data are controlled. The system management environment is furnished by the operating system of the host computer. GIS database functions parallel those of a non-spatial database management system, but with extensions beyond the addition, deletion, revision and Boolean (if-then) retrieval capabilities of a standard DBMS. The GIS DBMS contains hardware and software facilities and incorporate storage structures to minimize data redundancy and to aid spatial searches. In addition, the GIS DBMS ideally has the file management capabilities to handle a huge collection of data files.

Database creation and data entry refer to the process of bringing data into the electronic environment of GIS. A GIS database is often conceptualized as a series of thematic categories or topics of information (often called *layers)* held within the database. These layers may contain information that has been captured from aerial photography, remote sensing satellites, conventional maps, or other sources. Data entry is the process of loading data into a GIS database. Data in a computer-compatible format (such as digital remotely-sensed data) can be loaded directly. A database may also be created by digitizing or scanning maps or by digitizing information on aerial photographs to create a computer-readable data set.

The primary GIS activities are data manipulation and analysis. Spatial analysis tools are used to model, make predictions, and reach conclusions about problems of interest. Such analysis involves combining data from multiple spatial data categories and performing analytical, statistical, measurement and other operations on the GIS data sets to transform the data into information suitable for a given application. These operations are ideally performed in an interactive mode on the spatial component of the data, as well as on the non-spatial attribute data.

Finally, the typical GIS has extensive capabilities for display and product generation. Maps, charts and tables resulting from the use of its analysis and modeling capabilities can be produced. The displays used range in complexity from tabular reports and simple monochrome plots to publication-quality three dimensional color graphics.

3. Cost and Accuracy

Costs for GIS implementation and operation include acquisition and maintenance of hardware, software and data; user training and support, staffing, consumables and other overheads. Costs to create and maintain the data sets to use in a GIS are far in excess of the costs of the hardware and the software. The largest cost in most GIS continues to be the database. For the last 20 years automation of geographical data has been performed chiefly by digitizing and key entry. In recent years, scanning and conversion from existing automated files have also become important. Nevertheless, no present technology permits easy and inexpensive capture of previously mapped data, let alone spatial data in other non-digital forms.

The level of precision offered by GIS in locating specific points of interest depends on the resolution of the digital maps and their inherent accuracy. The resolution of many digital maps is very coarse, for example that at the 1:100,000 scale. Resolution at the United States Geological Survey (USGS) “quad” scale (1:24,000) is approximately 20 meters but quad maps have proven to be of questionable accuracy for more detailed applications. Aerial photographs of higher resolution and accuracy can be digitized and converted to base maps in GIS. The creation of highly accurate cartographic base maps for GIS generally depends on the improved mapping technology, especially those based on the satellite *Global Positioning System (GPS).*

4. Integrated Databases

Data integration is the process by which different sets of data within a GIS are made compatible with each other. These data sets may or may not be defined in terms of the same geographical referencing system. Different data sets have different spatial coverage, many data collecting agencies have their own system of regions, and these regional systems are subject to boundary changes over time. Data integration is at the very heart of GIS. Indeed, the ability of GIS to integrate diverse information is frequently cited as its major defining attribute, and its major source of power and flexibility in meeting user needs. GIS is claimed to be an integrating technology because of the way it links together diverse types of information drawn from a variety of sources. The ability to combine together data of many different types and to display them in any combination is the main factor differentiating a GIS from mere database management systems on one hand and computer mapping systems on the other.[73]

Using GIS to integrate spatial databases is neither quick nor easy. Data for different regions may be collected in incompatible ways, may vary in reliability, or may be missing or undefined. The larger the number of different data sources needing to be integrated, the more such problems will be encountered. Other problems in data integration relate to the incompatibilities between spatial entities for which data are recorded.

5. Lessons for ITS

Many ITS products and services would involve provision and/or analysis of spatial information in the same way that GIS is currently being used for other applications. The following are some of the GIS capabilities that would be required:

- representation of the road network and other related structures on a digitized map;
- providing routing instructions and finding optimal routes;
- providing information about the location of road services and utilities; and
- determining and maintaining the location of the vehicle in relation to features represented on the map.

Automobile navigation in ATIS is a demanding application of digital maps and appears likely to become a common and economically important one. A few systems are commercially available and many prototypes exist. These systems determine location using map matching, GPS, wheel rotation sensors, solid state compasses, inertial devices (gyros and other novel devices), radio location and some combination of them. The costs and accuracies of these systems vary.

Requirements of the source maps, and the associated costs, depend on the methods used and the user interface, as well as on functions performed in addition to location determination (such as map display, verbal directions, pathfinding and destination finding by address or landmark). Typical map requirements for particular systems include positional accuracy to the order of a car length, detailed street classification, turn restriction data and topological encoding. Creating such digital maps to support navigation is a daunting and costly task. There have been several pilot projects and commercial operations and consortia which have as their mission the production of digital maps for navigation or the promulgation of standards for such maps. All systems require faster retrieval than GIS systems have typically provided.

C. Products and Services

GIS is a complex and diverse field, more a loose consortium of interests than a mature industry. The existing products reflect this, and it is possible to speculate endlessly about whether the future products would hold greater uniformity or greater diversity. Numerous surveys of GIS products have been published. Estimates of the total number of GIS products in market range up to 1000.[74] GIS-related services include systems design, applications programming, database development, organizational management, and a wide array of consulting and support services.

A minimal GIS consists of a computer with minimal accompanying memory, some sort of GIS software, geographical data, a person to operate the system and a set of procedures which are to be followed in its use. More complete GIS commonly include digitizing tablets, color graphics terminals and hardcopy devices such as plotters and electrostatic printers.

1. Hardware, Software and System Development

Few hardware devices are completely GIS-specific, but some devices such as digitizers, plotters and scanners find especially important applications in GIS. The development of GIS-specific software represents the primary GIS business, since the product has no other application than GIS and is essential to the existence of a GIS. Some commercial GIS software systems are hardware specific, others run on a variety of hardware systems. Similarly, some systems interface with a variety of DBMS, graphics software and so on while others offer less flexibility. System development for GIS applications include software development, quality assurance, documentation, installation, training, field support, marketing and others.

A few GIS vendors have attempted to offer similar products across the entire range of computing platforms (i.e. mainframes, PC's, workstations, minicomputers). ARC/INFO (a software product of ESRI) started as a mainframe product but is now widely used on PC's. Others, such as Intergraph, have historically provided software for customized hardware environments. TYDAC is an example of a vendor that began in the marketplace under MS-DOS, and has migrated to OS/2 on the same platform, and to Unix workstations. As the networking advantages of Windows NT and Unix become clearer, and these operating systems become increasingly available, they will likely come to dominate the GIS field. Also, the MacIntosh Graphics User Interface (GUI) environment is also popular.[75]

2. Information

As an information system the primary function of GIS is providing data or information to its users. Information can be communicated in the form of raw data or can be processed to create other information that is of interest to the user. As stated earlier, a GIS is most effective in communicating and processing locationally-referenced data, combined with attribute data. Data represented on maps and charts usually include layers of attribute information that are associated with specific points on the maps.

3. Spatial Analysis, Navigation and Routing

Few GIS's have spatial analysis and decision-support capabilities. The market for GIS as information management tools is currently far larger than that for spatial analysis so vendors have invested relatively little in developing and promoting analytical and modeling capabilities. Spatial analysis is often confused with data manipulation operations which include buffering, overlay, and query. The former is defined as quantitative (mainly statistical) procedures and techniques applied in locational analytic work.[76] Examples of spatial analysis are pattern and relationship recognition, spatial regression, network analysis, edge detection and regionalization. Decision-support capabilities are explicitly designed to provide the user with a decision-making environment that enables the analysis of geographical information to be carried out in a flexible manner. Some of the decision-support functions of GIS which bear on ITS technologies are navigation and routing.

Functions to help users make navigation and routing decisions can be built into the GIS applications. Location identification (using either dead-reckoning, GPS, or map-matching techniques) and shortest path algorithms serve as navigational aids to users. Dead reckoning is the process of establishing position by measuring distances from a reference point. Map-matching is used to remove accumulated errors from dead-reckoning, and signal interference errors from radio navigation techniques such as GPS and Loran-C. The path travelled by a vehicle is determined by dead reckoning or radio navigation, and this path is integrated with roads and intersections. Dead reckoning with map matching is like navigation with absolute sensors in that the error in estimated position does not continue to grow (as it does with dead-reckoning alone). It differs in that, once lost, map matching algorithm is unlikely to recover; whereas if absolute sensors fail for a time or region, outside that period or region they have their usual error characteristics.

4. Future products and services

New ideas in the computer industry will continue to influence technological innovation in GIS products and services. Three dimensional technologies are expected to proliferate in the 1990's, as high performance graphics adapters for mass-produced workstations become, available from vendors. The display capabilities of exiting GIS's will seem very primitive. It is extremely likely that future GIS's will have the capability to model and represent subsurface conditions, and toanalyze earth surface features and distributions without the distortions produced by conventional map projections.

Future GIS products will support multi-media such as unstructured images (both digital and NTSC), text and sound. GIS technology will provide a framework for all forms of spatial data storage, retrieval, analysis, display and modeling. It will provide the front end technology for multimedia spatial databases including video, CD-ROM, tabular and other forms of data.

The accuracy of the base maps in GIS is expected to improve significantly with the adoption of GPS technology for data collection.

5. Lessons for ITS

The products and services that will support most ITS technologies are characterized by large databases and a variety of decision-support functions, similar to GIS applications. Also like GIS, the choice of hardware, software and operating systems is an important issue for ITS technologies and will affect product differentiation and design strategies. The specific ITS applications will dictate the computing environments which are most appropriate as well as the analytic modules required.

D. Diffusion/Penetration

The GIS business which started in the late 60's was relatively small over its first decade of existence. However, it has been growing rapidly in the last decade. The number of firms claiming to provide at least some GIS-related products or services number in the thousands. Annual gross sales are difficult to determine, in part because of varying definitions of what the GIS business includes.

Market forces and healthy commercial competition are the primary incentives for thinkers to come up with new ideas, concepts and techniques in the GIS field. It was apparent, 20 years ago, that GIS would grow rapidly only if large commercial organizations could be enticed to enter it. Development in the GIS field demanded many elements: hardware to provide the fundamental enabling capabilities required; construction of a sound theoretical basis for geographical relationships and a model of how geographical reality could be abstracted for data processing; engineered software products which would encapsulate the scientific notions of spatial analysis and geographical data processing: creation of demand for spatial information in order to address complex problems about geography; creation of an industry which could manufacture and distribute GIS technology; and creation of a research environment with all its competitive mechanisms.

All the market surveys carried out in Europe and North America paint a story of increasing use of GIS and related data sets. The surveys show global sales of between $500 million and $4 billion per annum for GIS software, hardware, services and data, the sum varying with information source, with the definition of GIS adopted and with the base year taken. All surveys are unanimous that growth in the total expenditure by users is of the order of 20 to 30 percent per annum. Some individual vendors such as ESRI report growths of income of over 40 percent per annum. This and the ubiquitous nature of GIS applications has led organizations such as IBM to identify GIS as an area on which to concentrate.

The immensely broad spectrum of what different individuals consider as a GIS complicates establishing a benchmark of the number of systems now in operation. Based, however, on sales of systems of known capabilities, there were not less than 20000 installations worldwide in 1990 with at least significant claims to being a GIS. In early to mid-1990, annual sales seemed to be running at about 6000 systems per annum, including PC products. The advent of new low price systems such as Atlas GIS later in that year made the forecasting of sales much more difficult.

The GIS boom that began in the early 1980's is still accelerating. New vendors are entering the market with new and exciting products, education and training programs are proliferating, the GIS software industry is reporting rapid growth rates, new textbooks and magazines are appearing, and GIS technology continues to find new applications and new acceptance.

Over the last two decades, the GIS field is coming of age with the founding of the U.S. National Center for Geographic Information and Analysis and its equivalent in other countries, the selection of GIS by IBM as one of its five strategic markets for the 1990's; the adoption of GIS by virtually all US national agencies, the massive emerging general interest in cartography and geography; environmental crises at local, national and global levels, resource shortages, the decay as well as rapid growth of cities and the need to manage natural resources better.

1. Success Factors

The main reason behind GIS's success is its great commercial application. Recent estimates suggest that GIS could become one of the most dynamic computer-related businesses of the 1990's. Studies show that GIS is already a big business worldwide, and more importantly, that it is rapidly expanding. For example, the European market for GIS products and services was estimated at over 300 million dollars in 1989. Most of this spending was by utilities or government, but some nine percent was being spent on environmental applications.

GIS has commercial application because of its enormous value to many industries (real estate, banking, sales and marketing) and because it can be used to address many significant global, national and local infrastructure, social and scientific problems. In the U.S., one reason for the digital mapping industry's growth and the popularity of GIS is the long-term commitment of its largest customer - the federal government. The government's primary map-making agencies, the Defense Mapping Agency, the U.S. Geological Survey (USGS), and the Census Bureau, all use GIS's.

Another significant factor in the expansion and continued success of GIS has been the rapid decline in computer hardware and software prices over the past few decades. The introduction of the microprocessor and the microcomputer in the late 1970's has greatly enhanced this success. Almost all early GIS software systems operated on mainframes or minicomputers, but recently lower-priced microcomputers and workstations are being used. The widespread adoption of GIS is expected to continue as smaller, faster and cheaper microchips are developed in the future.

2. Lessons for ITS

Competition and innovation will play major roles in the marketability and acceptance of ITS products and services. Like GIS, the hardware and software needed to support ITS technologies have to meet specific requirements with regards to processing speed, storage capacity, price, and ability to meet users' needs. Ways to deliver these requirements at low cost will come from continued research and testing by the industry, the government and the academic institutions.. Establishment of cooperative organizations such as ITS America will promote understanding and concerted efforts among these institutions in achieving these goals.

E. Private Sector Economics

The GIS industry's main business comes from developing value-added geographic data products using the data provided by the government. Incentives for product development in the GIS business come from federal policies that require government agencies to release data at the cost of dissemination. The data that is released is often in raw form and needs to be processed to be useful. The GIS industries that provide these value-added services impose fees thereby raising the price of data and restricting access, especially for small organizations and for individuals.

Companies like Intergraph have gained profits from increased interests in GIS products. Integraph started as a supplier of Computer-Aided Design software, but in 1988 earned a third of its revenues by selling GIS hardware and software. In the late 1980's, Intergraph had the greatest share of the GIS combined hardware/software market. Its competitors included IBM, DEC and Prime. GIS Software suppliers such as Environmental Systems Research Institute (ESRI) and Caliper Corporation grew enormously, profiting from the digital mapping's popularity. The same can be said of companies that create customized maps such as Analytical Surveys Inc.

Profit potehtials from digital mapping are also high for makers of paper maps, because GIS can automate map-drawing. The process itself is expensive, but automation can be used to create new maps using the same information from a single digital database. Rand McNally has already published paper maps created with digital mapping systems. Companies that make GIS applications strictly for automated map drawing also stand to make substantial profits.

Data sharing among users of spatial data is increasing. Federal efforts to maintain national digital databases by agencies such as the U.S. Geological Survey, the Bureau of Census, and the Soil Conservation Service have induced the improvements of data translators and the establishment and use of digital data standards. These activities will reduce the cost of database creation and shift efforts to updating and revising the data and to the addition of specialized data themes.

1. Sources of revenues

The most common sources of revenues come from selling GIS data or products, licensing access to data, providing GIS services for a fee, or some variations of these. Revenues are earned by pricing data above the cost of dissemination, allowing industries to provide more usable data and better services in order to increase data usage at lower costs to the users. Different fees are usually established for different classes of users which include public agencies, universities, media, private individuals, and commercial enterprises.

2. Pricing

The cost of GIS software can only be traced from the early 1980's since it was then that the first GIS entered the market. There was a decline in costs over that period, becoming more pronounced as more and more systems entered the market. The list price for a minicomputer version of ESRI's ARC/INFO in 1983 was about $100,000 (or about $200,000 at 1990 prices); in 1990 a first copy for a 386-based computer of like performance (but with much more software functionality) was about $10,000, with heavy discounts for multiple copies.

In practice, such list prices are rarely paid; most vendors will discount to many classes of customers and some have given GIS software to organizations purchasing hardware; it is thus difficult to quantify the trend precisely but dramatic price reductions and increase in quality of the product have occurred simultaneously. The extent to which this can go on is unknown, except in the mass market where GIS's are sold for PC's and low cost workstations in a manner analogous to dBASE, Lotus l-2-3, Excel or even word processing packages like Word and WordPerfect. If this occurs, we should expect to be able to buy fully functional GIS's for about $500 in the mid-1990' s.[77]

3. Lessons for ITS

The private sector stands to make profits from selling and providing ITS products and services. The data which will drive the functions in these technologies including routing information, advisories, digitized maps, real-time traffic data and others will come mostly from public agencies who are involved in collecting, maintaining and distributing these data. Data sharing and data integration among users and providers of ITS technologies will also facilitate the creation of standards which help vendors and providers come up with competitive products and services.

As in the case of GIS, resources expended on **ATIS** will shift over time from implementation to updating and expanding the database. It is well known that the institutional challenges of maintaining and expanding GIS databases can be even more challenging than establishing them in the first place. The same may be true for ATIS.

F. Role of Government

Government agencies acquire and use geospatial data to carry out their functions. However, the government is changing from producers to consumers of data. Government's role as principal provider of spatial data is decreasing. But the public sector continues to help ensure the quality and accuracy of data, the free access to public information, the regulation in pricing of GIS products and services, and the protection of public interests through certain laws.

1. Data Collection, Maintenance and Distribution

Spatial data gathering by government agencies is usually funded through the agencies' budgets, and the public derives benefits from the agencies' programs. The U.S. Geological Survey (USGS), through its National Mapping Program (NMP), provides various cartographic, geographical and remotely-sensed data, products and information services to the public. USGS's mission is to meet the mapping needs of the country including federal and state agencies, commercial companies and individual citizens.

While many geographic data users build their own maps to meet their specific needs, the most common starting point is the base topographic information compiled by USGS. The Survey conducts control surveys, undertakes field completion and cartographically finishes and prints the maps. These tasks are primarily focused on the 1:24,000 scale series. Other map series include those at the 1:100,000, 1:250,000 and 1:500,000 scales; these have hitherto been derived by manual cartographic means from the primary series. However, just as the USGS achieved the milestone of national cartographic coverage at the 1:24,000 scale, it was experiencing a dramatic increase in the need for map revision and a demand for digital cartographic data. Most of these increased needs are rooted in the equally dramatic spread in the use of GIS by federal, state and local government users of USGS maps and the National Digital Cartographic Data Base.[78]

The Office of Management and Budget (OMB), through'the USGS, receives annual reports from federal and state agencies regarding their requirements for maps in graphic form as well as for map-related data in digital form. The process is embodied in OMB Circular A-16. In 1983, OMB established the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC), chaired by the USGS. The committee was charged with facilitating the coordination of the collection and sharing of spatial data. Circular A-16 later expanded this effort and assigned leadership roles to federal departments for coordination activities related to certain categories of data. It also established an inter-agency coordinating committee named Federal Geographic Data Committee (FGDC) to provide policy guidance and oversight to these activities and to promote the coordinated development, use, sharing and dissemination of surveying, mapping and related spatial data. The Department of Interior was assigned the responsibility for chairing the FGDC. It is intended that the FGDC will support domestic surveying and mapping activities, aid the use of GIS and assist users in meeting their program objectives.

One particular characteristic of the U.S. is that the federal government cannot copyright information collected using public funds. This is not true in other countries where creation and distribution of national data sets is more regulated because the base map series and digital data derived from that series are copyrighted by the government. This copyright facilitates the creation of cooperative ventures between the government and the private industries. In the U.S., multiple sets of digital highway data exist, some created by government agencies and others by the private sector. Many have been derived from the USGS base map series. Duplicated efforts should be minimized because significant resources are involved in satisfying the data collection and maintenance requirements for each basic data coverage.

2. Pricing Policy

Pricing policies for access to publicly produced geospatial data reflect philosophical differences between the federal government and state and local governments. Federal policies mandate that, as a general principle, access to federally produced data should be priced at the cost of reproducing and distributing data, but should not include the costs of collecting data. A trend in state and local governments is to price data to recover the costs of both collecting and maintaining data.[79]

The history of the Census Bureau pricing policy for street centerline databases is particularly illuminating, as described by D.F. Cooke in a recently published book, Sharing *Geographic Information:*

> During the first two decades of ACG [Address Coding Guide] and DIME [Dual Integrated Map Encoding], the Bureau sold copies of geographic files for "cost of copying," just as it sold its data products. The cost rose from $70 per reel of tape to $140 during this period. When high-density 9-track tapes (6,250 bpi) became available in the early 1980's one could buy a complete copy of GBF/DIME for less than $3,000.
>
> It is significant that the TIGER/l: 100K DLG [Digital Line Graph] data production partnership between the USGS and Census included a "joint marketing" agreement for TIGER. This resulted in a new data-pricing policy influenced by the USGS, which had a history of pricing DLG products above cost of copying. When the pre-census edition of TIGER was released in 1989, the artificial prices ($175 for the first county in a state plus $25 for each additional county) added up to $87,000 for a nationwide copy. Though lower than some previous price estimates for TIGER, this departure from previous access costs jeopardized broad dissemination of the new TIGER resource.
>
> However, as predicted by Census officials (who were ambivalent about the new pricing policy), a private company bought one copy of TIGER and contracted for private production and distribution of eighteen other copies, resulting in nineteen organizations sharing access to nationwide TIGER by splitting the acquisition cost and benefitting from a commercially competitive cost of copying. Under this arrangement, a nationwide copy of TIGER cost each organization $10,000 instead of $87,000.
>
> By 1991, new data publication technology -- CD-ROM-- helped lower economic barriers to sharing the "final" TIGER release. The Bureau now distributes TIGER primarily on CD-ROM for $250 per disk. Although this remains a somewhat arbitrary price, the nationwide total of $11,000(forty-four disks) no longer constititutes a barrier to widespread use....
>
> Demand for street centerline data is such that several private companies currently compete with the Census Bureau to provide improved [Street Centerline Spatial Database]... products....**

State and local governments see data as a source of revenue. This makes sense from an economic perspective. Geospatial data are not free, and a strong institutional framework is needed to create and maintain geospatial data. Organizations and individuals who use these data, especially for private gain, should contribute to their capture and dissemination. Copyright and other restrictions on use do not prevent access to government data, but instead protect the public's investment and intellectual property rights. These restrictions allow the government, as a steward of the public's property, to receive income to support data programs.

Currently, differential pricing aids access by the academic community and others requiring subsidized access. Access at the cost of dissemination can continue only as long as a government's resources support that approach, and many think most governments can no longer afford such policies. Fees are more popular than taxes as a means of providing revenues.

3. Partnerships

The implementation of a regional or statewide GIS typically requires enormous interjurisdictional coordination. The barriers to achieving this coordination nearly always prove to be the principal obstacle to efficiently and effectively developing a GIS data base that can be shared by all participants. These barriers include:

- Institutional inertia and culture of different organizations and jurisdictions;
- The willingness of each organization to pay or contribute other resources necessary to develop the GIS;
- The potential for some jurisdictions to want to become free riders and benefit from free or low-priced GIS data developed at the expense of others;
- Real or perceived requirements for confidentiality of data;.
- A desire of agencies to maintain control over the use and dissemination of their data;
- Incompatibility of data in terms of specifications, accuracy, and structure;
- Differing perceptions on the value of sharing data; and
- Issues of equity, leadership, politics and ego.

The ability to overcome these barriers usually depends on there being champions in each agency who favor cooperative development and maintenance of a GIS, although sometimes there exist regulatory requirements or financial incentives to achieve the needed cooperation.

In addition, a facilitator is usually required. The facilitator can be from one of the agencies, but just as often is from the private sector, usually a consultant who is assisting with the implementation of the GIS.

Some type of informal or formal partnership is nearly always required. These partnerships can involve a wide variety of different institutional arrangements such as the following:

- MassGIS is an example of multi-agency GIS whose establishment was motivated by a desire to achieve cost savings by avoiding redundant data collection. MassGIS evolved from a five agency organization to one encompassing many other agencies through reciprocal agreements involving the provision of MassGIS information in exchange for new information;
- A city, county and electric utility executed a formal agreement to establish a GIS organization under the direction of a three party board who had the responsibility of developing a GIS to be funded with a public bond issue. The agreement calls for the establishment of a core data base to be maintained by the organization and assigns responsibilities to participating organizations for development and maintenance of supplemental data;
- Four public agencies and an electric utility in two counties entered into a formal agreement for cooperative development of a GIS and sharing of data. The allocation of funds was according to six shares, one for each of the county agencies and two for the utility that served each of the two counties;

- The city and county of San Diego jointly developed the Regional Urban Information System under one of the first multi-participant agreements developed in the United States. The goal of RUIS, a project and not an entity, was to create and share a common digital base map among all the cooperating parties. Only 23 percent of the costs of map development were spent upon base map conversion because of an arrangement to share an existing base map with a gas and electric utility serving the region. Under the agreement, a full-time administrator works for the management committee and both the city and country have full time coordinators for the project. A private company was given an exclusive contract to develop and operate the system;

- In 1990 the City of Cincinnati, the Board of Commissioners of Hamilton County, the Cincinnati Gas and electronic Company and the Cincinnati Bell Telephone Company entered into an agreement to develop and manage a shared database of geographic, infrastructure, and land data. The relationship is a contractual one rather than a joint venture, and calls for the participants to share, according to percentages spelled out in the agreement, the costs of all hardware software, goods, services and shared data elements. The agreement also assigns responsibility for acquiring, entering and maintaining various types of data, and delegates the responsibility for implementing the GIS to the City of Cincinnati, which set up a separate department. The agreement calls for relatively free sharing of data among the participants but participants are not obligated to provide non-core or other proprietary data;

- The Northwest Land Information System Network (NWLISN) is a consortium of federal and state agencies in Oregon and Washington which established a cooperative framework for sharing of GIS type of data, reducing duplication of digital data sets, and developing joint data mapping and analytic programs. This cooperative effort established a meta data management system called the Spatial Data Index. This is a referral service to locate existing coverages of different types of geographic related information. As opposed to establishing a core data base and unified schemas and formats which are shared among participants, NWLISN, depends upon describing data as the means of achieving integration and cooperation among participating agencies; and

- The Wisconsin Land Information Program established an ARC/INFO GIS. This occurred without any official sanction or formal agreement, but was the result of “techies” from a number of state agencies holding informal meetings. Thus cooperative GIS development occurred because technical people perceived the value of data sharing and who figured out how to jointly develop GIS on their own.[81]

In GIS public-private ventures, the private sector usually requires that potential partnerships limit risk and provide a certainty of return over a defined period of time. Government entities, on the other hand, select partners from the private sector competitively, and periodically reopen competition for the opportunity. GIS industry involvement usually reduces bureaucratic conflict among government partners, but several problems may arise in such partnerships. Often, partnerships provide for data collection but not for data maintenance and the private sector may find it more attractive to drop out of the partnerships and just rely on their ability to access public data. Memoranda of understanding among government entities are sometimes difficult to enforce. Personnel turnover is frequent in government entities, and the resulting lack of continuity of individuals involved in a partnership causes problems.

4. Standardization

Standards can facilitate transfer of information between a GIS technology and other information systems. They serve as common media or a set of rules with which communication and various transactions can take place. These standards include models and procedures for data structure and representation, database languages, data transfer and communications and computer hardware/architecture to facilitate data sharing in an integrated information environment. Many of the standards and guidelines for general computer systems and information management are applicable to a GIS. Complexity in defining spatial data standards for GIS stems from the different levels of detail required by different applications and the different types and structure of data currently used in the organization.

Within the federal government, basic geographic data standards exist. Federal Information Processing Standards (FIPS) geographic codes for uniquely identifying, locating and indexing data spatially were among the first computer standards established during the late 1960's to standardize computer usage for federal agencies.[82] Soon afterward, the automation of cartography began.. Federal GIS standards are emerging from existing standardization efforts in digital cartography. For example, the USGS has drafted *Spatial Data Transfer Standards (SDTS)* as a Federal Information Processing Standard. These standards use the object-oriented database model to represent real world entities that can be transferred among and interpreted by dissimilar computer systems. The objects represent spatial phenomena such as highway, pavement, road and other geographic features that can be referenced to National Geodetic Control Points or the Topologically Integrated Geographic Encoding and Referencing (TIGER) System developed by the Bureau of Census.[83]

5. Legal Issues

The legal aspects of GIS's are concerned with the relations between the products, the providers and the users. Liabilities that users seek to impose on GIS data and software providers have been the focus of information technology law. Exposure to liability is increased by several trends in the GIS community namely: the use of data from unknown sources and of unknown quality; the availability of value-added data products that may disguise the quality of the underlying data; the increasing use of data in mass market and other business applications; and the growing base of naive users who are not familiar with GIS and their limitations. Specific examples of liabilities are:

- *Errors and omissions in represented locations* - These typically result from measurement and data-handling mistakes. National map accuracy standards prescribe a reasonable level of misrepresented locations. In automated map-making, data entry occurs when measurement data are transformed into numbers and stored in a computer file, or when maps are digitized. A court is likely to consider the process used for data entry and whether or not a reasonable standard of care is established and utilized in the process of design and implementation, including data priority rules and training procedures aimed at minimizing errors. In a court case (Reminga vs. United States 1978) the federal government was held to have inaccurately and negligently depicted the location of a broadcasting tower on an aeronautical chart, contributing to mistakes and resulting fatalities in an airplane accident.

- *Representations of error-free data* - These can result in liability when the form of representation is confusing or inappropriate for the user's purposes. In a court action (Aetna Casualty and Security Co. vs. Jeppeson and Co. 1981) it was asserted that a fatal airplane crash resulted from a defective aeronautical chart published by Jeppeson. The chart depicted the instrument approach to an airport from information promulgated by the Federal Aviation Administration (FAA) and described by FAA in a tabular form. The chart graphically displayed two views of the approach, one from above and another as a profile or side view. The court found that the chart had a defect, in that the profile or side view appeared to be at the same scale as the top view, whereas there was a factor of five between the two. The plane crashed on approach and the cause was determined to be, in part, the pilot's mistaken reliance on a chart feature which appeared to be 15 miles away from the airport but which was actually 3 miles from the airport. The court ruled that the chart publishers were at fault because 'The professional must be able to rely on the accuracy of this information if he or she is to benefit from the mechanization or special compilation of the data'.

- *Unintended or inappropriate use of maps* - These occur among the public and the private users and are most likely where map designers and developers are not available to the user and the user lacks experience or access to expertise about the map and its represented measurements.

By using standards and reporting truthfully the condition and limitations of their data, GIS providers are usually protected from these liabilities. Providing products with disclaimers attached also help.[84] [85]

Concerns about privacy and confidentiality have also mounted due to increased volume of available data (spatial and attribute), the increasing number of data providers and users, and the integration of data from different sources. The use of copyright protects data about individuals. Copyright gives a producer both economic and privacy benefits. Copyright allows producers to limit the dissemination of unpublished works that were generated as self-expression or for other limited purposes. Copyright protection could be used to limit data distribution and the purposes for which the data may be used.

6. Lessons for ITS

There are enormous parallels between the institutional issues pertinent to GIS and to ATIS in the areas of pricing, multi-participant agreements, standardization and legal issues. The GIS community has grappled with similar pricing issues faced by those seeking to implement ATIS. GIS data can be available for barter, free, a combination of free basic service and non-free premium service, the cost of reproduction (i.e. marginal cost), cost recovery, or market value. The experience of the Census Bureau also shows that if data is greatly overpriced, either no one will buy it, or the private sector will turn the high price into a profitable opportunity. A private firm may buy the information at a price no one else is willing to pay, and resell it for a profit at a lower price, assuming the elasticity of demand supports this strategy.

ATIS, like GIS usually requires multiple jurisdictions to cooperate to produce the core set of data. Achieving this cooperation is one of the most challenging problems in developing a multi-agency GIS, just as it is in implementing ATIS. The wide variety of multi-participant agreements used to implement GIS are instructive for ATIS, many of which involve public/private partnerships. These agreements address nearly all the same issues that are required in cooperative agreements to develop an ATIS.

The development of accuracy and data interchange standards for GIS is also directly relevant to ATIS. Digital map data bases for navigation and routing also need to conform to similar standards. Indeed, the relationship between digital map data bases for GIS and ITS is so close, one wonders why accuracy and spatial data interchange standards should be different between the two.

Many of the same liability concerns that apply to GIS will apply to ATIS. Areas of potential liability will include errors and omissions in represented locations that may have severe safety implications, any attempt to represent a digital data base as being error free, or potential unintended or inappropriate use of maps that lead to lawsuits. All of these problems can be avoided by adhering to standards and truthfully reporting the limitations of the data.

X. CHAPTER TEN — SATELLITE GLOBAL POSITIONING SYSTEM (GPS)

GPS is the common term for a U.S. Department of Defense satellite and control system designed to be visible to a receiver at all times on a global basis. One can buy a receiver that uses the signals from the GPS satellites to determine the receiver's location within roughly 17 meters (military or undegraded civilian code) to 100 meters (degraded civilian code). With a supplementary base station, accuracy can be improved to better than 1 centimeter for stationary measurements and 5 to 10 meters in mobile operations of up to 55 miles per hour. If a GPS receiver can obtain a fix on three satellites, it can establish location in two dimensions. But if the GPS unit can obtain a fix on four or more satellites, it can determine location in three dimensions - latitude, longitude and altitude.

Using GPS for location identification and navigation is a major focus of research in the design, development and implementation of ITS driver information systems, vehicle guidance, and traffic management/control functions. Important lessons can be learned from the application of the GPS technology to land, maritime and aviation purposes. Issues such as accuracy, reliability, coverage, cost and government regulation pertaining to GPS and its applications are discussed in this paper.

A. History

GPS is the most revolutionary development in the radionavigation arena.[86] The GPS program started in 1973 when branches of the U.S. military service (i.e. Air Force, Army, Navy, Marine Corps and Defense Mapping) combined their technical resources to develop a highly accurate, space-based, positioning and navigation system for global military use. GPS resulted from extensive studies, tests, analyses and operational demonstrations. Rockwell International led a team of more than 20 companies which designed a four-satellite GPS constellation for the DOD. The first group of satellites was launched in 1978. Others followed later.

The GPS was designed primarily as a navigation system, allowing aircraft and other vehicles to know their latitude, longitude and altitude frequently (e.g. once per second) and to measure speed and direction of motion in real time. In 1983, an aircraft using GPS for navigation crossed the Atlantic for the first time. Soon after, the effectiveness of GPS for navigating helicopters and missiles was demonstrated. By 1985 ten satellites had been launched.

By 1994, the NAVSTAR system of 24 Global Positioning System satellites orbiting at about 11,000 miles above the earth was scheduled to be fully operational. The satellites would enable a person almost anywhere on the earth to track his or her position twenty-four hours a day. The only exceptions are where tall buildings, canyons, steep mountains, heavy forest canopy or other obstructions block the line of sight to the orbiting satellites.

To date, the federal government has invested almost $10 billion in the system. Annual operating costs for satellites and base stations is over $100 million. However, the eventual goal of the GPS is substantial civilian funding. The commercial potential has always been understood and non-military use of the system was encouraged from the outset. Most research and technical data were left unclassified. This encouraged free flow of information, and also enablecll developers working on non-military applications to simultaneously pursue commercial development.

Earlier, in 1978, the Congress and several elements of the Executive Branch questioned the cost justification for a military-only GPS. It was felt that the introduction of GPS into the civilian community could reduce the need for many other federally-provided radionavigation systems. Congress directed the Departments of Transportation and Defenses to jointly develop a government-wide radionavigation plan with the purpose of determining an optimum mix of federally-provided systems. The resulting document was given the title of *the Federal Radionavigation Plan (FRP).* This policy statement addresses how and for what period each system should be part of the Federal Radionavigation systems mix.[88]

B. Technology

GPS is a satellite-based system for identifying position, velocity and time. It has three major segments - *Space, Control* and *User.* The Space Segment consists of the satellite system, which have 20,200 km. circular orbits with 12-hour period and an inclination angle of 55 degrees. Each satellite uses two L band frequencies for transmission - *Ll* (1575.42 MHz) and *L2* (1227.6 MHz). Ll carries a precise *(P)* code and a coarse/acquisition *(C/A)* code. L2 carries the P code. Both frequencies carry same navigation data message.

The Control Segment consists of five monitoring stations, three of which have uplink capabilities. The monitor stations passively track all satellites in view using a GPS receiver, thus accumulating ranging data from the satellite signals. The information from the monitor stations is processed at the Master Control Station (MCS) to determine satellite orbits and to update the navigation message of each satellite. This updated information is transmitted to the satellites via the ground antennas, which are also used for transmitting and receiving satellite control information.

The User Segment consists of receivers that provide positioning, velocity and precise timing to the user. A GPS receiver consists of a number of parts including an antenna and associated pre-amplifier, a radio frequency (RF) front-end section, a signal tracker block, a command entry and display unit, and a power supply. A microprocessor controls the overall operation of the receiver and likewise computes the receiver's coordinates. Some receivers also include a data storage device, an output to interface the receiver to a computer, or both.[89] The microprocessor may compute waypoint information or convert coordinates from the standard WGS 84 geodetic datum to a regional one. It also manages the input of commands from the user, the display of information and the flow of data through its communication port (if the unit has one).

The majority of self-contained GPS receivers have a keypad and a display of some sort to interface with the user. The keypad can be used to enter commands for selecting different options for acquiring data, for monitoring what the receiver is doing, or for displaying the computed coordinates, time or other details. Users may also key in auxiliary information, such as that required for waypoint navigation or weather data and antenna height for geodetic surveying . Most receivers have well-integrated command and display capabilities with menus, prompting instructions, and even on-line help. Some receivers have a basic default mode of operation that requires no user input and can be activated simply by turning the receiver on. Some GPS receivers are designed as sensors to be integrated into navigation systems and, therefore, don't have their own keypads and displays; input and output are accessed only via data ports.

1. Accuracy

Computer simulation programs are used to project accuracies for the GPS constellations. At any given time of day, the programs calculate the positions of the GPS satellites and identify the ones that are visible from a specific location on earth. Four of the visible satellites are selected and used to calculate the location that the receiver would provide. Since a GPS receiver determines location by estimating the user's range to each of the four satellites, the programs mimic the real errors in this process by introducing a range error for each of the simulated satellites. The range data are used to solve for the user's location, and the instantaneous position error is determined by subtracting the true position from the calculated position.

As stated earlier, the accuracy of a GPS receiver depends upon whether or not the satellite signals have been degraded. Under a process called Selective Availability, the degraded civilian C/A code is received resulting in accuracies of roughly 100 meters. If an undegraded military code is received, accuracies of 17 meters or better can be achieved. The accuracy of both precise and degraded signals can be improved by using differential GPS as described below.

2. Differential GPS (DGPS)

Differential GPS uses differential corrections to the basic satellite measurements performed within the user's receiver. It is based upon accurate knowledge of the geographic location of a reference station, which is used to compute corrections to GPS parameters, error sources, and/or resultant positions. The DGPS reference station is fixed at a geodetically surveyed position. From this position, the reference station tracks all satellites in view and computes corrections based on its measurements and geodetic position. These corrections are then broadcast to GPS users to improve their navigation solution. For a civilian user of GPS under Selective Availability, differential corrections can improve navigational accuracy from 100 meters to better than 10 meters.[90]

3. Lessons for ITS

The accuracy of a specific technology in determining locations of vehicles and other transportation features is one of the major criteria in the choice of ITS products and services. Options such as inertial navigation (e.g. dead reckoning, map-matching) and radio navigation (i.e. GPS, Loran-C, Transit, etc.) techniques can be used in various ITS applications as described earlier. Accuracy requirements for maritime and aviation navigation are pretty much well-defined. However, there are no definite accuracy requirements for ITS applications. Some applications require accuracies in the order of 5 to 15 meters. The requirements for monitoring the location and status of vehicles are somewhat less stringent. For example, the ADVANCE project in Chicago is looking for positioning accuracies of 45 feet or better.[91] While GPS signals can be used by anyone who has a receiver, the available accuracy (which depends on factors that are inherent in the receiver, the satellite signals, or the locational topography) can limit the usefulness of the technology.

C. Products and Services

In 1980 only one GPS receiver was available on the commercial market. Today, more than 50 manufactures make more than 300 different types and models of GPS receivers. There are receivers designed specifically for the military receivers for waypoint navigation, geodetic surveying, and time transfer; receivers that use the C/A code and those that additionally use the P Code; single and dual frequency receivers; hand-held receivers and others more substantial in size.[92] Manufacturers of GPS equipment are divided among those who sell only to the military, those who sell only to civilian users, and those who make products for both. The following describes the different types of receivers in the market and the GPS services provided by the military and the commercial industry.

1. Receivers

Based on the type of signal trackers, receivers are classified into two broad groups - *Continuous* and *Sequencing.* Continuous receivers can track four or more satellites simultaneously. In addition, it can give instantaneous position and velocity. This is valuable in high dynamic or high accuracy applications, hence they are often used for surveying and scientific purposes. The disadvantages of these kinds of systems are their size, cost and power consumption.

Sequencing receivers normally use a single channel and move it from one satellite to the next to gather this data. They usually have less circuitry so they are cheaper and consume less power. Unfortunately the sequencing can interrupt positioning and can limit their overall accuracy. Variations of single channel sequencing receivers include:[93]

- Starved-Power Receivers - Geared for portability and usually designed to run off small batteries. They are perfect for personal positioners for hikers or day sailing in small boats. Their main disadvantages are degraded accuracy, limited interfacing and their inability to measure velocity with any precision.

- Single Channel Receivers - Not limited by power and can remain "on" continuously. They can be a bit more accurate and can measure velocity as long as there are no significant accelerations or course changes.

- Fast-Multiplexing Receivers - The design is similar to slow sequencing receivers but they move from satellite to satellite much faster. Unfortunately they require more complex circuitry and end up costing as much as a two-channel sequencing receivers, which are much more flexible and more accurate.

- Two-Channel Sequencing Receivers - A second channel is added to double the system's inherent signal-to-noise ratio. This means it can lock on to signals under more adverse conditions, and can track satellites closer to the horizon. Velocity measurements can be much more precise. Their disadvantages are that they usually cost more to build and require more power.

2. Satellite Service

The DOD will declare the GPS constellation fully operational when 21 satellites are functioning in their assigned orbits. The system is still under development, and signal availability and accuracy are subject to change without warning at the discretion of the DOD.

GPS provides two levels of service - a Standard Positioning Service (SPS) and a Precise Positioning Service (PPS). The 1992 Federal Radionavigation Plan[94] describes these two services as follows:

Standard Positioning Service

SPS is a positioning and timing service which will be available to all users on a continuous, worldwide basis with no direct charge. SPS will be provided on the GPS Ll frequency which contains the coarse acquisition (C/A) code and a navigation data message. SPS will provide the capability to obtain horizontal positioning accuracy within 100 meters (95 percent probability) and 300 meters (99.99 percent probability). GPS Ll frequency also contains a precision (P) code that is not a part of the SPS. During GPS constellation build-up, the P code may be periodically available. However, when GPS is declared fully operational, the P code is not planned to be available to the general public.

Precise Positioning Service

PPS is a highly accurate military positioning, velocity and timing service which will be available on a continuous, worldwide basis to users authorized by the DOD. PPS will be the data transmitted on GPS Ll and L2 frequencies. PPS was designed primarily for military use. It will be denied to unauthorized users by use of cryptography. It will be made available to U.S. Federal and Allied Government (civil and military) users through special agreements with the DOD. Limited, non-Federal Government, civil use of PPS, both domestic and foreign, will be considered upon request, and will be authorized on a case-by-case basis, provided:

- it is in the U.S. national interest to do so,
- specific GPS security requirements can be met by the applicant, and
- a reasonable alternative to the use of PPS is not available.

3. Future products and services

Some analysts believe that new technologies in micro-electronics, antennas, and batteries will make wristwatch-size GPS receivers available in the future. Also in order to reduce receiver costs for the same level of accuracy and type of service, manufacturers will bring in more large-scale integrated (LSI) circuit design. GPS receivers will be made with one or two analog integrated circuits (IC) including a central processing unit. However, development of an LSI-based GPS receiver will require a huge investment that only a limited number of manufacturers will be able to afford.[95]

Real-time differential GPS (DGPS) is expected to make Selective Availability less controversial, as DGPS correction services and real time DPGS-capable equipment expand.

4. Lessons for ITS

Vehicle location and navigation products and services that would enter the ITS market would rely on accurate and reliable position data. Either radio and inertial navigation systems (or both) including GPS are expected to be utilized by these products on a continuous basis. Cost, accuracy, portability, dependability, coverage and ability to track locations while in motion are some of the major factors that will influence the design of navigation equipment in ITS. Limitations in accuracy and coverage of the available systems will result in different products that provide various levels of accuracies and area coverage. Similarly, recreational, business and tactical users will demand product and service features that meet their needs.

D. Diffusion/Penetration

Research concerning civilian applications of GPS, such as surveying, began in the early 1980's. It was already obvious then that the technology was potentially useful to civilian aircraft and commercial shipping. When Rockwell produced its first receivers for the military in 1982, civilian scientists were already testing a prototype receiver for surveying. Later scientists demonstrated accuracies of 1 mm for surveying applications. GPS was used to site locate the English Channel Tunnel in 1987. In 1991, the

International Maritime Satellite Corporation (IMSC) announced it would spend $320 million to purchase four new satellites to complement existing DOD satellites. The development of relatively inexpensive transmitting and receiving equipment has broadened the potential market significantly. GPS is now an attractive option for navigation, logistics and fleet management of railcars, trucks, automobiles and small aircrafts and recreational boats.

1. Marine Transportation

The handheld GPS units now available have been manufactured mainly for marine navigation. Although GPS has no official recognition as a navigation aid at sea and has not yet received legal status ***de jure*** by the International Maritime Organization (IMO), it is increasingly being accepted de ***facto*** aboard ships.[96] When the Safety and Navigation Committee of IMO, the latter a U.N. affiliate organization based in London, began a worldwide navigation study in the 1980's, it set about establishing minimum performance standards for marine navigation aids. At the time no single radionavigation system provided worldwide coverage, hence nothing was available that would fully meet IMO's global requirements. Many maritime commercial operations have already equipped their vessels with GPS, and the trend will only increase now that nearly-round-the-clock, two-dimensional coverage is available worldwide. Ultimately, GPS will be officially recognized in the maritime industry. But until GPS is declared operational, liability and credibility issues arise when asking an organization like IMO, responsible for safety rules for the world's merchant fleet, to officially approve it as a navigation system.

2. Aviation

The attention given to the application of GPS in aviation has increased significantly. In the early 1980's the Radio Technical Commission for Aeronautics (RTCA) concluded in their study of GPS that satellite services were not only desirable, but in fact appeared to be the only viable method available for providing navigation and air traffic services to meet future aviation requirements on a worldwide basis. Much of the current activity of the aviation organizations addresses the development of aviation standards and specification for GPS and the Soviet Union's Global Orbiting Navigation Satellite System (GLONASS), including the work by RTCA to establish minimum operational standards for GPS. The aviation applications of GPS include en route, terminal, approach and landing phases, as well as runway incursion detection. GPS applications also affect the cockpit, the Air Traffic Control (ATC) system and many ground-based services.[97]

In August 1993, the Airline Competitiveness Commission called for reforms in the aviation industry and suggested that GPS form the backbone of civil air traffic management.

3. Land Transportation

Whereas maritime and aviation interests have historically dominated the civilian users of GPS, land users are expected to exceed these more traditional users.

Electronics leader Motorola is now developing for mass market an automatic vehicle location and guidance system that incorporates a low cost GPS receiver. Motorola already sells multichannel GPS receivers that are used primarily in surveying. Motorola proposes three sensor inputs to provide route guidance and navigation for vehicles: a GPS sensor or receiver, a wheel-speed sensor, and a compass. Combined with onboard digitized map data, the sensor inputs would show a driver the vehicle's precise position within about 10 meter's accuracy on a dashboard map screen. The company envisions a system that also could digest inputs from traffic control centers about local road hazards and dynamic traffic conditions. The system may be both visual and auditory, and it should have two-way communications, permitting the vehicles themselves to serve as traffic probes. Motorola doesn't expect to be alone in the market, Trimble, Ashtec, and Magnavox's Nav-Corn subsidiary, have already developed GPS-based automatic vehicle location systems.

Burlington Northern railroad is developing a train control and transportation management system that will depend upon GPS for determination of train locations. Train locations will be transmitted to dispatching offices which will in turn transmit movement authorities to trains. The dispatching offices will monitor the progress of trains, as well as many other factors bearing on the operation of the railroad, and will continually update movement authorities in order to achieve optimum efficiency.

A number of services are evolving that make use of GPS. For example, within the trucking industry, companies have equipped vehicles with GPS receivers to aid in fleet management. Knowing the location of every vehicle across the nation at any instant in time will allow more efficient planning and operations. Urgent pick-up and delivery services to customers will be possible and rapid and optimal rescheduling of each vehicle's itinerary is expected to result in improved productivity.[98]

4. **Success Factors**

GPS already has, and continues to gain added credibility with the Department of Defense operations community following its successful implementation in Saudi Arabia as part of Operations Desert Storm. The positioning capabilities of the system proved their worth to U.S. ground forces trying to navigate their way around the treeless, unmarked desert.[99] U.S. government users of GPS now include the Coast Guard, the National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA), the Department of Transportation (DOT), and all branches of the Department of Defense.

There are positive indications that the military forces of the NATO nations, as well as other allied countries, will use GPS. Because of the accuracy, worldwide coverage and flexibility provided by GPS, non-governmental civil use has grown rapidly and exceeds military use. User population estimates will be influenced by many factors, such as the resolution of civil aviation system coverage and integrity issues.

Over the years, the civilian GPS community has expanded to include public agencies at all levels of government, equipment manufacturers, and a wide variety of professional groups ranging from surveyors and photogrammetrists to land, marine and aviation interest groups.

Worldwide military and commercial markets for GPS now exist. In addition, there are now nearly a hundred commercial manufacturers of GPS-related equipment. In 1990, the market for GPS equipment and services was $88 million, and it is projected to exceed $5 billion by 1996. Sales to commercial and marine and automotive buyers are expected to exceed military sales by 1995.

5. **Lessons for ITS**

GPS has already gained wide acceptance for vehicle navigation and route guidance in the ITS community. In fact, most operational tests of ITS technologies and services in various parts of the country involve GPS. Automobile manufacturers in the U.S., Europe and notably Japan have started designing vehicles equipped with GPS receivers. Transit systems and other land transportation industries are exploring the technology. Worldwide coverage, accuracy and ease of use make GPS highly suitable for many ITS functions. However, all "land mode" agencies including the Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), the National Highway Traffic Safety Administration (NHTSA) and the Urban Mass Transit Administration (UMTA) have to approve of the system and set guidelines for its use.

E. Public/Private Sector Economics

For certain applications such as positioning and surveying over a limited area, a number of privately-operated systems are available to the user as an alternative or adjunct service. The authorization of commercial radiodetermination satellite service (RDSS) by the Federal Communications Commission was expected to make radiolocation information available over a wide coverage area. However, former contenders for RDSS have gone into bankruptcy and no longer exist. At the 1992 World Administrative Radio Conference (WARC), a portion of the RDSS frequency allocations were transferred to the Mobile Satellite Service (MSS). Several MSS applicants have announced plans for providing radiolocation services in addition to voice communications. A few experimental licenses were issued by the FCC early in 1992. [100]

Several commercial concerns are now offering differential GPS (DGPS) services for positioning and surveying applications. Operators using licensed U.S. communications links to transmit DGPS corrections are subject to constraints as directed by the National Command Authority (NCA).

Since the role of privately-operated systems is increasing, and there is current interest in increased private sector role in federally-provided radionavigation systems, the whole issue of private sector role in radionavigation services needs to be examined.

The dilemma that faces a potential GPS supplier is whether to wait until GPS becomes more secure in commercial terms or to enter a high risk market now. The radionavigation consumer seems to come back into the commercial marketplace every five years for a technological update or renewal for defunct equipment. Today, however, this consumer might be reluctant to switch to using a GPS system that still lacks a fully operational constellation of satellites or unambiguous national policies and that also currently requires higher-priced receivers.[101]

1. Sources of revenues

Because of the nature of electromagnetic medium, radionavigation services presently provided to meet U.S. requirements are available to any suitably equipped user. There is no direct charge or fee levied by the U.S. government for the use of any federally provided radionavigation systems. The only cost recovery for radionavigation services from civil users, either domestic or foreign, is obtained from the aviation community for DOT provided air transportation services. This cost recovery is achieved through indirect measures, and at this time covers only part of DOT's costs. There is presently no corresponding cost recovery from the marine users of DOT provided radionavigation systems.

The National Transportation Policy supports the institution of user fees to recover costs from users of federally-funded or federally-provided services who are not now paying user fees. Fees would be set at an amount so as to generate total revenue from each of the user groups consistent with the cost of services provided to that group. This policy is part of the Administration's effort to impose user fees where a service provides benefits to identifiable recipients above and beyond those which would be recovered through an appropriate and convenient fee system.

The US Coast Guard will attempt to establish a cost recovery program for those services in which there is a direct transaction such as licensing, inspection, permits, and similar services. A majority of the costs of services provided by the FAA is already recovered through the Airport and Airway Trust Fund, which is financed by a system of user fees, including a passenger ticket tax an aviation gasoline fuel tax, a jet fuel tax, a freight waybill tax and an international departure tax.[102]

2. Service Pricing

Estimates place the manufacturer's costs of components for a basic C/A GPS receiver at about $250, which theoretically could allow a retail price of $500 - given sufficient levels of production and sales. The current low-end price for such unit is about $2000. A true consumer market that could support these levels of production and price by unleashing new competitive forces may well emerge.

However, buyers are judging the performance and benefits of GPS against Loran-C. Today, many so-called GPS receivers sell for several times what popular Lorans cost, yet still offer only two-line or four-line seven segment displays. Many consumers have already concluded that the limited advantages of GPS - namely global coverage and improved performance in bad weather - are not worth the significant additional cost.[103]

3. Lessons for ITS

In using federally-provided navigation systems such as GPS for implementing ITS technologies, the direct cost to the government, as the operator of ITS navigation services, and to the user, who must buy the equipment needed to use the services, must be carefully analyzed. The analysis of these costs must consider the initial investment, operation, maintenance and replacement costs, as well as the unamortized capital investment remaining at the time that replacement of the system is contemplated. In the civil sector, the cost of user equipment, more than any other single factor, will influence the acceptability of the product or service.

F. Role of Government

The current national technology policy enunciates a theology of converting defense technology to civil applications. GPS, almost a model of dual-use (military/civil) technology, closely fits this policy. In 1993, U.S. DOT Secretary Pena specifically referring to GPS as "a good opportunity to carry out one of the major themes of the president by applying military technology to civilian use... .[104]

However, the government has no statutory responsibility to provide GPS services to civil users. However, once it undertakes to provide such services - thereby inducing reliance on them - the government needs to exercise due care in operating the system. The fact that the service is provided free has no legal importance. The government must take reasonable measures to ensure that the system transmits accurate information, and system operators must provide timely warning of problems when they arise.[105]

The Federal Government operates radionavigation systems as one of the necessary elements to enable safe transportation and encourage commerce within the U.S. The goal is to provide this service in a cost-effective manner. In order to meet both civil and military radionavigation needs, the Government has established a series of radionavigation systems over a period of years. Each system utilizes the latest technology available at the time it was introduced. The systems are designed to meet an existing unfulfilled need, usually in terms of improved accuracy and/or expanded coverage.

1. Regulation

The Federal Radionavigation Plan (FRP), the government's definitive policy guide on the operation of all federal radionavigation systems (i.e. GPS, Transit, Loran-C, etc.) as described earlier, addresses how and for what period each system should be part of the Federal Radionavigation systems mix.

Radionavigation systems operated by the U.S. Government will be available subject to direction by the National Command Authority (NCA) because of a real or potential threat of war or impairment to national security. Radionavigation systems will be operated as long as the U.S. and its allies accrue greater military benefit than do adversaries. Operating agencies may cease operations or change characteristics and signal formats of radionavigation systems during a dire national emergency.

Because of national security considerations, the GPS Precise Positioning Service (PPS) will be restricted to U.S. Armed Forces, U.S. Federal Agencies, and selected allied Armed Forces and governments. While GPS/PPS has been designed primarily for military radionavigation needs, it will nevertheless be made available on a very selective basis to U.S. and foreign private sector (non-governmental) civil organizations. Access determinations will be made by the Government on a case-by-case evaluation that:

- Access is in the U.S. national interest
- There are no other means reasonably available to the civil user to obtain a capability equivalent to that provided by GPS/PPS.
- Security requirements can be met.

The government is currently developing policy for submitting applications, granting approval for user access, and establishing operational procedures and compliance requirements for accessing the data from the GPS/PPS. .

The U.S. Coast Guard's GPS Information Center (GPSIC) is the operational entity of the Civil GPS Service (CGS) which provides GPS status information to civilian users of the Global Positioning System. Its input is based on data from the GPS Control Segment, Department of Defense, and other sources. The mission of the GPSIC is to gather, process and disseminate timely GPS status information to civil users of the GPS navigation system.

Within the civil community, differences persist between public and private sectors, reflecting the usual tensions encountered by regulating institutions and regulated users and vendors. That is complicated by the fact that many public agencies are themselves GPS users who, on the one hand, may compete with private service providers and, on the other, may have an inside track for becoming certified to obtain access to the higher accuracy Precise Positioning System (PPS) of GPS. At present, the Civil GPS Service (CGS) Steering Committee sometimes seems a forum more for expressing than alleviating the differences within the civilian community. Although participation in the CGS is open, as a governmental creation, the committees leadership and membership reflect a heavy weighting toward official agencies.[106]

2. Liabilities

Given the wide variety of factual and legal possibilities, and the lack of legal precedent, it is difficult to predict how cases involving GPS will fare in the U.S. judicial system. As a provider of GPS, the U.S. government cannot be sued unless it first consents (doctrine of sovereign immunity). The government has waived this immunity in certain circumstances by passing legislation permitting lawsuits against it. For civilian GPS users, an important waiver of sovereign immunity is *the Federal Tort Claims Act.*

The Federal Tort Claims Act (FTCA) waives immunity in claims against the U.S. for money damages arising from a loss of property, personal injury, or death caused by the negligent or wrongful act or omission of any employee of the government while acting in the scope of his employment. There is, however, the discretionary function exception which precludes a lawsuit when the negligent act or omission arose from the exercise or performance, or the failure to exercise or perform, a discretionary function. In a GPS context, the discretionary function exception is important. The decision to implement Selective Availability (SA) and provide accuracies at a given level in clearly an exercise of discretion. The fact that the government could have and even should have provided the better accuracy levels of the PPS does not matter. For instance, a pilot might claim that an aircraft would not have strayed off course and crashed had the better signal been available. But the pilot would still be barred from suing under FICA. The FTCA also does not waive immunity when the claim arises in a foreign country, and when injuries are suffered as a result of combat activities. If an outbreak of hostilities caused the U.S. suddenly and without notice to use SA to degrade the Standard Positioning Service (SPS) beyond that promised, or to delete the SPS signal entirely, this provision of the FTCA can be invoked to avoid liability.

Several other legal concerns may affect a given case, depending on the facts. For instance, a number of civil users of GPS information intend to use it to produce computer software and other products for retail sale. If faulty GPS information negatively affects the accuracy of the software or other products and the customer sues the producer for an injury that results, the government may be required to indemnify the manufacturer or contribute to the damages paid to the retail customer under the FTCA law.

3. Military versus Civilian Needs

National security requirements and military involvement are anathema to civil radionavigation markets. If GPS is to be employed as a useful tool in future theaters of operation, how will it be denied to the ever increasingly sophisticated potential aggressor? Is selective availability enough? Will the military require an option for regional scrambling, jamming or blackout? What will happen to the signals in the rest of the world that is going about its normal business and relying upon GPS for navigation? The military needs flexibility to maximize performance without limiting its options; the civil markets needs rigidity, long-term stability and adherence to specifications. For GPS to be used in the civilian arena and for a commercial market to evolve, there must be a way to face up to this dichotomy. Several issues are involved here, but the fundamentally conflicting requirements and objectives between the military and civil communities must be resolved.

The civilian community had widely believed that the current policy called for implementing Selective Availability only in the event of military emergency. The civilian GPS community has yet to match the DOD's development of institutions and procedures to gather, clarify and articulate the community's needs. Similarly, civilians lack a mechanism for forging a common front to propose policies that would aid civilian manufacturers, researchers, and users. This is complicated by competitive interests among manufacturers, by the diversed and dispersed constituency of end users and by lingering anxiety about unresolved policy issues.

4. Lessons for ITS

The development and implementation of GPS represent a great example of government leadership in the development of a technology that has broad benefits to the commercial sector. In the same way, the government can and will provide the leadership for ITS technologies that would benefit the private industries. Much of the costs of the huge investment needed to implement the GPS technology was borne by the government, which was willing to do so because of important military benefits provided by the technology. Commercial users will be likely to contribute significantly to future development and maintenance costs because viable commercial applications have been developed. It is the involvement of non-military and commercial users which ensured the continued success of GPS. This involvement was made possible by an early and open access to technical data necessary for product development and commercialization.

XI. CHAPTER ELEVEN — ON-LINE COMPUTER SERVICES; A CASE STUDY OF PRODIGY SERVICES COMPANY

Important lessons can be drawn from the history of the deployment of Prodigy Services Company that are pertinent to the deployment of Advance Traveler Information Systems (ATIS). Prodigy is one of the major on-line computer information services along with America On-line, CompuServe, Delphi, and GEnie. Prodigy offers some of the same kinds of services as can be found on the Internet, such as e-mail, but only recently has it begun to offer to subscribers full access to the Internet.

A. History

Prodigy Services Company is an outgrowth of TRINTEX formed in February 1984 by CBS, IBM, and Sears Roebuck and Company. TRINTEX was conceived to provide subscribers with two-way electronic transactions such as shopping and banking, as well as the exchange of messages and access to information and educational services. This was a partnership designed to exploit the entertainment expertise of CBS, the computer hardware and software knowledge of IBM, and the merchandising know-how of Sears. TRINTEX was slated to become commercially available by 1988. CBS withdrew from the joint venture two years before the service was to go on-line due to a reassessment of its priorities. [107]

In 1988, coincident with the initial marketing of Prodigy in Atlanta, Hartford, and San Francisco, IBM and Sears changed the name of the company from TRINTEX to Prodigy. The name of Prodigy had been selected as the one consumers would see advertised. The parents of the company wanted the corporate name to be strongly identified with the name of the service.[108]

Prodigy was not the first on-line service to be developed. The oldest is CompuServe, which was an outgrowth of an effort to utilize excess capacity of mainframes during off-peak business hours. CompuServe began in 1972, founded by Jeffery Wilkens and his father, and soon thereafter became a subsidiary of H&R Block. Companies like CompuServe were involved in remote data processing. Through timesharing arrangements they would perform various types of computer data processing for businesses. After 6 P.M on weekdays and over the weekends the demand for computer services dropped sharply. In 1979, the founders of CompuServe decided to let the excess mainframe capacity become available to the growing number of computer hobbyists at nights and on weekends for $5 per hour through a service they called “MicroNET”. Radio Shack offered subscription kits to this service for $29.95. Besides the subscription kit, computer users only had to buy an acoustic coupler to go on-line.“’

America On-line also predates Prodigy. It was founded by Bill von Meister who created a service called the Source as early as 1985. America On-line originally developed services explicitly for Commodore, Apple and IBM compatible computers through a company called Quantum Computer Services. Delphi on-line services is also a predecessor of Prodigy and dates back to 1983.

Prodigy officially began service in September of 1990. Within two years it had garnered the largest market share with about two million subscribers, yet their interest was primarily in e-mail, not Prodigy’s on-line shopping which, combined with advertising, accounted for less than 10% of total revenues by 1994.11’ In 1992, Prodigy decided to change to a more traditional pricing plan and implement a $.25 charge for each e-mail beyond 30 per month. This heralded the beginning of a migration of members to other on-line services. In 1993, Prodigy cut 250 employees, the first of several lay-offs to help streamline operations. By the spring of 1995, Prodigy had still not had a profitable year.[111]

Prodigy began using live TV advertisements late in 1993 to attract subscribers. By late 1994, Internet access was provided and the user interface improved. A completely new Windows-based interface, dubbed "P2," will be introduced very soon to combat growing complaints about Prodigy's slower operating speed and outdated graphics.

There has been a convergence of the features on-line services offer with those of the Internet. Prodigy only recently has offered full Internet access whereas Delphi has offered it for some time. Part of the history of such services as Prodigy is the history of the Internet. An outline of the Internet's evolution is as follows:

- During the cold war the Advanced Research Project Agency in the Department of Defense, which later became the Defense Advanced Research Project Agency (DARPA), funded a study by Bolt Beranek and Newman to determine how to preserve communications between military installations and research centers in the even of a nuclear attack. As a result BBN developed a packet switching protocol (Network Control Protocol) and a network controlling computer (Information Message Processor). In 1980 the original ARPAnet was implemented and connected Stanford University, the University of California at Los Angeles, the University of California at Santa Barbara, and the University of Utah in Salt Lake City. By 1972 the basic Internet technology was in place: ARPAnet had become a network connecting 40 sites. Users were able to exchange small text files via electronic mail or what was to become known as "e-mail." Large text files could be transferred using the *file transfer protocol (FIT),* and even remote login was in place, allowing control of a remote computer over the network.

- As an outcome of the first International Conference on Computer Communications held in Washington D.C in 1972, an InterNETwork Working Group was established to develop a protocol that would allow computer networks throughout the world to communicate with one another. A year later the Internetting project of DARPA sought to figure out how to link packet-switched networks. As result, the two basic Internet Protocols were developed, the Internet Protocol (IP) and the Transmission Control Protocol (TCP). The TCP/IP protocols are used today by nearly all new networks.

- DARPA declassified the TCP/IP protocols and made them available to everyone for free.

- Digital Equipment Corporation developed an open operating system for UNIX computers, and AT&T Bell Labs created the UNIX-to-UNIX Copy Program (UUCP), which allowed any UNIX computer to communicate with any other UNIX computer with just a modem and transfer files. As the installed base of DEC minicomputers grew with UNIX operating systems, a large, but loosely connected network of computers operating over telephone systems emerged by the end of the 1970's.

- A gateway was established that connected the Computer Science Research Network (CSnet) and the ARPAnet backbone, which many regard as the real birth of the Internet.

- Steve Bellovin at the University of North Carolina sought to create an electronic newspaper, which began with the original release of Usenet. The Usenet resulted in three things that shaped the culture of Internet communications, the creation of usenet hierarchies, "flaming," which occurred when disgruntled users inundated the message file of others who upset them while on-line, and the transmittal of "smiley faces."

- The Unix-to-Unix Copy Program was modified to permit connections to IBM type of personal computers.

- Networks began to proliferate by the early 1980's and various mergers and changes occurred. BITnet was implemented as a source of news and opinion, not unlike Usenet. FidoNET, a system providing for personal computer "bulletin boards," was established. The National Science Foundation Network (NSFnet) linking supercomputing centers over very high bandwidth communication lines was created. Bitnet merged with CS Net, which in turn closed down after NSFnet was created in 1989. Meanwhile many huge independent networks had come on the scene including Prodigy, CompuServe, Delphi, America On-line and GEnie. Most of these independent networks are connected to the Internet. Altogether there are nearly 4000 networks spanning the globe that now connect to the Intemet.[112]

B. Lessons for ITS

Just as the government funded TCP/IP and UUCP protocols and Internet spawned numerous private services, public investments in ITS are likely to spawn numerous private services as well. Indeed the private sector will capture most and perhaps all of the economic rents of publicly invested ATMS unless there is a mechanism to capture some of those rents and reinvest them back into ATMS.

C. Technology

When Prodigy was first introduced, the only technology required of subscribers was a personal computer and a modem. According to an April 29, 1989 press release regarding an announcement of Prodigy on-line banking services, computer users without a modem could purchase a Hayes Personal Modem 1200 at a special introductory price when they became Prodigy Members.

While the equipment at the user end was simple enough, Prodigy services could not become economically viable until the installed base of personal computers had reached a critical mass. Thus the falling price of personal computers and their diffusion in the market place was acritical factor in bringing Prodigy to the threshold of being a successful business.

The other key part of the technology was the development of the communications infrastructure, without which Prodigy would not have been possible. The history above outlines the type of communication technology that supports Prodigy, other on-line services and the Internet.

D. Lessons for ITS

ATIS will not take off as a popular consumer service until the installed base of home and business computers, in-vehicle navigation equipment, and personal digital assistants reach a critical mass, just as Prodigy did not become viable until sufficient numbers of the public had bought personal computers. Also, like Prodigy, a precondition for ATIS deployment is the development of both public and private telecommunications infrastructure.

E. The Private Sector

Prodigy is a privately financed and operated service whose revenues come from subscribers and advertisers. A complex independent private network supports Prodigy Services utilizing a central computing system, phone line connections across the country, and interface software at each user's computer.[113] E-mail connections are now provided using the Prodigy network as well as the Internet, but not until competition made it a necessity has Prodigy worked to offer full Internet Access. Part of the reason seems obvious. If Prodigy users are surfing the Internet, they are no longer the captive audience of the companies whose advertisements appear at the bottom of each Prodigy screen. Currently, Prodigy's Internet offerings include only basic e-mail, FTP, and Gopher services as well as a World Wide Web browser, none of which displays advertisements.

Prodigy Services Company is unique among on-line services in that it depends upon advertising for some of its revenues. From the standpoint of its subscribers, Prodigy's competitors are the other on-line services such as America On-line, CompuServe, Delphi, and GEnie. However, from the standpoint of its advertising customers, Prodigy's real competitors are the TV networks, magazines, and newspapers. Unfortunately, advertising as well as shopping revenues have been disappointing for Prodigy. The soon-to-be-released revision of Prodigy acknowledges this problem and relegates advertisements to an even smaller portion of the screen, though an attempt is made to make them interactive and more entertaining.

F. Lessons for ITS

Advertising can be an important source of revenue for ATIS. However advertising is not without its problems. It may be perceived as a nuisance, and the public may turn to similar services from other sources which offer no advertising. It will be very difficult to force ATIS users to remain captive to computer screens containing advertising. For example, the poor user reaction to Prodigy's advertisements may be a lesson for how or whether private firms invest in ATIS.

When using advertising as a means of raising revenues, it is important to bear in mind that the, competitors of an ATIS service provider are not just other ATIS user services but include all forms of advertising media as well. Advertisers will pay based upon such factors as number of viewers, number of people exposed to an advertisement, etc. ATIS may not be able to compete with television, radio, newspapers, magazines, etc. for advertising revenue.

Prodigy has also been plagued with the problem of offering on-line services in an information environment defined partly by the Internet. Prodigy has found that Internet users are looking for services different from Prodigy's original offerings, and it has thus had to adjust its services. Early Prodigy users concentrated on e-mail instead of shopping services. In a similar vein, ATIS service providers may presume they know what their customers want, whereas the demand for ATIS services will in fact be shaped in part by the types of information and services people are obtaining from other sources such as on-line services or the Internet. An ITS system needs to grow with user inclinations. The service features should not be imposed on users at the outset in an inflexible manner.

Prodigy has lost market share due to antiquated technology. An ATIS could suffer a similar fate due to advancing technology if competition is allowed.

G. Government

Government has played only an indirect role in the deployment of Prodigy, largely through efforts to develop the TCP/IP protocols and the extraordinary decision to remove these protocols from under the cloak of the military establishment and make them free to the public. This allowed private companies like

Prodigy to leverage their privately developed on-line services through internetworking, and to enable their customers to reach people throughout the world using the Internet.

Currently, the federal government is investigating ways to regulate content on the Internet. Since its inception as a “family-oriented” network, Prodigy has taken it upon itself to censor its content, leaving the service with a clientele that includes, by far, thk greatest female and child market shares in the business.[114] This censoring has caused repeated debates concerning the free dissemination of information. In the meantime, Prodigy has no way to censor the Internet to which it has just provided access. Government regulation of the Internet may on one hand help Prodigy’s cause, while on the other hand it may provoke an even greater censorship debate that could ultimately curtail Prodigy’s current censoring and lose the “family-oriented” market share.

The federal government is also considering ways to charge user fees for the Internet. This could indirectly affect costs at private services like Prodigy that provide Internet access. Many opponents of federal user charges claim that the government would be double-charging for a service that was originally designed with taxpayer money.

H. Lessons for ITS

ITS may be able to capitalize on prior government investments in telecommunications and ATMS infrastructure just as Prodigy did. In particular the Internet offers opportunities for internetworking that can substantially enhance ATIS related services.

ATIS service providers need to avoid getting between a rock and hard place on issues of privacy, security, and censoring of content. Prodigy has found that their approach to censorship, for example, is inconsistent with that of the Internet, which makes it challenging to appeal to Internet users and build a family oriented on-line service at the same time.

I. Services

Prodigy offers over 500 specific services. Under its basic “Core” plan, users can access hundreds of various news, sports, weather, and general information features as well as on-line entertainment. Other services include phone and television listings, on-line banking and shopping, and e-mail. With the “Plus” services, users have access to bulletin boards, stock quotes, financial information, and an airline reservation system.

J. User Fees

When Prodigy was brought on-line in 1988, it chose to follow a different pricing policy than other on-line services. Whereas others charged per minute, Prodigy charged members a flat fee of only $9.95 per month. Prodigy was able to charge the low fee by deriving part of its revenues from advertisers. At the bottom of each screen and for transactions that involved purchases, an advertisement would appear. At the outset 80 advertisers including direct marketers and retailers were supporting Prodigy Services. Among these were Air France, Bantam Books, Broadway Department Stores, Dreyfus Service corporation, Microsoft Corporation, Panasonic Company, Sony Corporation, and Speigel Inc.

Prodigy was also placed in local service areas, allowing most members to connect with just a local call.[115]

In comparison to other on-line services, Prodigy has an advantage in providing unlimited usage of a wide variety of informational services for just a monthly fee of $14.95. Once again, Prodigy is able to take advantage of revenue procured from its advertisers. A comparison of on-line services follows.[116]

Service	Start-up Cost	Monthly Fee	Package	Additional Fees
America On-line	none	$ 9.95	5 hours	$2.95/hr.
Compuserve	none	$ 8.95	Unlimited basic	$4.80-$9.60/hr.
Delphi	none	$10.00	4 hrs. ($9/hr. business hour surcharge)	$4.00/hr.
Delphi special	$19.00	$20.00	20 hours (same surcharge as above)	$1.80/hr.
GEnie	none	$ 8.95	4 hrs. ($9.50/hr. business hour surcharge)	$3.00/hr.
Prodigy	$29.95	$ 9.95	5 hrs. Core	$2.95/hr.
Prodigy Value Plan	$29.95	$14.95	Unlimited Core. 5 hrs. Plus	$2.95/hr.
Prodigy 30-30 Plan	$29.95	$29.95	30 Hrs. Core or Plus	$2.95/hr.

K. Lessons for ITS

The experience of Prodigy has shown that a small flat fee for access to basic services has proved to be one of this company's most successful strategies for building a market for its on-line service. ITS will undoubtedly want to provide some type of basic service for free or for a nominal fee. If there is a fee, the question is whether the charge should be for each request of basic ATIS data or whether a flat fee should be charged that permits unlimited queries. Higher fees might be charged for higher value information.

XII. CHAPTER TWELVE — THE NATIONAL WEATHER SERVICE

From the earliest days of the republic, making weather observations and forecasting has been an important role of government. Government engages in these activities to serve military operations, to promote safety, and most importantly to support and foster commerce and economic activity.

The mission of the National Weather Service (NWS) is to help ensure the safety and welfare of the public and to support governmental and commercial activities affected by weather. To support this mission the NWS does the following:

- Issues weather warnings and forecasts
- Observes weather, river and ocean conditions
- Develops and operates meteorological, hydrological, and oceanic services
- Conducts research
- Promotes community awareness concerning weather related national disasters.

The NWS provides two broad categories of services:

(1) Centrally prepared forecasts that give guidance to local forecasters; and
(2) Twenty-four hour per day warning services to the general public.

A nationwide network of various centers and local offices, supplemented by a large number of volunteer weather observers, gathers data, prepares warnings and forecasts and disseminates information generally through the mass media.

1. Central Forecast Guidance

This type of service pertains to the forecasting of large-scale, slowly evolving weather. Centralized services are provided by such agencies as the National Meteorological Center, the National Severe Storms Forecast Center, two Hurricane Forecast Centers, and the Climate Analysis Center. Specific services include:

- General Weather Guidance. Centrally processed data, analysis, forecasts, and outlooks to be used for local forecasting by NWS field offices, government agencies, the private sector and overseas users. Each day the National Meteorological Center processes 50,000 surface observation reports, 3,000 ship reports, 4,100 upper air observations, and about 9,000 aircraft reports in addition to information from weather satellites and ocean buoys.

- Severe Storm Guidance. Messages concerning expected severe local storms including tornadoes and thunderstorms.

- Hurricane Guidance. Forecasts regarding the path and intensity of hurricanes, other tropical disturbances and accompanying sea conditions.

- Climate Guidance. Monthly and seasonal outlooks

2. **Local Warnings**

Fifty-two Weather Service Forecast Offices, 222 Weather Service Field Offices and 13 River Forecast Centers collectively provide the following services:

- Weather Warnings and Forecasts. Warnings of severe weather, zone forecasts and field forecast support for aviation and marine operations as well as the fire weather program.

- River and Flood Warnings and Forecasts. Flashflood watches, warnings and river forecasts.

- Marine Weather Services. Wind, wave, weather, and ice warnings and forecasts for those living and working along the sea coast, off shore, on the great lakes and the high seas,

- Agricultural Weather services. Observations and forecasts to enhance agricultural efficiency, energy conservation, and environmental protection.

- Fire Weather Services. Warnings, forecasts, and advisories for wildfire control and suppression, as well as advisories to federal natural resource agencies regarding prescribed burning and smoke management, insect control , promotion of wildlife habitat, etc.

- Tsunami Warnings. Dissemination of watches and warnings of seismic tidal waves for Alaska and the Pacific Ocean.[117]

A. History

In 1890 President Ben'amin Harrison signed legislation that created a Weather Bureau in the U.S. Department of Agriculture.[118] Making weather observations and forecasts was by no means new to the nation. As early as 1797 Thomas Jefferson saw a need for a network of weather observers throughout the country. Between 1776 and 1816 he had established weather observers in all the counties of Virginia.[119]

The Smithsonian Institution published the first weather forecasts in the United States shortly after it furnished weather instruments to telegraph operators, thereby establishing a weather observation network. The Civil War disrupted this observation system, but not long after it was over, Congress enacted a national weather warning service under the Secretary of War.[120] Near the end of the 19th century the Weather Bureau had begun an exchange of weather warnings and other types of information with Europe over cable, which marked the start of large scale international weather exchange.[121] By 1910 the Weather Bureau, whose operations had been transferred to the Department of Agriculture twenty years earlier, started issuing weekly forecasts. In order to meet the growing needs of aviation, the Department of Agriculture established an aerological section.

As World War II loomed, automatic telephone weather service began in 1939. A year later the Weather Bureau was transferred to the Department of Commerce, in order to, as Prescient Roosevelt explained, "permit better coordination of activities relating to aviation and commerce generally."[122]

In the last half of the 20th century the growth in aviation and advancements of technology have resulted in constant improvement and expansion in weather service capabilities. In 1954 the Weather Service installed radar systems to detect and track hurricanes. In April 1960 the National Aeronautics and

Space Administration placed into orbit the first weather satellite, the polar orbiting TIROS-1. Shortly thereafter, the Weather Bureau in collaboration with the military, NASA and the private sector established a global weather satellite observing system.[123]

In 1968 President Nixon designated the Department of Commerce to be the lead agency in coordinating U.S. participation in the World Weather Program.[124] In 1970 the executive branch of the U.S. government issued a reorganization plan which formed the National Atmospheric and Oceanic Administration (NOAA) under the Department of Commerce. Incorporated into NOAA was the U.S. Weather Bureau under the new name of the National Weather Service. The Department of Commerce was given responsibility for coordination of weather related programs across all federal agencies. The Office of the Federal Coordinator for Meteorological Services and Research in the Department of Commerce is a key focal point for coordination along with a number of interagency committees.

By 1982 the NWS had grown to an organization with over 250 weather stations, 5,000 personnel and a budget of about $300 million. Expenditures for weather related operations of all federal agencies-- the Department of Commerce, eight other agencies and the military -- were running about $1 billion per year and employing 18,700 people.[125]

Toward the end of the 1970's the Departments of Commerce, Defense and Transportation asserted there was a need for a new radar system better able to detect and monitor hazardous weather. The Joint Doppler Operational Project was established to investigate the use of Doppler Radar for detecting tornadoes.[126] After more than a decade of planning based on scientific and technological advances, in 1988 the NWS began a dramatic- modernization of the NWS and the Department of Commerce issued a strategic plan for doing so. This modernization program involves:

(1) Next Generation Weather Radar (NEXRAD). The NWS will deploy about 120 Doppler radar systems to improve forecasts of severe storms and track storm movements. The Federal Aviation Administration and the Department of Defense will deploy additional NEXRAD systems.

(2) Automated Surface Observing System (ASOS). Replacing the manual systems across the country will be over 1000 ASOS providing nearly continuous data on pressure, temperature, wind speed and direction, runway visibility, cloud ceiling heights and precipitation.

(3) Next Generation Geostationary Operational Environmental Satellites. These new satellites will provide imagery of higher spatial and temporal resolution for short run warnings and forecasts.

(4) Advanced Weather Interactive Processing; System. This system will integrate all sources of weather data at field offices and help make rapid forecasts.[127]

This massive effort requires substantial reorganization of the National Weather service including consolidation and training and retraining programs.

As of May, 1995 the fate of the U.S. Department of Commerce and the National Oceanic and Atmospheric Administration (NOAA), of which the NWS is a part, is unclear. The U.S. House of Representatives has passed legislation that would eliminate the U.S. Department of Commerce and dismantle NOAA. The precise manner in which the NWS will survive and function is unclear, since its ultimate fate will be jointly determined by the House, the Senate and the President.[128]

B. Lessons for ITS

The weather service has grown to offer an exceedingly broad array of products and services. This growth occurred along with technological advances and ever increasing demand of weather related information as the population and economy has grown. ITS can also expect to provide a broad array of products and services. Indeed, ITS planners have already identified 29 user services for all types of ITS including ATMS and ATIS.

Political, economic and other major forces that have little to do with the merits of an important public need, such as weather forecasting, can sharply alter the institutional framework for delivering user services, even when long experience has shown the institutional framework to be successful. Deployment of ITS needs to pursue an institutional approach that is flexible and can withstand the buffeting of politics and economics.

C. Technology

A vast amount of continually evolving technology supports NWS operations. This includes a wide variety of traditional observation instruments deployed in NWS and volunteer observation stations. Among these instruments are thermometers, barometers, rain gauges, ceilometers (height to clouds), anemometer (wind speed), and hygrometers (humidity). The Automated Surface Observing System, mentioned above is designed to automatically collect information that has traditionally been collected manually with these kinds of instruments.

Radar systems for monitoring severe storms have been a keystone of NWS technology since World War II. Now Next Generation Radar is being implemented as part of the NWS modernization program. This will improve the ability to measure atmospheric motion responsible for severe weather and increase the lead time for prediction of dangerous conditions.

Satellite systems and image processing are part of the NWS Technology. NOAA's National Environmental Satellite Data and Information Service manages civil weather satellites. Satellite systems include polar orbiting and geostationary satellites. The NOAA series satellites provide for stored and direct read-out radiometer data for day and night cloud cover, surface temperatures, vegetation indices and snow and ice mapping.

The geostationary satellites consist of the GOES series of satellites. GOES-7, for example provides nearly continuous cloud viewing, periodic day and night full and partial earth disc pictures, and partial disc pictures to meet special needs. Mapping and sounding information from GOES 7 are available to end-users through timesharing. Typical sounding functions of weather satellites include temperature and moisture profiles and earth surface and cloud top temperatures. GOES-7 also has a search and rescue transponder, which can provide an early alert of a ship or airplane in distress.[129]

The NWS has always used state-of-the art computer technology. The modernization program underway has introduced Class VII supercomputers to permit complex numerical atmospheric modeling. This will improve short range warnings and forecasts and provide guidance for better medium and long range forecasts.

The communications for the NWS is exceedingly complex, most of which is composed of leased facilities. Some of the main components that existed before the modernization program began are:

- The Main Telecommunication Network of the Global Telecommunications System connects the World Weather Centers.
- International Exchange System consisting of high speed data channels, multiplex channels, low speed data channels and low speed radio data broadcasts.
- NOAA Weather Wire services available in 48 states using telegraph and other data circuits. These circuits are mainly within the boundary of a given state. Mass media subscribers (about 70% of total subscribers) access Weather Wire Service warnings, forecasts and data.
- National Warning System, a multi-point interstate and intrastate hotline to promptly warn the public of tornadoes and other severe storms.
- Multiple Access Recorded Telephone Announcement System, which allows the public to phone for recorded information on current weather forecasts and warnings. These systems fall in three classes depending on the volume of simultaneous calls that can be handled.
- NOAA weather radio, a VHF-FM continuous weather service not subject to the potential breakage of land lines and which local radio stations can copy and rebroadcast. By using a tone signal, the NWS can turn on specifically designed radio receivers so that announcements of hazardous conditions can be transmitted to schools, hospitals, churches, public safety officials, public utilities, and so on.
- The AFOS communication network serving the Weather Service Forecast Offices and the 134 Weather Service Offices. A national nerve center connects four regional communication loops. If one site has difficulty communicating, the nerve center can bypass it and maintain the loop's integrity.[130]

Elements of the current telecommunication system are discussed in the section below, "Dissemination of Weather Information and Cost of Services."

A keystone of the different types of telecommunication networks and transmissions are data interchange standards and telecommunication protocols. For example, the Committee for Automated Weather Information systems, the Working Group for Communication Interfaces and Data Exchange published *Standard Formats for Weather Data Exchange Among Automated Weather information Systems* and *Standard Telecommunications Procedures for Weather Data Exchange,* which is based on Federal Information Processing Standard 100.[131]

In general, the trend over time has been automation of weather observations, and deployment of ever increasingly sophisticated sensors and electronic data gathering equipment. Over the past several decades there has been a transition from paper and film displays of weather to electronic digital displays. This has been made possible by new high resolution atmospheric observation systems and large scale graphic and satellite imagery.

The enormous volume and complexity of new data threatens to overwhelm certain collection, analysis, and storage systems. For example the growing demand for historical data for research and operational uses has resulted in the proliferation of data bases, some of which may be duplicate and incompatible. Accordingly, the coordinating arm of the federal government set up a Working Group for Meteorological Information Management whose purpose is the following:

- Review information plans of different agencies
- Plan a national reference system for meteorological data and information
- Work with the National Bureau of Standards to coordinate information processing standards
- Prepare a coordination plan to manage federal meteorological information[132].

D. Lessons for ITS

The development of communication standards and protocols has been crucial to the success of the weather service operations and will be equally important to ITS.

Like the NWS, organizations responsible for implementing ITS may find themselves inundated with data. Development of a national ITS information management plan would seem to have merit. Such a plan might be exceedingly useful to both public and private providers who find that they need to collect, store, retrieve, and analyze unprecedented quantities of data. An information management plan with some of the same ingredients as the NWS's would include a national reference system, coordination with the National Bureau of Standards or other appropriate standard setting body, and preparation of a coordination plan to manage archived state and regional data.

E. Dissemination of Weather Information and Cost of Services

The NWS (NWS) currently disseminates the weather information through seven main systems:

(1) NOAA Weather Wire Service
(2) NOAA Weather Radio
(3) Radar Data Dissemination
(4) NOAA Family of Services
(5) Climate Data
(6) Weather by Telephone
(7) Satellite Data

Together these dissemination systems provide the vast constellation of weather information products that the general public, business and government depend upon.

1. NOAA Weather Wire Service (NWWS)

The NWWS is a satellite communication system that is the primary means of disseminating NWS forecasts, warnings and other products to the mass media (radio, TV, newspapers, etc) and emergency management services. GTE Corporation operates this communications system under a contract to the NWS. Every day, more than 50 major NWS offices transmit over 6,400 weather products by satellite to GTE's main facility in Mountain View, California. From there the weather products are re-broadcast by satellite to over 1,300 end users. Forecasts and warnings are now also distributed in graphical form via the Internet for display on computers.[133]

Each end user must purchase a receive-only micro earth station which consists of a 30 inch antenna, a low-noise amplifier, and a controller. The controller is connected to output equipment provided by the customer (e.g. a personal computer or printer). Users may lease or purchase the equipment, and in either case must pay one time fees for installation and relocation. Users specify which Weather Wire reports they want to get (e.g. individual reports, state reports, specific products for an area, forecasts for all states). Users must agree that all severe weather and flood bulletins, statements, advisories, watches and warnings that originate with the NWS shall:

(1) be stated as coming from the NWS
(2) not be modified, except for presentation format
(3) be issued verbatim and as soon as possible
(4) not be released after expiration.[134]

Customers which produce their own weather warnings etc., must differentiate their products from those of the NWS.

2. Radar Data Dissemination

The NWS has nearly completed its transition from simple NWS radar to NEXRAD. The only kind of radar product available under the pre-NEXRAD system is reflectivity. A user must purchase equipment to connect to the NWS radar and lease a telephone line. End users can turn to commercial firms which offer a wider range of radar data.

NEXRAD Information Dissemination Service (NIDS) will offer the new radar service obtained directly from new radar installations around the country called WSR-88D's. These radar stations provide a vast array of new radar products. NIDS providers disseminate these products by connecting various users to the radar sites. End users contract with NIDS providers to receive these products in return for paying a fee. Commercial companies can become service providers by entering into an agreement with the NWS.[135]

3. NOAA Family of Services

NWS offers a collection of data services called the Family of Services (FOS). Users can select individual services for a one-time connection charge and an annual user fee. User Fees for fiscal year 1994 were as follows:

Connection	One-Time Annual Maintenance Fee	Connection Fee
Domestic Data Service	$ 7,000	$ 2,500
International Data Service	$ 8,000	$ 2,500
Numerical Product Service	$66,000	$ 5,000
High Resolution Data Service	$15,000	$ 5,000
Digital Facsimile Service	$ 9,000	$ 2,500
AFOS Graphics Service	$51,000	0
Public Product Service	$ 4,000	0

A number of private firms subscribe to the FOS and resell the information they receive and/or enhance or customize the information and charge higher fees for the value added services.

The FOS is not expected to undergo significant changes as a result of the NWS modernization. However, data availability may be upgraded to real time over communication broadcast satellites.[136]

4. Climate Data

The National Meteorological Center provides well over 60 climate data products through the Climate Analysis Center Climate Dial-Up Service. The products include near term and seasonal outlooks for temperature and precipitation, drought indices for different parts of the United States, comparisons of current weather to record conditions, and cooling and heating degree days for 200 U.S. cities.

Information is available through dial-up services offering different baud rates and error correction capabilities. Until recently there has been a fixed fee schedule that varied with frequency of use. The fee schedule has now become a function of connect time with a one-time activation charge.[137]

5. Weather by Telephone

For many years the NWS has provided recorded telephone announcement systems at its field offices throughout the country. Weather information has varied with location. Typical information callers may receive consist of public forecasts, marine forecasts, tropical weather, current conditions, and extended forecast. Many of the systems allow callers to talk directly with NWS personnel. These publicly provided telephone systems, numbering about 300 in the early 1990's, have been gradually phased out whenever the private sector can offer better service. For example, a "900" telephone service operated by a private company, Weather Radio Network Corporation, was implemented in 1993. This "900" service commercially distributes NOAA Weather Radio Broadcasts for all major urban areas of the United States.[138]

6. Satellite Data

The National Environmental Satellite, Data and Information Service (NESDIS) allows government and external users to obtain high quality satellite imagery from GOES satellites in nearly real time. There are several ways for users to receive these images. One is for users connect to the main GOES Central Data Distribution Facility in the Washington D.C. area or to one of five Satellite Field distribution facilities throughout the country. Users must sign an agreement with the government and pay a one-time connection fee and an annual charge. Users have some choice over the imagery they receive.

The other option is to connect to a GOES-TAP circuit at the nearest access point. This approach, called NWS GOES-FAX, is offered for free, but requires a written agreement with the government. Users of this service get only the imagery the government offers, and have no menu of choices.

Private vendors also sell GOES imagery, which they may enhance in a variety of ways. Therefore users can obtain this type of information from either public or private sources.[139]

F. Lessons for ITS

There are different categories of weather products and services. These categories depend upon whether weather information is the result of centralized guidance, intended for local consumption, intended for distribution to the public "as is" (e.g., warnings and watches) or as value-added products, and the nature of collection and dissemination technology. If dissemination of weather service information is a guide for ITS, one can expect a wide variety of different approaches.

G. Role of Government, the Private Sector and Volunteer Organizations

The federal. government and the private sector have formed a partnership for the provision of weather related information that is fundamentally quid pro quo. The NWS provides a variety of basic weather services for free or at a price sufficient to cover costs while, with a few exceptions, the private sector distributes it through the mass media. For example, the NWS disseminates free weather warnings, advisories and bulletins to radios and TV's. The mass media packages this information and more widely disseminates it to the general public. Because of this type of arrangement, only a modest fraction of federal weather service funding and staff resources goes to dissemination of information. Were dissemination entirely a public responsibility, staffing requirements and corresponding costs would be much larger. Moreover, the weather information would probably be less widely available and the public benefits correspondingly less.

The mass media also purchases certain types of information for a nominal price, repackages the information to make it more attractive and useful, and then disseminates it to the public. The media earns revenues from these value-added products and service from advertising sponsors, billing their viewers and listeners, or sometimes through volunteer contributions, as in the case of public TV and radio.

From time to time there have been calls to completely privatize the NWS. In the current budget climate, there is extreme pressure to privatie. In the past, calls to privatize the NWS have been rejected on a number of grounds. First, there are high administrative costs to switching over to a completely private system, although private providers would be subject to the discipline of the market place and would be more likely to control on-going costs. Second, it has been argued that weather information is a universal public service to which all should be entitled. Third, more people benefit when government provides basic services either for free or at a price that covers costs in comparison to the number of people who benefit when there are just private providers. Some people who now receive weather service information for free or at prices that cover costs would be unwilling to pay for it at higher prices sufficient to earn the private sector a profit. Fourth, there are large economies of scale in pooling the enormous amount of weather related information and performing centralized analysis and guidance in forecasting. Many feel it is better that the public sector be the monopoly provider of these centralized functions than a private firm.[140]

An interesting feature of the national weather service historically is that in addition to public and private sector resources, volunteers have played a major role in the generation of weather information. NOAA's NWS sponsors a Cooperative Weather Observer Corps composed of nearly 10,000 volunteers. These are a mixture of local citizens, corporations, and governmental agencies. Vacation resorts, prisons, monasteries, churches, zoos, radio-TV stations and so on operate these volunteer stations. Collectively, over a million hours of time is donated each year. Many individuals have made daily measurements for over 30, 40 or 50 years. These records are invaluable time series for research.[141]

H. User Fees

As the discussion above makes clear, the NWS generally makes weather information services available either for free or at a cost sufficient to cover hookup and annual maintenance costs. Most of the information is disseminated through the mass media but some of reaches the public directly. Much NWS information is enhanced by the private sector and resold at higher prices. Since the Reagan Administration there has been increasing pressure to charge fees that would recover the full costs of weather information or even to charge fees that are commensurate with fair market value.

A report prepared in response to President Reagan's plea to approve his proposals for more widespread imposition of user fees argued that it would be unwise as a matter of public policy for the federal government to collect user fees because of the benefits of the quid-pro-quo arrangement between the public and private sector. This report argued further that charging user fees for specialized services such as aviation, marine and agricultural services would be unwise in some cases on equity grounds, in other cases because the weather service is essentially a public good, and because of administrative costs. [142]

The Omnibus Budget Reconciliation Act passed in October 1990 authorized NOAA to sell its data, information, and products at fair market prices rather than only for the added cost provision as in the past. The act calls for collection of user fees not exceeding $2 million in FY 1991 through 93 and not exceeding $3 million in FY 1994 and 95. Certain products named in the act can be excluded from added fees:

- Warnings
- Watches
- Exchanges under international agreements
- Those for non-commercial use of government and non-profit institutions.

Concern has been expressed that an increase in fees could put weather information out of reach of the majority of private weather organizations potentially resulting in loss of quality of service and economic utility to the end users and general public. according to the Committee on NWS Modernization of the Commission on Engineering and Technical Systems of the National Research Council such a policy could vitiate the policy that the private sector be the primary means of dissemination.[143]

I. Lessons for ITS

An attractive option for the ITS community is to follow the model of the NWS in implementing ATIS. There has been a partnership between the public, private and volunteer sectors in the collection, analysis and dissemination of data and weather information. Government has seen its responsibility as providing centralized guidance in weather forecasting and trying to minimize harm and economic costs associated with severe weather. Government, either directly or through the private sector, offers certain basic services for free or at price sufficient to cover costs, although there is some movement in the direction of pricing weather information according to its market value. The private sector offers value-added products and services, or may in effect have a concession from the government to sell certain NWS information, as occurs through the GTE NOAA Weather Wire. In a similar vein, government could assume responsibility for providing centralized information management and traffic management, as well as the dissemination of link travel times. The private sector could provide non-basic and value added ITS services, as well as play a major role in the dissemination function. Possibilities of volunteer contributions should *not* be ignored. In some metropolitan areas, volunteers already play an important role in serving as probes in order to help gather link travel times.

XIII. CHAPTER THIRTEEN — ELECTRIC POWER GENERATION, TRANSMISSION AND DISTRIBUTION[144]

A . History/Diffusion

1. The Early Years (1879 to 1932)

The first serious electricity experiments began in Europe as early as 1730.[145] However, it was not until the industrial revolution approximately a century and a half later that the real potential for electricity drew any sizeable attention. Across the ocean in Cleveland, Ohio, Charles Brush invented the arc light on April 29, 1879, and shortly thereafter Cleveland demonstrated the first electric street lighting system in the country. The year 1881 marked the first time that statistical information became available, when a total of one municipal and 7 private companies were in the street lighting business.[146] Although Brush was one of the earliest pioneers, he was not alone in his experimentation. His chief rival was none other than Thomas Edison. Working with a franchise given to him by the New York City Board of Alderman, Edison developed and implemented a central power station and distribution system for that city, which began operating on September 4, 1882.

By the early 1880's, a number of electric illuminating companies had expanded their domain to include the street-car business. In this way they could provide power both for cars during the day and street lights at night. Finding new ways to utilize electric power allowed these companies to take advantage of the economies of scale inherent in larger, centralized generating plants.

Alternating current systems were introduced in 1886, which enabled transmission over longer distances. The growing popularity of central stations and long transmission lines led to centralization of the power companies, causing smaller, private companies to consolidate in order to compete.

2. Competition

Tension began to build in the power industry by the close of the 1880's. Intense conflicts arose both between rival companies and between the companies and city governments. Banking on the belief that open-market competition among companies would yield the least expensive rates, some municipalities had granted franchises to every company that applied to provide electric service.[147] Where demand was heavy in some commercial districts, companies vied vigorously for patrons. By contrast, in areas where there was only need for a few lights in each house, no access to electricity was available.

In these early years, acquiring investment capital to establish new electric companies was difficult, and funds that were available went mostly for further expansion in already serviced communities. Since returns on the necessarily enormous initial investments came only after a very long period of time, and franchises were usually awarded for much shorter periods, potential investors tended to shy away from this high-risk situation.[148] The result was that many municipalities initiated their own electric systems because of the difficulty that private companies had in raising funds to invest. Statistics indicate that by 1902, a total of 3,620 central electric stations was in operation -- 2,805 owned by private companies and the remaining 815 by municipalities.

Introduction of hydropower caused considerable controversy, since by this time transmission technology was more advanced and inexpensive power could be brought to areas much larger than the region in immediate proximity to the water source. Despite the fact that Congress retained control over the nation's rivers, private companies often attained the rights to water power development. The 1906 Congressional Reclamation Act stated that surplus power from reclamation dams could be sold, with preference given to "municipal purposes," such as street lighting and water pumping. The identity of the purchaser was of no interest to Congress, only the purpose for which the power would be used.[149] This 1906 Reclamation Act was the first of many "preference" provisions enacted by the Congress in the electric power field. Since that time more than 30 statutes of a similar nature have been passed, and are now collectively recognized as "public preference clauses.[150]

Competition within the electric power industry intensified and became more problematic. Operational costs were driven sky-high by the construction of duplicate lines and power plants, and based upon the uncertainty it created in the industry, competition became a major stumbling block to acquiring new investment capital.[151] One effect was that the most financially and politically successful companies bought up smaller companies in a blatant effort to reduce competition. Unfortunately, this action brought about fear of these new electric utility giants due to their political and financial power. This concern, coupled with the fact that municipal electric utilities were now able to undercut prices of the private companies by nearly half, spurred the growth of public power systems. During the period of 1897 to 1907, each year between 60 and 120 new public systems were created through referenda, at a rate of increase more than twice that of private companies. The year 1912 saw the operation of 1,737 public power systems and 3,659 private companies.[152]

3. Regulation

In 1898, Samuel Insull, of Chicago Edison and president of the National Electric Light Association (NELA), argued against competition in the electric power industry, saying instead that the best electric service at the lowest possible price could only be obtained by granting a monopoly to one entity operating in a given territory. Insull proposed that state governments regulate the companies to be granted exclusive local franchises. In 1905, a report commissioned by the National Civic Federation recommended that the issue of electric utility ownership should be decided by each community. Despite this suggestion, at the 1907 NELA annual meeting it was proposed that implementing regulation would end "the necessity or excuse for municipal ownership by securing fair treatment for the public."[153]

By 1916, regulatory agencies operated in 33 states.[154] However, even from the beginning doubts were raised as to the extent that state regulation of private utilities would protect consumers. Meanwhile, with their monopolies secure the electric companies flourished. Holding companies emerged, which brought several Investor-Owned Utilities (IOUs) under common ownership. Although these agencies were exempt from regulation when they operated in more than one state, the actions of any given utility were governed by the regulatory agency of its individual state. Complaints filed in courts by consumer groups often failed to win judgments due to their understandably limited financial resources. In the end, though, competition for service areas between public and private power systems continued with devastating rate wars the result of each side attempting to outdo the other.[155]

4. Concentration

The rise of the holding companies precipitated a surge of mergers between 1922 and 1927, in which over three hundred small private companies were acquired each year by these conglomerates. When it was over, fifteen private utility holding company leaders dominated 85 percent of the country's electricity. By 1923, a peak had been reached in public utility service whereby 3,066 public systems served one out of every eight electricity consumers. During the next four years, however, this number diminished by 746 public systems.[156] One of the reasons for this decline was that the private companies had the ability to expand, taking advantage of cost savings from scale economies in generation, while municipal systems could only supply power within the city boundaries. As a necessity, the small public systems began to purchase more and more of &heir power from the private companies that could generate large amounts of it less expensively. In 1907, fewer than 7 percent of these systems bought all requirements from private companies, but by 1923 the number had grown to over one third.[157] In this way, a trend developed for private electric utilities to specialize in electricity distribution. An effect of this action was that IOUs had increasingly more control of the power supply and thus could exploit the small public systems that were forced to purchase their electricity at inflated prices.

During the 1920's, growing dissatisfaction with state regulation enabled Franklin Roosevelt to gain support for his dream of a power industry "regulated" by public ownership acting as a "yardstick" for IOUs. Roosevelt's philosophy said that government competition was a better alternative to regulation, and that individual communities should have the right to exercise municipal ownership over their own electric utilities. This theory later became known as the National Power Policy.

B. Lessons for ITS

The establishment and growth of the electric utility industry in its early years has a close relationship to transportation as result of the direct connection between the development of the electric utility industry and electric trolleys. Moreover, there are strong parallels to ITS and ATMS/ATIS in particular. Central power stations can be seen as an analogue of traffic management centers, transmission lines the analogue of telecommunication trunk lines and wide area networks, and distribution systems the analogue of the part of ITS that reaches into businesses and homes.

Economies of scale associated with traffic management centers argue for severely limiting their number within a metropolitan region in order to achieve cost savings, to avoid duplicative right-of-way acquisition and installation of wire-type communications (e.g. fiber optic cable), and to avoid destructive competition. While unlimited franchises may not be appropriate for advanced traffic management centers, they may be appropriate for ATIS. However there is a danger, as experienced in the initial years of the utility industry, that franchisees will target only the most profitable markets, which in many cases will be those already served, and leave less profitable, and unserved markets alone. Were ITS to follow this pattern it could result in significant equity and political problems. The early history of the electric power industry also indicated that franchises must be awarded for a period of time sufficient to allow private firms to earn a reasonable return on capital otherwise they will shy away from the investment. ITS is also subject to development of new or competing technologies just as generation of alternating current superseded direct current. There appears to be a parallel in ITS regarding the emergence of wireless communications that at the minimum will complement or at most compete and eventually supersede wire communications.

Ownership of one or more portions of the triad of generation, transmission and distribution of electricity confers on the owner potential market power regarding other portions of the triad. The same will be true for ITS. This means, for example that monopoly power over the control of the generation of traffic information, potentially can result in undue influence on the price charged to firms or public agencies implementing or selling ATIS systems and services. It is one thing if a government agency that owns a traffic management center decides that traffic data should be distributed for free to all comers. It is another thing if a franchise monopoly is granted to a single firm to set up a traffic management center and the firm charges prices that are excessive in relationship to the cost of generating traffic information.

There is a clear precedent in supplying electric power to giving preference to municipal customers as opposed to private customers, especially public utilities. In the ITS arena this might translate into a giving preference to public customers of traffic and traveler information over private customers, especially when the information has been generated using taxpayer dollars. This is not necessarily good public policy, however, since the benefits of ITS are likely to be maximized by not discriminating against any class of customers.

Another potential lesson from the electric utility industry is that public providers of traffic and traveler information can be the basis for "yardstick" competition. Public providers of such information would serve as a competitive benchmark against which private providers must compete from the standpoint of pricing and service quality. It should be noted that there are other ways to impose competitive pressures to keep down costs and increase service qualities. 'One of these is to ensure markets are "contestable" and there is always the threat of new entrants.

C. From the New Deal to the Eisenhower Years (1933 to 1952)

Passage of the Tennessee Valley Authority (TVA) Act in 1933 marked the first of President Roosevelt's power policies to be implemented. Also included in this policy was the subsequent creation of the Public Works Administration (PWA), the Bonneville Power Administration (BPA) and the Rural Electrification Administration (REA). The general purpose of these agencies was to encourage the development of public and cooperative power systems.[155] The 1935 Federal Power Act (FPA) was passed in an attempt to reduce abuses by IOUs in interstate transmission and bulk (wholesale) power transactions by having the Federal Power Commission, the federal regulatory agency at that time, regulate the rates in these activities.[159] As part of The New Deal's campaign against the investor-owned electric utilities federal legislation was enacted with the aim of breaking up the private holding companies.[160]

Today five federal power agencies market electricity from 132 hydropower projects throughout all parts of the country except the Great Lakes region and New England.[161]

The purpose of the Public Works Administration (PWA), set up in June 1933, was to stimulate employment by supplying loans and grants to state and local governments for various public welfare and infrastructure projects, including public power systems. In terms of municipal power systems, the PWA was most significant in establishing the acceptability of revenue bonds as a means for financing these ventures.[162] It was believed that private lenders often withheld their funding from municipalities desiring to establish public power systems, out of sympathy for the private companies.[163]

Despite the fact that electricity enjoyed a widespread commercial use in the United States by 1900, in 1935 millions of Americans still did not have electric power. Many of these people lived in outlying areas, and only about 10 percent of farms had central station electric service. In response to this need, President Roosevelt issued an Executive Order in August 1935 that established the Rural Electrification Administration (REA) as a rural electrification banker. This agency provided low-cost loans to construct generation, transmission, and distribution systems. From this funding farmers and rural businessmen established their own electric cooperatives, building the facilities to serve their specific needs. As a result, during the next 40 years, the percentage of farms with access to electricity escalated from about 10 percent to over 90 percent.

1. State and District Power Systems

During the span from 1932 and 1950, the creation of state and district electric power agencies was authorized by various states. These agencies, which could provide electricity beyond city limits, were therefore better able to exploit economies of scale inherent in central generation. Statistics indicate that as of March 1, 1939, 77.7 percent of all PWA loans and 56.2 percent of all grants made to non-federal electric power projects were given to these state and state-chartered power projects.

Another type of agency created during this time was the public utility districts (PUD's), which are area-wide government entities set up to provide electric and water services. By the close of World War II, eighteen states had authorized the generation of PUD' S.[164] In common with municipal systems, PUD's are owned and operated by the people they serve. From 1933 through 1952 the installed capacity of the different state and district power suppliers rose from 155,000 kW to 1,648,000 kW.

2. Municipal Electric Systems

The years 1933 through 1952 saw a net total of 163 new municipal electric systems created, many aided by PWA loans and grants. The municipal percentage ownership of total utility generating capacity grew from 5.7 percent (1,966,000 kW) at the beginning of 1933 to 7.3 percent (6,019,000 kW) by the end of 1952. However, municipal utilities still needed to purchase much of their power from other sources. Without the formation of PUD's, municipal systems simply could not obtain the economies of large-scale generation, and thus could obtain power more cheaply by buying it from either federal sources or IOUs than by actually producing it.

3. Investor Owned Utilities (IOU's)

Two pieces of federal legislation, the Public Utility Holding Company Act of 1935 and the Federal Power Act of 1935, did much to impact the activities of IOU's.

The Public Utility Holding Company (PUHC) Act of 1935 attempted to decentralize control of the country's power supply by forcing the partial breakup of the private conglomerates that controlled over 80 percent of the nation's power supply, and prohibiting ownership of controlling shares in utilities by banking firms. While the purpose of this law was plainly to reduce the size of individual IOU's and to put a wedge between the utilities and Wall Street, its effect is disputable. To begin with, exceptions were made right away which allowed nine of the major holding companies to remain intact.[165] Second, this Act did little to discourage the close relationships between Wall Street firms and power companies, although now control by banking firms was not employed as directly.[166] Lastly, according to some the law had no consequence at all, only resulted in "the same thing just wrapped up in a different package."[167]

The intent of the Federal Power Act of 1935 was also to reduce potential abuse of industry power by IOU's. This law gave the Federal Power Commission (FPC), which was predecessor to the Federal Energy Regulatory Commission (FERC), the task of overseeing wholesale bulk power contracts, while it prohibited private utility executives or directors from holding positions with other utilities or with banking firms except with approval from the FPC. Nonetheless, immediately following the passage of the Act, hundreds of applications to the FPC for exemption were granted.[168]

During this time the generating capacity owned by IOU's doubled, although it declined in overall percentage ownership within the industry since the generating capacity of publicly-owned facilities grew at an even faster rate.

D. Lessons for ITS

Strategies designed to encourage the rapid deployment of ATMS and ATIS also need to apply a steady and balanced approach over the long run and avoid swinging back and forth from approaches that emphasize competition one day and government control the next, which marked the early history of the electric power industry.

As in middle years of the electric power industry, municipalities and other governmental entities deploying ATMS/ATIS will struggle to achieve the cooperation necessary to achieve economies of scale and system reliability. The challenges of inter-jurisdictional cooperation are enormous. The electric power industry addressed this problem in part by establishing Public Utility Districts and power pooling arrangements. In the case of ITS, the question is whether Metropolitan Planning Organizations can serve this function, and what legal requirements or authority might be necessary in addition to that which exists today. Significant questions remain regarding whether localities will be willing to sacrifice home rule and autonomy to subsume certain transportation responsibilities under a regional umbrella.

The concentration of market power in the hands of a few firms can be a significant problem, but it also seems that anti-trust actions did little to mitigate it in the electric power industry. Government needs to pay close attention to the concentration of firms in different elements of ATMS and ATIS.

The electric power industry was slow to address rural needs, resulting in remedial action by Congress. ITS America and the Federal government have identified Advanced Rural Transportation Systems as a separate category of ITS. This seems to be an action of appropriate foresight and could head off opposition to ITS from rural quarters or congressional action necessary to remedy an overemphasis on urban areas.

ITS could well benefit from being a major contributor to job creation just as the Publics Works Administration did in the 1930's for various infrastructure projects including power systems. The job creation ability of ITS could strengthen its public support and help speed its deployment.

E. From the Eisenhower Years to the Early 1970's

Private electric utilities fared rather well until 1965. Due to steadily increasing demand, they enjoyed continued scale economies in generation, which maintained low rates despite the rising price of coal.[169] However, underneath the surface were concerns which could potentially harm the industry. Despite the fact that utility plant investment by IOU's appeared to be in (correct) anticipation of demand, in a 1962 paper two academic economists named Harvey Averch and Leland Johnson claimed that this type of regulation was causing over-investment in order to expand the base on which the allowable rate of return was calculated.[170] In addition, the scale economies in generation, which had seemed endless since the late 1800's, began to diminish. As the costs of fuel, capital and operation rose, utilities did not raise rates (because they were either unable or unwilling to), and in this way the demand kept growing. However, after 1965 the cost of a kWh no longer declined as output grew, and the elevated demand could no longer be met by supply at an equal or lower price. By 1970, the industry began to raise rates, and demand growth, which had been so steady since 1900, began to taper off.[171]

1. Public Systems

For the first few years of the Eisenhower administration, a “no new starts” policy on federal power projects was in effect, although the generating capacity at federal plants continued to rise as projects begun during the Roosevelt administration came on line. For example, in the case of TVA, the wholesale distributor in its area, constant expansion of its generating and transmission facilities was necessary to keep pace with the demand. Nonetheless, public power systems suffered a distinct drop in popularity from the Roosevelt era to the Eisenhower administration. Municipal electric system numbers declined, from 2,025 in 1952 to 1,980 in 1960 and to 1,924 by 1971. During this time, municipal systems continued the trend of buying power from outside sources.

In an effort to keep up with the private sector, some municipal utilities organized themselves into joint action agencies in attempts to derive the scale economies and reliability identified with power pooling arrangements. These same organizations later became active in antitrust actions to obtain entry into regional power pools, to obtain partnerships in nuclear plants and pumped storage, and to obtain wholesale (wheeled) power from IOU’s.[172]

Power pooling was an old concept that had been utilized during the 1920’s by large private companies to squeeze out smaller competitors. During the 1950’s and 1960’s. though, especially with the arrival of nuclear power, pooling among privately- and publicly-owned utilities allowed joint exploitation of resources. The unusual public-private partnership that developed from these pooling adaptations brought about an affiliation of public and private electric utility interests unseen since the dawn of the industry.[173] Of course, this alliance was seen as one of economic necessity, rather than friendly co-existence.

The development and control of nuclear power was a crucial issue. The Atomic Energy Act (AEA) of 1946 was created to manage the development of atomic energy and to assure preference to publicly-owned electric utilities for any power generated by federally-funded and built nuclear power plants. The basic understanding at the time (though not explicit stated in the law) was that atomic energy development was to be kept out of the private sector. However, the private electric utilities did not agree with this opinion and therefore fought for their increased control of and involvement in atomic energy. The private companies also sought to repeal parts of the PUHC Act to allow IOU’s to combine resources so as to construct nuclear power plants. During that time it was difficult for anyone to express their disagreement with the positions of the private companies, lest they be branded a communist sympathizer for supporting public sector control during the Cold War era.[174] In 1954, President Eisenhower signed a new AEA which allowed private development of nuclear energy.

By order of the 1970 AEA Amendments, the Nuclear Regulatory Commission (NRC) produced antitrust reviews as part of the licensing process for new nuclear power plants. Under these rules, the NRC was required to evaluate the effect of licensing on the access of small systems to bulk power supplies and transmission capacity.[175]

2. Reliability

During January 1965, a loose connection in a relay at a South Dakota power plant caused a blackout that quickly expanded to include six other states in the Midwest and left more than two million people without power. This disaster was blamed, in part, on the high level of interconnections among power companies in the area.[176]

In a comparable incident ten months later, the "Northeast blackout" disabled the power supply in six states and two Canadian provinces. This time, an operational interruption knocked out a relay, causing 30 million peopleover an area of 80,000 square miles to be without electricity within the space of twelve minutes.[177]

The growing number of power failures such as these two created the impetus in Congress for legislation that would increase the reliability of transmission systems. The private companies, who wanted to maintain autonomy over their own networks, offered to voluntarily increase reliability. In 1968, nine regional power councils banded together to form the North American Electric Reliability Council, which would oversee power planning. By the mid-1970's, nearly all of the federal private, public and rural co-op power systems were managed by twenty-seven regional power pools.[178]

F. Lessons for ITS

Economies of scale and the regulatory environment were particularly favorable to large private utilities up until the mid-1960's. It is likely that telecommunications companies (and possibly also automobile companies) playing a significant role in ITS will also fare well and through their market power, earn particularly attractive returns for their investors, perhaps levels high enough to attract criticism from academics and the public. High rates of return may be warranted given the risks of investment, but if the public comes to see advanced traffic management and traveler information services as being a public utility and therefore a right, just as the provision of gas, electricity, and telephone service is perceived as a right in a modem society, there could be a backlash.

The challenges of ensuring reliability in supplying electricity have proved to be great, and major blackouts and brownouts are by no means unknown. ITS will need to explore a variety of institutional mechanisms to ensure reliability just as the electric utility industry has. It is unclear how far to take the analogy of the electric power industry, but it is possible that localities may have to ban together in ITS Districts (perhaps under the aegis of the MPO) in order to provide a counterbalance to powerful firms or organizations supplying traveler information in order to ensure reliable and low cost service.

G. The 1970's and Early 1980's

Several major events during the 1970's impacted the electric power industry. In 1973, an oil supply crisis ensued as a result of Middle Eastern oil producers stopping direct shipments to the United States, and OPEC nations increasing the price of their oil several-fold. This crisis had financial repercussions on the electric utility industry, which had to deal with higher costs and decreased sales.

In April 1974, certain financial problems caused Consolidated Edison to sell some of its facilities to an agency in the State of New York. The company also was obliged to omit its common stock dividend, the result of which made people seriously reconsider investing in electric utilities. This incident forced investors to realize that utility securities were not always 'blue-chip,' but could involve some financial risk.

A third important event was the passage of the Public Utility Regulatory Policies Act (PURPA) in 1978. During the 1970's, citizen coalitions argued for development of solar and other renewable energy sources. The Ford Foundation Energy Policy Project released a report in 1974 stating that the gross national product would continue to increase at a reasonable rate after 1985 without further growth in energy consumption. Several labor unions adopted strong pro-solar, anti-nuclear platforms. The pinnacle of this crusade was the passage of PURPA in 1978, the content of which encouraged conservation and efficient use of energy and mandated that power companies purchase power generated by small independent facilities, thus helping to decentralize control of the power supply.

Two additional incidents nearly brought the industry to a standstill. The first was the core meltdown and escape of radiation at the Three Mile Island plant. The second was the largest municipal bond default in history when cost estimates for five plants in the Washington Public Power systems escalated from $4 billion to $24 billion, and consumer demand collapsed as part of the public outcry.[179]

In the aftermath of these incidents, the electric utility industry was troubled as the 1980's began. Nuclear power was arrested with the cancellation of 103 nuclear reactors between 1974 and 1986, with no new orders placed since 1978. On top of that, the industry's projection that demand would grow at the traditional rate of 7 percent per year dropped to an average of 2 percent.[180] As a result, many utilities were caught carrying excess capacity and could not take advantage of the scale economies that had been anticipated by investment decisions. Faced with rising costs, utilities were forced to boost rates, which made demand for electricity fall even further.

H. Lessons for ITS

ITS, if it finds itself on a trajectory of rapid and successful deployment will always be subject to external changes or unexpected structural change that could suddenly arrest its development. The ITS community, including those responsible for implementation, need to continually engage in strategic planning that assesses the threats and opportunities to successful deployment and respond to the threats. ITS America may prove to be an extremely important institution for carrying out this task. Complacency or lack of vigilance with respect to potential implementation problems could undermine rapid and successful deployment.

I. A Snapshot of the Industry in the Late 1980's

This section will complete the historical overview by looking at the industry as it was approaching the 1990's. Comparing various segments of the industry on the basis of several measures of electric utility performance permits basic quantitative conclusions to be reached.

- Public power companies (numbering 2,203 facilities in 49 states) outnumber private power companies (numbering 213) by more than ten to one, as seen in Table 1. Started in 1935, the rural electrics now comprise the second largest group, numbering 924. There are 13 federal power agencies and 59 joint action agencies.[181]

- Private IOU's dominate the industry in terms of kilowatt hour generation and sales, with the largest installed capacity (measured in kilowatts, abbreviated kW, or megawatts, abbreviated mW) and the largest percentage of power, claiming about 77 percent of both totals (Table 2).

- Most local public systems distribute much more electric power than they can create, thus their share of kWh sales to ultimate customers at 15.1 percent is much higher than their share of kWh generation of 8.5 percent. Public utilities purchase power from IOU's and federal producers to make up the difference in what they generate versus what they actually sell to consumers.

Table 1

NUMBER OF SYSTEMS IN THE ELECTRIC UTILITY INDUSTRY, BY OWNERSHIP, 1986

Ownership	Number	Percent of Total
Major Private Power Companies	190	5.50%
Non-major Private Power Companies	2	3.67
Local Publicly-Owned Systems, including municipals, public Utility districts and state and county systems	2,203	64.50
Joint Action Agencies	59	1.70
Rural Electrics, including 865 distribution co-ops and-59 G & T co-ops	924	27.00
Federal Power Agencies	13	0.38
Total	3,412	100.00

Source: American Public Power Association, Public Power, 1988 Directory, Washington D.C., 1988.

- Close to 103,000,000 customers are served by the electric utility industry. Of that number, about three-fourths of them are served by IOU’s. The remainder of the consumers are served by municipals (13.6 percent) and rural co-ops (11 percent). Because they sell virtually all of their power wholesale, federal agencies serve only one percent of ultimate customers.

- The majority of the nation’s long distance transmission lines, which carry electricity at high voltages and allow the economical transfer of bulk power, are controlled by IOU’s. According to Table 3, IOU’s own 482,798 (78.8 percent) of the total circuit miles of overhead electric lines (22,000 volts and above). The remaining transmission lines owned by federal, rural and local public systems total 129,131 miles.

- Despite the fact that IOU’s produced 77.5 percent of the total amount of electricity generated in the nation, the percentage of generation by private versus public utilities varies widely from state to state. For example, all of the generating capacity in Nebraska is publicly owned, while in Washington D.C., Hawaii, New Hampshire, Pennsylvania, Rhode Island, and West Virginia, none of the generating capacity is directly controlled by the public sector. In most states, however, somewhere between 70 and 100 percent of the generated electricity is privately produced. Other than Nebraska, the states with a higher-than-average public share include Alaska, Arizona, Colorado, Kentucky, North Dakota, Oregon, South Dakota, Tennessee, and Washington.

- Non-utility capacity in this country is growing, with this group comprising 3.5 percent of the total generating capacity available, a figure which reflects an increase in share of 10 percent over 1985.[182]

J. Lessons for ITS

If the composition of electric power industry around the year 1990 is measure of a mature industry, the following can be expected to occur with regards to ATMS/ATIS when they reach a mature stage of deployment.

- By virtue of the large number of municipalities, counties, states, and regional planning organizations there will be many more public providers of ATMS/ATIS than private providers.

- Private providers will provide most of the useful information furnished customers, and serve a greater number of customers than public providers.

- Individual localities may produce and supply some of the information and management systems for ATMS/ATIS but the balance will come mainly from private providers.

- Private companies are likely to control long distance transmission of data for ATMS/ATIS despite the fact that public providers will furnish most the traffic management and information.

- The relative mix of public and private provision of ATMS/ATIS will vary around the country.

These outcomes are by no means certain to result. In fact, traffic management centers are much more likely than electric generation plants to be publicly owned and operated, because of public agency concerns about relinquishing responsibility and control over traffic management. Advanced traveler information systems are another story, however, and are more likely than electric power to be supplied by private firms.

K. Recent Trends in the Electric Utility Industry

Currently, the outlook for the electric utility industry is one of change and uncertainty. Both the structure of the industry as well as its federal regulation is changing. In addition, environmental concerns and technological advances present more uncertainties. The key trends are as follows:

- Despite a comeback in consumer demand, recovery has not been geographically uniform. Some areas still possess an excess generating capacity, while in the northeastern United States, projections that reserve margins would fall below acceptable levels by the early 1990's[183] were confirmed by brownouts during the winter of 1993-94.

- Because of the regional differences in supply and demand, economical transmission of power between geographic areas becomes crucial. At this point, the demand for transmission service in and across some networks has outgrown the capacity of those networks. In addition, often it happens that the transmission line owner is not involved in the power transaction. For this reason the issue of setting a separate price for transmission has been raised. The Federal Energy Regulatory Commission for some time has been evaluating transmission access and pricing regulatory reform.

- In 1987, the United States demand grew at the average rate of about 4.5 percent.[184] If demand continues to grow at this rate, the country will encounter serious shortages of electricity by the year 2000. Since the lead time for much power plant construction exceeds ten years, utilities must plan now for increasing generation capacity in the future.[185]

- Several problems haunt the need for new capacity. In the first place, since current regulatory and market changes make it difficult to accurately predict returns on investment, many utilities are not particularly eager to sink capital into new plants. Second, concern about the greenhouse effect and acid rain has placed pressure on the power industry to reduce reliance on coal as an energy source. However, consumers are still opposed to nuclear power in certain areas.

- Coal-fired power plants are also under scrutiny by Congress, which is proposing that utilities be required to install expensive pollution control equipment in these plants. In addition to discouraging the construction of new coal-fueled generation capacity, these proposed regulations may promote the closure of existing plants where the cost of refitting is too high.[186]

- Electric utilities, for the. most part have fully accepted the potential role of pricing and conservation in meeting demand.

- The emergence of a variety of telecommunication technologies to support broad band data transmission have made smart home technology for load management an attractive option for utilities seeking to satisfy demand. Furthermore, electric utilities, like cable and telephone companies have wires directly to homes and businesses, which makes it possible for them to play a major role in linking them to the emerging national digital information superhighway.

L. Lessons for ITS

The ITS community needs to pay attention to some issues that have become evident as a result of recent trends in the electric power industry. One is that there can be excess capacity in one geographic area and shortage of capacity in another, posing major management challenges. Scarcity of radio frequency spectrum, lack of communications infrastructure and costs may result in shortage of communication capacity in some areas, while there may be an abundance in others. A corollary issue is whether there is a role for conservation and pricing to mitigate problems of insufficient capacity. Finally, new technological options are continually emerging, as they have recently in the electric power industry, and could force planners to rethink the most expeditious way to deploy ATMS/ATIS.

M. Technology

1. Generation, Transmission, and Distributibn

The electric utility industry is made up of three basic components: generation, transmission and distribution, which correspond respectively to the manufacture, transportation to the market, and the retail distribution of electricity. Although these general functions may also apply to other products, the difference in this case is that electricity travels from its point of generation to the point of ultimate use in a continuous flow at a speed approaching that of light, and thus cannot be stored in its original form.[146]

Generation of electricity, which is the production of electrical energy from mechanical or thermal energy, usually occurs at a large central station. However, usually the power station is not near the consumers and so the power must be transmitted over high voltage lines, often over long distances. Once reaching the consumers' neighborhood, the power is stepped down to a lower voltage at a substation, and finally it is sent through local distribution lines to the individual customers.

The most capital intensive industry in the country is the electric power business. Capital investment averages $35-40 billion each year with $3 or $4 of investment required to match every $1 of annual revenue.[187]

2. Sources of Power

To generate electricity, the utility industry has employed a wide variety of fuel sources, beginning with coal. With the advent of long distance transmission, exploitation of hydropower sites began. During the 1960's, environmental problems associated with burning coal became an issue that forced many utilities to switch to oil. Ironically, recently many of these same utilities are switching from oil back to coal in order to cut down on foreign oil dependence. Although natural gas has always been considered a clean, efficient fuel, fears that the supply of natural gas was insufficient convinced the federal government that electric utilities should reserve that fuel from 1965 to 1970. The early 1960's saw the emergence of nuclear power plants, although environmental opposition, changing rules for construction and safety, and skyrocketing costs impaired the growth of nuclear power.

Using different fuels implies trade-offs between capital and fuel (or fixed and variable) costs.[188] For example, coal and nuclear fuel have the lowest fuel cost, yet the highest capital cost. By contrast, oil and natural gas have greater fuel costs, but require lower capital investments. Gas-fueled internal combustion has the highest fuel and lowest capital cost power. Generally, plant capacity for base-load generation depends on low fuel cost, high capital cost plants. Supplemental fuel for peak load requirements is usually more costly, but does not require enormous capital investments for reserve capacity.

Although coal has been the dominant fuel for nearly all of the industry's history, other energy sources have been used in varying degrees since 1960. Right now the power industry employs solar energy, cogeneration techniques, refuse-driven facilities, and wind technology, in addition to oil, gas, nuclear, and hydro power for creation of electric power.

A 1988 report indicates the division of non-utility capacity (which made up 3.5 percent of the total available in the United States in 1986) as follows:[189]

Gas	33%	Wind	7.5%
Biomass	19%	Hydro	5.0%
Coal	17%	Solar	0.5%
Oil	3%	Geothermal	1.0%
Waste	11%	Other	3.0%

N. Lessons for ITS

ATMS/ATIS together have elements of generation, transmission, and distribution just as the electric power industry does. Furthermore, unless wireless technology is used, ITS will require a technology a bit analogous to substations for local distribution of information to drivers/motorists, which may very well take the form of area processors and controllers for managing the information flow to and/or from beacons, signals, video cameras, changeable message signs, and so on. Because of the technological parallels there is likely to be institutional parallels. One of these is the question of whether a central authority or local authorities should have control over local distribution.

ITS may also find that in the long run it is subject to substitute sources of management and information that pose competition to the major suppliers, just as independent suppliers and alternative fuels have emerged in the electric power industry. There is a need to accommodate this possibility in designing an architectural and institutional framework for the deployment of ITS.

0. Private Sector Economics

1. Institutional Mechanisms for Power Supply

Ownership of the electric utility industry in the United States can be broken down into three segments: the investor-owned electric companies (often referred to as "privately-owned"), government-owned electric power agencies (also called "publicly-owned"), and the cooperative sector comprised of rural electric cooperatives. The public segment of the industry is then divided into four categories: (1) federal power agencies, (2) municipal power systems, (3) state and district power agencies, all directly owned by various government entities and (4) joint action agencies, which are power pooling organizations composed of municipal and rural co-op utilities.[190]

Each ownership segment of the industry does not necessarily perform all the basic functions of generation, transmission and distribution to ultimate customers. One of the few groups that generally carries out all three operations is the investor-owned utilities (IOU's). Federal power agencies typically only generate and transmit electricity, leaving distribution to other agencies that purchase their power wholesale. While federal power agencies serve some industrial plants and a few residential and commercial customers, these sales are generally only a small fraction of their overall sales. Nearly all municipally-owned electric systems are of the distribution-only type, with the exception of some of the larger ones which generate, transmit and distribute electricity. As for state and district power agencies, this group is divided in that about one-quarter generate and transmit only, an additional one-quarter perform all three functions and, the remainder distribute only. Joint action agencies, for the most part, are involved strictly in power supply, providing both the generation and transmission of electric power. Last, rural electric cooperatives come in two categories: those that generate and transmit electricity, also known as Generation and Transmission (G&T) cooperatives, and those that also sell to ultimate customers, distribution cooperatives. [191]

2. Costs of Electric Power

The U.S. Department of Energy has collected data, reported in Table 2, that indicates the average (per kWh) cost of producing (including any purchasing of power) has been generally lower for private companies than for public companies. However, since 1977, average costs for transmission have run higher for private systems. In comparison, privately-owned electric utilities have incurred greater average distribution costs (per customer) than have public since 1965. By 1986, private systems reveal higher average production costs (as well as transmission and distribution), in part because of changes in data collection created so as to increase comparability between public and private systems. The areas of customer accounts and administrative and general expenses have always had lower average (per customer) expenses in privately-owned systems.

Before the oil embargo of 1973 the price of a barrel of oil was under $2.00, making it economical to use oil fired plants to provide electricity base loads. However, as energy prices rise sharply from $15 to more than $40 dollars a barrel due to actions of the Arab Oil Cartel, strong economic incentives emerged to convert to other forms of energy and to conserve energy. Although prices have retreated dramatically today, the threat of higher oil prices continues to loom in the future.

In the 1970's and 1980's sharp increases in oil prices, nuclear power plant costs, inflation, interest rates, and debt service costs hit utilities. The cost of decommissioning generating facilities, especially nuclear plants, also blindsided the utility industry. For example, the cost to decommission the Wolf Creek Nuclear Plant in Missouri was estimated by the regulatory commission staff and utility to be $103 million, and the same procedure for the two Susquehanna units in Pennsylvania was estimated at $303.7 million.[192]

These changes not only severely impacted the electric power industry, but also strained the regulatory framework in which private power companies operate. Regulators were caught trying to mediate between customers opposing rate hikes and utilities attempting to recoup their operating and capital costs. In addition, the regulatory process could not keep up with changes in the external environment: rates were altered only following a motion of a utility, commission, or some other party and

Table 2

**AVERAGE ELECTRICITY COSTS,
PUBLIC VS PRIVATE ELECTRIC UTILITIES
(1946-1986)**

OPERATIONS	Production Per kWh Sold (in mills)		** Transmission Per kWh Sold (in mills)		Distribution Per Customer (in dollars)	
	Public	**Private**	**Public**	**Private**	**Public**	**Private**
1946	$4.35	$4.30	$0.27	$0.14	$9.37	$9.19
1950	4.96	4.68	0.26	0.13	12.04	11.77
1955	4.42	4.68	0.26	0.13	14.18	13.79
1960	4.20	4.70	0.25	0.15	16.19	10.24
1965	3.98	4.34	0.21	0.15	17.48	17.93
1970	4.76	4.61	0.23	0.15	22.14	24.15
1971	5.49	5.25	0.24	0.16	22.82	25.41
1972	5.97	5.71	0.25	0.16	24.13	26.02
1973	6.70	6.47	0.26	0.17	25.52	27.53
1974	10.72	8.01	0.29	0.18	26.46	29.98
1975	12.70	9.35	0.31	0.21	27.63	31.78
1976	13.73	12.04	0.34	0.29	29.5 1	34.18
1977	15.87	13.28	0.35	0.54	31.76	33.78
1978	17.27	14.37	0.37	0.64	34.81	35.94
1979	19.69	16.32	0.40	0.67	37.68	38.17
1980	24.14	20.16	0.43	0.68	41.90	44.83
1981	27.89	23.53	0.48	0.81	45.19	48.97
1982	29.00	24.64	0.56	0.86	50.62	53.80
1983	28.55	25.85	0.60	0.92	54.06	57.36
1984	29.20	26.26	0.64	0.95	57.71	59.43
1985	29.52	28.91	0.69	1.01	60.53	62.04
1986*	27.26	30.47	0.72	1.79	60.97	73.16

Table 2 (continued)

AVERAGE ELECTRICITY COSTS, PUBLIC VS PRIVATE ELECTRIC UTILITIES (1946-1986)

	MANAGERIAL			
	Customer Accounts Per Customer		Administrative and General Per $100 Revenue	
	Public	**Private**	**Public**	**Private**
1946	$3.73	$2.82	$7.22	$6.11
1950	4.44	3.35	7.90	6.85
1955	5.33	4.00	6.73	6.59
1960	6.38	4.94	6.29	6.31
1965	7.06	6.15	6.23	5.80
1970	8.86	7.98	5.87	6.25
1971	9.61	8.77	5.84	6.06
1972	10.31	9.18	5.88	5.96
1973	11.33	9.55	5.78	5.79
1974	13.26	10.61	5.19	5.65
1975	15.25	12.33	4.98	5.14
1976	16.34	14.50	4.99	5.09
1977	17.17	12.75	4.94	4.68
1978	18.59	15.87	5.11	4.64
1979	20.25	16.41	5.21	4.24
1980	22.5 1	18.40	5.08	4.45
1981	25.82	20.87	5.05	4.22
1982	28.97	23.33	5.42	5.17
1983	30.08	24.47	5.57	5.19
1984	31.82	25.16	5.54	5.69
1985	33.31	26.02	5.85	5.51
1986*	34.86	29.01	6.27	6.01

* Data for 1986 are not comparable with previous years. The 1986 data for public power systems reflect expanded coverage of utilities, with adjustments to increase comparability between private and public systems.

** Production costs include the cost of any purchased power.

Source: U.S. Department of Energy, Financial Statistics of Selected Electric Utilities in the United States, 1986. February, 1988.

usually only after a long hearing process. Regulation's lack of responsiveness to a wide scope of external pressures forced commissions to confront many of the flaws of electric utility regulation.

Theoretically, it is possible to identify operating costs using accounting records for fuel, labor, materials and costs of wholesale purchases from third parties. Most commissions determine capital costs by multiplying an estimate of the nominal cost of capital by the depreciated cost of the book value or original costs of its assets. During the 1970's and early 1980's, large growth in new construction costs compelled regulators to adopt a number of more realistic and expedient procedures that departed from earlier regulatory practices. These amounted to providing supplements to the permissible rate of return, permitting automatic fuel and gas price increases and enlarging the rate base which allowed IOU's and other utilities to meet their cash flow requirements to finance construction and cover their capital costs. In some cases IOU's and others were forced to write off major losses when major investments were deemed imprudent or not "used and useful."

In granting utilities permission to add generating capacity, regulatory commissions have had to confront new economic realities partly resulting from the success of conservation and non-traditional sources of power frequently supplied by independent power producers. In the past, regulatory agencies merely examined whether additional generating plants were suitable for meeting base, intermediate or peak loads. However, success of conservation and new alternative fuels has demonstrated additional options for satisfying demand. Since the 1973 oil embargo, conservation, cogeneration, active and passive solar, and wind have been provided on a broader scale. Though relatively minimal in contrast to oil, coal and nuclear generation, non-utilities made up 3.5 percent of the country's generating capacity and 4.3 percent of generated power in 1986.[193]

Among those involved in the electric utility industry there is some concern that non-utility generators may be short-term entities, whose contribution to supply may change depending on economic conditions. Because non-utilities are not "obligated to serve," the amount of electric power they supply could be volatile, affected by conditions in the markets for electricity or other goods produced by these companies. This circumstance makes non-utility sources potentially undependable and thus increases the uncertainty associated with reserve capacity planning.

3. Rate Regulation and Customer Costs

Virtually every state has the power to regulate consumer rates charged by private utilities. By contrast, the regulatory body governs the rates of public utilities in only about a dozen states. Also every state regulates private utility sales to public utilities and governments, only one-third of the states regulate sales of public utilities to such public agencies.

The lack of state agency control concerning the rates of public utilities does not imply that no government rate regulation exists. Public utilities are required to provide service at reasonable rates and without undue discrimination under common law. The rates of publicly owned or cooperatively owned utilities not under state regulation are usually determined by municipal governments or other non-state jurisdictions.

Those regulatory commissions that have the power to control rates of privately owned electric utilities can require prior approval for rate changes, suspend proposed rate changes, and initiate rate investigations. In most states these regulatory agencies have the authority to prescribe temporary rates pending an investigation, and institute a plan for automatic periodic changes in rates to mirror those of fuel costs. Almost all regulatory commissions provide for formal or informal representation of parties to a proceeding. Formal representation may be attained by a People's Counsel or State Attorney General, while informal representation refers to the right of interested parties to intervene in rate proceedings.

According to Table 3, residential customers of private electric utilities paid an average of 1.91 cents more for each kWh used in 1986, as compared to customers of public electric utilities. Also, the average charge for a kWh of electricity from publicly-owned systems to commercial and industrial customers (at $.0129) was 13 percent less than from investor-owned systems.[194] Customers of privately-owned electric utilities have always paid higher rates, on average, than have customers of publicly-owned systems. The average residential IOU customer (who consumed 8,608 kWh in 1986) used 20 percent less electricity than the average residential customer of publicly-owned utilities (at 10,306 kWh).

As a result of the Public Utility Regulatory Act of 1979, states were required to consider six rate making and five other standards that would directly affect IOU's and large public utilities.

- Cost of service
- Declining block rates
- Time-of-Day rates
- Seasonal rates
- Interruptible rates
- Load Management Techniques
- Master metering
- Automatic adjustment clause
- Information to consumers
- Termination of service
- Advertising

Regulatory commissions of nearly every state considered each standard, and most have voluntarily adopted rules pertaining to the majority of them, which has had a direct affect on utilities under their regulatory authority. The same holds true for unregulated utilities with sales over 500 million kilowatt hours. As of December 31, 1986, between 52 and 95 percent of the utilities surveyed by FERC had adopted each standard. For instance, 85 percent approved a cost of service standard. Eighty-three percent opted to eliminate declining block rates where they were not justified by costs. Seventy-four percent adopted load management techniques. A smaller fraction instituted time of day and seasonal rates, 60 percent and 67 percent, respectively. Eighty-five percent approved the standard related to notification of service termination and 68 percent agreed that all consumers should be given clear and concise explanations of existing and proposed rate changes. [195]

Regulated utilities were more likely to take final action than non-regulated utilities. Looking at state regulated utilities, the ratio of adoptions to final actions was higher than for unregulated utilities for seven of the eleven standards. Although recent published data does not permit, a breakout by investor-owned versus public utilities, the first annual report on the progress in considering PURPA standards implies that a sizeable proportion of investor-owned utilities did in fact adopt most of the standards.[196]

Despite the fact that this regulatory program has been basically voluntary since it only requires that decisions be made on whether or not to adopt the PURPA standards, it nonetheless has had a significant effect on the distribution of electricity and retail costs. Over 50 million residential and close to 7 million commercial and industrial customers have been affected positively by cost of service standards alone. [197]

Table 3

AVERAGE KWH CONSUMPTION AND CHARGE FOR ELECTRICITY FROM PUBLIC VS PRIVATE ELECTRIC UTILITIES (1946-1986)

	SALE STORES IDENTICAL CONSUMERS				SALES TO COMMERCIAL AND INDUSTRIAL CONSUMERS			
	Average Annual kWh Consumption (per customer)		Average Revenue per kWh (cents)		Average Annual kWh Consumption (per customer)		Average Revenue per kWh (cents)	
	Private	**Public**	**Private**	**Public**	**Private**	**Public**	**Private**	**Public**
1946	1,298	1,739	3.29	2.32	28,110	22,475	1.50	1.29
1950	1,767	2,518	2.95	1.99	33,653	25,124	1.54	1.33
1955	2,573	3,824	2.76	1.69	49,038	38,329	1.45	1.19
1960	3,454	5,208	2.62	1.58	61,944	49,421	1.49	1.22
1965	4,618	6,634	2.39	1.53	79,201	66,396	1.40	1.18
1970	6,700	9,015	2.22	1.47	107,041	89,653	1.40	1.17
1971	7,039	9,378	2.32	1.56	110,973	92,778	1.50	1.26
1972	7,391	9,630	2.42	1.63	117,793	98,384	1.58	1.31
1973	7,742	10,080	2.54	1.70	124,0821	03,785	1.68	1.40
1974	7,550	9,797	3.10	1.94	121,1121	02,974	2.19	1.64
1975	7,830	10,125	3.51	2.33	119,3811	10,076	2.62	1.97
1976	7,840	9,539	3.78	2.79	125,2961	11,414	2.82	2.38
1977	8,256	10,791	4.06	2.79	130,6021	24,331	3.12	2.38
1978	8,453	11,383	4.31	3.00	132,610	129,874	3.39	2.65
1979	8,319	10,940	4.64	3.22	133,355	129,342	3.66	2.88
1980	8,53 1	10,744	5.36	3.77	129.499	124,586	4.38	3.41
1981	8,277	10,391	6.20	4.32	129,022	126,429	5.07	3.88
1982	8,252	10,188	6.83	4.74	122,096	127,807	5.72	4.31
1983	8,366	10,389	7.17	5.03	124,308	126,815	5.79	4.48
1984	8,556	10,344	7.54	5.29	132,214	128,801	5.97	4.62
1985	8,540	10,362	7.80	5.57	130,853	128,097	6.14	4.92
1986	8,608	10,306	7.78	5.87	128,263	121,042	6.08	5.28

Source: "Public Power Costs Less," Public Power, Volume 46, Number 4, July-August, 1988.

4. Wheeling and Transmission

Generation may potentially be substituted by transmission. Rather than building new facilities, localities or regions of the country which have insufficient capacity can simply purchase bulk power from traditional regulated and unregulated local franchise utilities, wholesalers, or small power producers. However, the acquisition of this power is dependent upon a mode to transmit it. Often when a utility purchases bulk power from another utility or a small power producer, the power must be wheeled, or transmitted, over the lines of a third party. In the late 1980's, nearly 10 percent of the country's electric generation requirements were achieved by wheeling.[198]

Although FERC has the authority to establish wheeling rates once a filing has occurred, normally these transactions are voluntary and are set up under a negotiated agreement or under a wheeling tariff applicable to all similar potential purchasers.[199]

Due to the growth in capacity supplied by small or independent power producers, the issue of whether wheeling should be accessible on demand or be mandatory was raised repeatedly during the late 1980's. Advocates of mandatory wheeling favor the creation of a spot market for electricity, but opponents are worried about adequate service and reliability. Questions have been raised as to whether wheeling prices would be properly designed so as not to be inefficient or result in a poor allocation of electricity and transmission resources. The issue of pricing wheeled electricity in terms of a large, interconnected grid is complex. Fear of being bypassed by end user purchases haunts traditional local franchise monopoly utilities, who claim this could result in higher rates for local customers and 'reduced revenues.[200]

To those fearing FERC may give monopolies pricing flexibility and the ability to collect monopoly rents, transmission access and pricing are crucial concerns.[201] FERC must deal with the wheeling issue through a lengthy process on a case by case basis. Each request for a wheeling order must be submitted and considered separately, after which a determination is made as to whether the request meets the statutory criteria for mandated wheeling listed above.[202] In general the courts have maintained that antitrust laws and the provisions the Federal Power Act transferred to FERC under PURPA do not give FERC the power to mandate wheeling, and FERC has limited authority to order interconnections. However, the NRC has incorporated into its construction permits and generating licenses a wheeling requirement which applies only to utilities with nuclear plants.[203]

Wheeling issues are intimately tied to FERC's rule making on competitive bidding. FERC is encouraging competition in the electric power industry, to guarantee a market for electricity produced by independent power producers, and to promote a price scheme founded upon incremental costs (i.e. avoided costs). Notwithstanding realignments taking place in the wholesale electricity industry, these independent power producers are a significant force in fostering competition, reducing the cost of energy supplies, and consequently bringing about lower and more equitable rates for consumers. Without adequately coming to terms with the wheeling issues, competitive bidding most likely cannot be successfully implemented.

P. Lessons for ITS

Private utilities (IOU's) fit within an institutional framework that appears to have similar complexities to the framework within which private companies will function in deploying ITS. This institutional framework is characterized by a large number of public and private actors, at the federal, state, regional and local level with public and private sectors having varying responsibilities for generation, transmission and distribution.

The experience of the electric utility industry indicates no prior conclusions can be drawn regarding whether public or private provision of major systems, such as ITS, is less costly.

Private sector economics in the electric utility industry was greatly influenced by the ability of the Arab Oil cartel to make oil relatively scarce and drive up prices. Those designing the ITS Architecture and specific systems need to be sensitive to the possibility of firms using their market power individually or as a cartel to drive up prices, and should identify safeguards. Antitrust laws should help prevent this from occurring but specific provisions in franchise agreements and other regulations may be necessary to ensure against price gouging.

The ITS system architecture and specific systems should also be examined to determine the sensitivity of users, suppliers, and operators to sudden rapid increases (or decreases) the price of travel and user services. The experience of the electric utility industry is that the run-up in price due to the energy crisis, problems with nuclear power, inflation and rising interest rates and debt service costs destabilized the traditional regulatory framework. Congestion pricing, for example, could have a similar effect on transportation and its institutions.

Establishment and regulation of fees for ITS user services might profit from an examination of pricing, cost allocation, and cost recovery issues that the electric utility industry has faced over the years. For example, each of the different rate structures that regulatory commissions were required to consider under PURPA are suggestive of alternative approaches to pricing ITS user services.

Suppliers of ITS users services at the local and regional level will incur substantial costs and will developed entrenched institutional interests. Just as in the case of the "wheeling issue" in the electric utility industry, competitive pressures are likely to emerge to undermine the traditional relationships between long distance telecommunications suppliers and local or regional suppliers of telecommunications services. Not only will new entrants become threats but it is likely new entrants will try to bypass traditional suppliers to reach end users. This type of contention is already evident among long distance, baby bell and other telecommunications suppliers. Conflict could also easily erupt along public/private lines, especially if significant taxpayer dollars have been invested in infrastructure to supply traffic and traveler information, and then suddenly a private provider bypasses the infrastructure to reach the end user, charges for the service and earns a profit, when the public sector had no intention of charging a fee for service.

Q. Role of Government

Legally, the authority to regulate electric utilities rests in case law, administrative rules, and federal and state legislation. Although a great deal of the law, rules and legal precedent has existed for some time, regulation by nature is evolutionary due to its adversarial character and the ability of old issues unearthed from case law to take on new life and force.

First and foremost, regulation is responsive to contemporary issues. Today's historical regulatory basis was a burning issue of public interest decades or even a century ago. For instance, the legal authority that regulates rates to protect against monopoly pricing derives from a court decision involving a public policy battle more than one hundred years old.

In the 1871 case of Munn v. Illinois, the U.S. Supreme court ruled that under its police power, the state could regulate grain elevator rates in Chicago because the vast majority of grain shipments, for all intensive purposes, was controlled by a monopoly.

Constitutional provisions strengthen Munn v. Illinois and other case law. The U.S. Constitution, Article I, Section 8, bestows on Congress the authority to "regulate commerce...among the several states." According to the Tenth Amendment, collectively known as the "police powers" of the states, the states may employ those powers not explicitly given to the federal government.

There is often conflict between the distribution of powers between the federal government and the states. However, the Constitution says that the federal government must prevail, since according to Article VI, "This Constitution and the Laws of the United States which shall be made in Pursuance thereof...shall be the supreme Law of the Land."[204] The Constitution's dynamic tension — both in regard to the roles of federal and state government and the checks and balances among the executive, legislative and judicial branches — is the crux of electric utility regulation. Although the final arbiter can always change, at any time federal and state statute, administrative rules and case law provide a reasonably secure framework for the regulatory process and specific regulations.

1. Sharing of Regulatory Authority Among Levels of Government

Regulatory functions may be carried out by administrative agencies, executive departments, or legislative bodies such as city councils. Mostly through statutory authority, but also through administrative or judicial powers, each group controls different types of utilities in various ways. Regulatory agencies at the local, state and federal levels exert varying degrees of influence over electric utilities depending upon their size, type of ownership (public, private or cooperative), and organizational structure, among other factors.

2. Publics and Local Regulation

The definition of a "public utility" is a publicly owned utility operated by a municipality or state governmental agency. Public power systems are regulated by city or town councils, independent authorities, or commissions. These agencies are the voice of the local consumer/owners in regulating rates based on cost, approving utility budgets, issuing long term bonds, and exercising the rights of eminent domain, among other responsibilities. Recently, a survey of 496 public power companies indicated that:

- A city council had direct control over forty-six percent of the respondents, while an independent utility board controlled the other 54 percent. Board members were either elected by the general population or appointed by the Mayor, City Council or the State.

- twenty percent of those surveyed had 15,000 or more customers, while the other 80 percent served less than 15,000; and

- under city governing boards, seventy four percent of the utilities controlled major management decisions (setting rates, approving budgets, fixing salaries) as opposed to only 35 percent of the independent boards.[205]

3. State Commissions

State commissions have various degrees of authority and power. Some are quasi-judicial, others are quasi-legislative, and some are both. For example, the California Public Utilities Commission may receive testimony similar to a court, issue decisions and orders, cite for contempt, and has the power of subpoena. In addition, it has a regulatory responsibility for rates, service financing and safety of utilities. By contrast, the Georgia Public Service Commission has authorization only to issue administrative orders.[206]

Nearly every state regulates private utilities, although only about 40 percent regulate certain facets of public utilities. Greater than two thirds of the states regulate cooperatives in one way or another.

4. Federal Regulators

There are three commissions at the federal level that have jurisdiction over electric utility activities, in addition to numerous other federal agencies with statutory authority to issue regulations affecting industry. The three principal federal commissions are:

- The Federal Energy Regulatory Commission (FERC). This agency inherited most functions of the former Federal Power Commission. FERC regulates electricity in two ways, through control of non-federal hydroelectric projects on federal waterways, and control of the interstate transmission and sale of electricity at the wholesale level.

- The Nuclear Regulatory Commission (NRC). This agency, which took over responsibilities from the NRC after the Atomic Energy Commission was abolished in 1974, is in charge of licensing and regulating civilian nuclear energy to protect the public health and safety, maintaining national security and ensuring consistency with antitrust laws.

- The Securities and Exchange Commission. This commission, which was established in 1934, regulates security practices on the stock exchanges including the sale of new securities. In 1935, the Public Utility Holding Company Act authorized the SEC to regulate the finances and corporate structure of electric and gas utility holding companies.[207]

5. Generating Capacity

Regulatory commissions exercise their control over generating capacity through their certification, licensing and permitting authority. These commissions attempt to modify the scale, the split between generated and purchased power, and the types of generating plants to anticipated demands of residential, commercial, industrial and other consumers. Normally utilities are able to meet short-run demands by bringing base, intermediate and peak load facilities on and off line in response to rotating load characteristics, and reductions and increases in electricity requirements that change throughout the day, the week and the year. On the other hand, long-run demands are apt to necessitate a different mix of facilities that reflects expectations about the economy, population growth, future prices, technological and other changes and uncertainties. Utilities may also meet their needs by use of purchased power or by encouraging conservation. Regulatory commissions in many states can influence whether a utility constructs new plants, promotes conservation by end users, or buys power to meet its capacity needs. The regulatory agencies normally can also control the mix of facilities (type and fuel) for new plants through rulings during various permit proceedings.

6. Certification, Licensing and Permitting Requirements

Regulatory agencies in various federal, state and municipal categories have the power to issue certificates of convenience and necessity, licenses or permits to begin service, build major additions to generating plants, or discontinue facilities and services. Certificates of convenience and necessity are given by regulatory bodies to permit entrance into a market and enfranchisement of a utility to provide service. Applicants must establish that proposed service is required by "public convenience and necessity," and the petitioner is "fit, willing and able" to supply the service in a fashion consistent with applicable regulations. Usually the state regulatory bodies will prescribe those territories where an electric utility may operate. Franchises and permits for electric utilities must normally be obtained from state or local regulatory agencies that issue certificates of convenience and necessity. This function may either be performed by state or local governments, but varies from state to state. Certificates and permits for hydroelectric power plants are issued by FERC.[208]

State regulatory agencies are authorized to require certificates of convenience and necessity for both public and private electric utilities for:

- initiating new service
- making major additions to existing generating plants
- constructing other major additions to generating plants
- abandoning facilities or service.

Although virtually all private utilities are state regulated in one way **or** another, only about two thirds must gain certificates of convenience and necessity from state commissions to initiate or abandon service. Because so many are under control of local boards or authorities, only a little more than one fifth of the public utilities are required to obtain such certificates to start or terminate service. Both public and private utilities may receive certificates to initiate or abandon service by commissions in ten states. After service begins, however, most public and private utilities are exempt from having to acquire certificates for major additions to generating plants or for other significant construction. In those states where utilities do have this requirement, it is usually applicable more to privates than publics. Cooperative requirements demonstrate a similar pattern to privates, but certificates for beginning or ending service need to be obtained in only about half the states.

Those state regulatory commissions with the proper authority will issue such certificates, licenses or permits for start-up or major expansions after assessing the cost of service including financing requirements, the rate structure and the revenue required in order to meet future capacity needs. Major concerns are the cost to provide base, intermediate, and peak loads, and the extent that electric consumers and investors will shoulder those costs.

Almost all states demand public notice of certification proceedings, a chance for public hearings, and lay out the rights of intervention in certification proceedings. A public hearing is mandatory in about three fifths of the states.[209] Generally the staff of the commission furnishes an independent appraisal, and further interested parties such as individuals, corporations, public agencies, and public interest groups are allowed to contribute to the proceedings.

The legal authority to set standards for certification belongs to the regulatory commissions in nearly a third of the states. These standards normally are comprised of the following issues:

- air pollution controls
- water pollution controls
- water rights and usage
- land use
- radiological control
- relative environmental im acts of alternatives
- projected utility needs.[210]

4. The Rate Base

State statutes which provide regulation of electric rates usually stipulate that the rates imposed must be just and reasonable. A major determinant of the rates charged is the rate base, which should closely mirror the cost of providing service while also reflecting a reasonable return on the cost of capital. The composite of generating plants has a significant influence on the rate base due to its effect on cost. For instance, whether nuclear or coal fired plants are chosen to meet base load needs is apt to have a significant effect on costs. In addition, the specific availability of major generating capacity may affect the rate base because of the way construction work in progress is incorporated into it.[211]

The statutory language is general in most states, and merely indicates that the regulatory commission assesses the property value to include in the rate base. As a result, it becomes necessary to regard agency rulings in proceedings to understand the method for determining the rate base.[212]

The regulatory focus on the rate base and the manner in which it has been calculated have provided the historical foundation to allow regulated utilities to cover their capital costs. States determine the rate base using three general methods. The first method is based on original cost, which is generally the initial cost less depreciation. The second method is "fair value," which as one textbook explains, is "a figure somewhere between original cost and reproduction cost, arrived at by the exercise of 'enlightened judgment' or by a specific formula."[213] The third method is prudent investment. A major means that regulatory agencies have used to deal with potentially huge unanticipated costs of generation is application of "a prudent investment test." With case law this principle developed in reaction to the concept of "fair value" for determining the way to evaluate costs for inclusion in the rate base. Justice Brandeis argued in an influential dissent in the Southwestern Bell Case that the amount prudently invested should determine the rate base and the amount of capital charge should determine the rate of return.[214] States such as Florida, North Dakota, and Pennsylvania now utilize prudent investment as the fundamental criterion in determining what capital expenditures are permitted in the rate base.[215]

Taking into account the safety and economic risks affiliated with large capital expenditures, many regulatory commissions employ the criterion of prudent investment as a test to assess whether costs for large additions to generating capacity will be permitted. On the grounds that they are imprudent, commissions may reject expenditures which are unrealistic in terms of future demand, population growth, relative economic costs of alternatives. safety risks, rate base percentage, ability of the utility to repay its debt, and other factors.

Regulatory bodies have also been investigating incentives to keep down cost elements in the rate base. Cost incentives are ideally perceived as performance measures that incorporate rewards for productivity improvements. From 198042, the Michigan Public Service Commission granted the utilities automatic price increases (without an official rate proceeding) equivalent to some general standard of inflation less an offset for total factor productivity improvements.[216] The state of New York sanctioned an incentive rate of return plan for the construction costs of the Nine Mill Point No. 2 nuclear plant. Guidelines addressing productivity and thermal efficiency were developed for evaluation on a case by case basis. Measures for plant productivity included a capacity factor, operations availability, forced outage rate, scheduled outage rate, and equivalent availability.[217] A simpler strategy for incentive regulation is to generate performance measures or industry benchmarks for comparable types of firms (by use of an approach like those of mass transit peer groups or diagnostic related groups in the mental health field), and give utilities rewards for improved performance relative to other group members.[218]

The different categories state commissions allow in a utility's rate base include:

- Land held for future use
- Property held for future use
- Allowance for funds used during construction
- Contributions in aid of construction - credit
- Advance payment
- Research and development
- An inflation factor
- Excess of cost over original cost
- Materials and supplies
- Allowance for working capital
- Customer advances - credit
- Accumulated tax deferrals credit
- Pollution control equipment.

Not many states allow an inflation factor or excess of cost over original cost in the rate base. The majority, although by no means all include land held for future use and/or property held for future use. Nearly all include an allowance for funds used during construction, contributions which aid in construction, an allowance for working capital, advances for customers, credit for accumulated tax deferrals, and pollution control equipment.

To cite one case, the Ohio Public Utility Commission, a regulator of nine private utilities and no public ones, calculates the rate base from original cost less depreciation for used and useful plant. Once that figure is achieved, a reasonable working capital allowance and an allowance for construction work in progress are added at the commission's discretion. From this number customer advances or deposits, contributions in the aid of construction, deferred taxes, and accumulated deferred investment tax credits if permitted under the tax code are then subtracted.[219]

The rate base in most states is influenced by financing for new generating capacity through the allowance for funds used during construction (AFUDC). There are two components of AFUDC. The first, an allowance for borrowed funds utilized during construction, embodies the capitalized interest charges relating to construction work in progress (CWIP). This component appears as a credit to interest expense charges on the utility's income statement, or in other words, negative interest. The second component is an allowance for funds used during construction and shows up on the income statement as an addition to income. During the accounting year, AFUDC balances represent non-cash income. As soon as the generating facility is in service, the utility attaches the AFUDC to the rate base and depreciates the capital costs over the life of the new facility, permitting private utility investors to earn a rate of return on the undepreciated balance.[220]

8. Fair Rate of Return

The rate of return is directly applicable to the rate base. Regulatory commissions typically use the Supreme Court Hope Natural Gas decision to ascertain what rate of return to permit regulated utilities. A fair rate of return on assets of a utility should be in accord with returns on investments assuming similar risk (the comparable return standard) and sufficient enough to attract capital (the capital attraction standard). Normally regulated utilities will also contend that the rate of return should equal the cost of capital.[221] Regulatory agencies employ many different methods to determine rates of return including:

- Capital asset pricing model
- Discounted cash flow
- Comparable earnings test
- Price earnings ratio
- Midpoint approach.[222]

Although regulatory agencies dictate an allowable rate of return, the actual rate of return may differ. The prescribed rates of return fluctuate from as low as 8.87 percent in Arizona to 16 percent in Vermont. Regulatory objectives of the commissions and market conditions affect the variation. The actual rates fall slightly under the prescribed rates in most states, although the actual rate may sometimes exceed the prescribed rate by a small amount.[223]

Whether involving taxable bonds, tax-exempt bonds, or securities, the cost of capital will affect the rate base and in turn alter revenues depending upon the rate of return.

9. Transmission

As a result of the current situation in which there is an excess supply of electric power in some areas of the country but a capacity shortage in other parts, it is becoming more and more acknowledged that transmitted power is a viable substitute for generation. Within-regulatory circles, intense debate has occurred concerning the role transmission of bulk power can play in meeting local and regional demands.

As mentioned above, the chief agency responsible for rules and pricing for the interstate transmission of electricity is FERC. This organization has the power to investigate, issue, transfer, renew, revoke and enforce licenses for the construction, operation and maintenance of transmission lines and power houses. FERC also has authority to establish, review, and enforce rates and charges for the interstate transmission or sale of electric energy and interconnections.[224]

As certified by the Public Utilities Regulatory Policies Act of 1978, FERC is additionally authorized to perform the following acts:

- To order physical interconnections between applicants and electric utilities (Section 202).

- To order wheeling of electrical power if it is (1) in the public interest or (2) would conserve energy, promote efficient use of facilities and resources, or improve the reliability of the electrical system (Section 203). FERC is required to report findings concerning the economic loss, burden, effects on reliability, and ability to render adequate service due to the order. The agency may not order an increase in generating capacity to obtain compliance with a requirement to wheel.

- To exempt electric utilities from State laws, rules or regulations that prohibit voluntary pooling under certain circumstances (Section 205).

- To require public utilities to promptly report any anticipated shortages which would affect their ability to serve their wholesale customers, to submit contingency plans, and to accommodate shortages in such a way as to have minimum adverse effect on the public health and welfare (Section 206).[225]

In addition to PURPA's many other provisions, FERC is also required to examine automatic adjustment clauses at least every four years and to study methods to improve the reliability of service to electric consumers. The state commissions play a significant role in ensuring reliability. Utilities regulated by FERC must also submit detailed cost and accounting data.[226]

State regulatory commissions have control over intrastate transmission and sitting of transmission facilities, assuming there are no interstate ramifications. Regulatory agencies require certificates of convenience and necessity to construct major additions to transmission lines for private utilities in 30 states, for public utilities in 16 states and for cooperatives in 22 states. Both private and public utilities are subject to the same certification requirements for major additions to transmission lines in 15 states.

The authority of states to regulate rates on electricity that is resold is more limited compared to their authority to regulate generation, mostly due to FERC's function as a controller of transmission and wholesale electricity. Regulatory commissions can control resale rates from one private utility to another in 27 states, but from private to public utilities in only 22 states. Nine states regulate sales from public to private utilities and eleven states regulate sales between publics utilities.

10. Distribution

In terms of distribution, regulatory issues arise from the requirement of utilities with local monopoly franchises to furnish retail service to all customers. State regulatory agencies have the power to require certificates of convenience and necessity for major additions to distribution lines for private utilities in 20 states, for public utilities in 9 states and cooperatives in 14 states. This authority applies to both private and public utilities in 8 states.

As for distribution itself, each class of customers must be charged fair and reasonable rates. All rates proposed by public, private or cooperative utilities must be evaluated and approved by the state commissions which regulate those particular jurisdictions.

To determine rates, regulatory commissions evaluate many different issues, including the availability and costs of electricity from different means and sources, equity within and between classes of customers, the impact on rate of return, and the ability to service debt. Rate proceedings frequently deal with special issues such as lifeline rates and master metering.

R. Lessons for ITS

All levels of government, federal, state, regional, and local, are likely to exert varying degrees of regulatory control over ITS, just as in the electric utility industry. Regulations will vary from one level of government to another and from one jurisdiction to another. In some cases federal regulations will pre-empt regulations of lower levels of government and so will state regulations. The federal government can exert regulatory powers as a result of the interstate commerce clause of the U.S. Constitution. However, there will be a dynamic tension among the regulatory powers of different levels of government, as in the case of the electric utility industry.

City councils and independent boards responsible for ITS Districts, along with the governing boards of MPO's, will exert control over local and regional traffic policies and regulations, provided they do not conflict with state and federal regulations. And if there are conflicts, they may be tested before administrative law judges and in the courts if they cannot be resolved by other means.

Many state public utility commissions also regulate intrastate commerce. In recent years as a result of regulatory reform in the transportation industry, the role of these state commissions drastically declined. It is possible that their role will be revived as a result of ITS, particularly in regards to Commercial Vehicle Operations (CVO) and the interrelationship between CVO and ATMS/ATIS. It is more likely, however, that regulatory matters concerning CVO will be left to state transportation departments, and those organizational units within DOTs involved in traffic operations, safety and intermodal planning.

Federal regulatory agencies, including the Federal Communications Commission, and the National Highway Traffic Safety Administration, can be expected to have a strong role in ATMS/ATIS where federal interests are involved.

Government agencies and regulatory bodies have traditionally exerted substantial authority over entry and exit from markets concerning the generation, transmission and distribution of electricity. In addition rates charged have been widely regulated in the electric utility industry, and if not, rates have been under the direct control of local utilities, cooperatives and so on. Government is likely to play nearly as strong a role in the provision of ATMS because of the natural monopoly characteristics of a traffic management center. We are likely to see franchising of ATMS in at least some regions of the country with restraints to prevent monopoly abuses. We are also likely to see franchising of ATIS, but the franchising environment may be more competitive and require less regulation.

ITS will experience regulation regarding issues such as air pollution and infringement of traffic on neighborhoods in a manner that is on a par with electric utilities.

Equity and fairness is likely to play a major role in the provision of ITS just as it has in the electric utility industry. Prices charged will have to be just and reasonable, and the rate of return to private investors must be fair. Many of the same issues that have arisen in the electric utility industry regarding what is a just and reasonable rate to charge and a fair rate of return will apply to ITS. For example, the base on which a private provider of a toll road with electronic toll collection can earn a return, is likely to invite much scrutiny. Questions will be raised as to what should be allowed in the "rate base" and how to calculate the cost of capital. Some of the same methods for determining rates of return used in the electric utility industry are likely to be applied to toll road providers or franchisees. Also if an ITS facility owned or operated by a private company fails, the question will arise as to whether the private firm or the government should be liable for the costs. Then issues such as whether the investment was "prudent and reasonable" will come into play.

XIV. CHAPTER FOURTEEN -TECHNOLOGICAL INNOVATION IN THE WATER SUPPLY INDUSTRY

As movers of water and people, the water supply and transportation industries share many common characteristics. Both industries have central management systems that regulate flow over their distribution networks. In both industries, the public sector plays a large role as owner, investor, and regulator of infrastructure. And both industries are reaching a crossroads in their historical evolution. Neither has the funding nor the need to massively expand their distribution network of streets and pipes. Instead, they are emphasizing more efficient management of their infrastructure to improve flow while simultaneously preserving and conserving their distribution networks.

To increase efficiency and promote conservation, the water supply industry is pursuing its own version of Advanced Traffic Management Systems (ATMS). In recent years, water utilities have enhanced computer and metering technologies that regulate water treatment and distribution, identify major leaks and priority repairs in the distribution system, and make possible peak and off-peak pricing. ATMS-like technologies could be the foundation of ATIS-like technologies in the water industry. However, relatively fewer profit opportunities may limit the application of ATIS in the water industry.

The water supply industry has not been as market oriented as the transportation industry. Paradoxically, this orientation has not thwarted private operators from entering the industry, but it has slowed down the pace of technological innovation. This case study will analyze how technology development is influenced by the historical evolution of an industry, its industrial organization, funding mechanisms, and regulatory structure. As a new industry, ITS has much to learn from the water supply industry, particularly since technology plays a similarly important role in coordinating demand and supply over a distribution network.

A. History of the United States Water Supply Industry

1. The Evolution of the Industry

Although the water supply industry is one of the oldest industries in the United States, it grew slowly. By 1800, the United States had only 16 waterworks, a considerably lower number relative to Europeans countries. Part of the reason for the disparity in growth rates was that slow sand filtration, the European technology for water treatment, did not work well in the United States. Many water systems using slow sand filtration could not successfully treat the turbid waters of North America. In the second half of the nineteenth century, American inventors and entrepreneurs refined and adapted rapid sand filtration. Even though rapid sand filtration was invented in Europe, it became identified as an American technology because of the innovations added to the filtering technique in this country. Rapid filtration fueled a rapid growth of public and private water systems. By 1900, almost all towns and cities with population exceeding 2,000 people had water systems.[227] Today, water systems still primarily serve geographic areas ranging from small towns to large cities. There are relatively few regional water utilities.

Early in the twentieth century, the water industry had matured to the point where companies had replaced individual entrepreneurs as a source of technological innovation.[228] Much of the research and development (R&D) in the industry was an outgrowth of federal government investment in military research during World War II. In the Manhattan project, the Roberts Filter Manufacturing and the DuPont companies refined dual media filtering technology for the atomic plant at Hanford in Washington state. Dual media refers to a filtering system that used two materials, sand and coal, for filtering water. In 1960, General Electric, which had assumed management of the Hanford plant, performed the first public demonstration of the applications of dual media filtering technology. Soon thereafter, dual media and then multi-media filtering systems became the standard rapid sand filtration system in the water industry.[229]

2. Modern Technology

A water utility or system retrieves water from a natural or manmade source, cleans it, and then distributes it to its residential and commercial customers. Utilities in the United States usually draw water from ground and surface water sources such as rivers or lakes. After the utility treats water in a three or four stage process, it distributes water to its customers through a distribution network of storage tanks, water mains and pipes.

The treatment process is not uniform throughout the country. The most extensive treatment process consists of flocculation, filtration and disinfection. After logs and other large objects are removed from "raw" water obtained from ground and surface sources, the utility directs water into a holding tank or sedimentation basin. In this tank, organic rot is removed from the water by flocculation; that is the rot coagulates around iron salts or polymers until it accumulates into heavy masses referred to as floc which sink to the bottom of the tank and are removed. Before the water leaves the holding tanks, it is further treated with caustic soda to reduce acidity levels, thereby preventing corrosion of lead pipes and associated lead poisoning. From the holding tanks, the water is passed through various dual or multi-media filtration systems described above to remove microorganisms such as crytosporidium that cause severe illnesses. Finally, the water is treated with fluoride and the disinfectant chlorine to kill other disease producing bacteria.

Utilities have varying degrees of treatment depending on the quality of their water sources. Some waterworks do not have a filtering stage because their sources of raw water have low turbidity and pollution levels. Likewise, low levels of turbidity allow other systems to skip the sedimentation phase conducted in conjunction with flocculation. However, the degree of variation within water treatment may narrow as a result of recent amendments to the federal Safe Drinking Water Act. Utilities that rely on surface water will now have to install filtering systems to protect against chlorine resistant bacteria like cryptosporidium.

The dynamic and variable treatment process requires a sophisticated management system. Turbidity and pollution levels in raw water can change daily or weekly due to fluctuating weather or industrial discharges. Consequently, utilities have to continuously adjust their chemical treatment of raw water to maintain their effectiveness in cleaning and disinfecting the water. The key to adjusting chemical treatment is frequent sampling of raw water to measure turbidity and pollution levels. Sampling methodology is an area that has experienced some of the most extensive improvements in recent years according to industry sources. Like the transportation system, the water system has to extensively monitor exogenous factors like the weather in order to prevent injury and insure the safe operation of its services.

Monitoring and controlling water flow from the supply plant to the distribution system is another management task aided by ATMS-like capabilities. Within the last decade, the water industry has adopted the electric industries' Supervisory Control and Data Acquisition (SCADA) computer technology. SCADA continuously monitors all aspects of water supply including storage levels and pumping pressure used to distribute water over the distribution network. By obtaining data on water demand from residential and commercial customers, SCADA technology can adjust the level of supply to meet varying levels of demand over the course of the day. This way, the water utility can achieve efficient, cost effective, and stable service delivery.[230]

SCADA interacts with metering technology throughout the distribution network to obtain information on levels of demand for water. Meters measure the hourly and daily rate of water consumption of individual customers as well as geographic subsections of service areas. Therefore, metering technology allows for demand management by enabling utilities to introduce differential rates for peak and off-peak usage. Also, metering technology enables the utility to establish priority needs for repair and rehabilitation in its distribution network. By comparing the level of water supply with the level of water passing through meters in the distribution network, the utility can determine the location of major leaks.

As with the transportation system, the need for advanced management systems is critical. Increasing equipment costs and diminishing sources of pristine water have spurred water utilities to reduce demand and encourage conservation. Also, aging distribution networks cannot accommodate huge increases in demand. In some older cities, particularly in the Northeast, pipes and water mains 70 to 100 years old consist of obsolescent materials and are thus more susceptible to ruptures, leaks, and lead contamination. Just like transportation agencies, water systems do not have the massive capital budgets necessary to simply ripe out and replace the obsolete sections of their distribution networks.[231] Also, like transportation agencies, they have a limited capacity to build more distribution networks and expand existing ones. Therefore, they have to identify priority repair needs and promote more efficient water usage in order to minimize wear and tear on the system. In other words, they need advanced management systems much as transportation systems need ATMS.

Dissemination of advanced management technology in the water supply industry has been relatively slow. Instead of developing advanced technology directly for its own needs, water utilities often adopt technology from other industries. Examples of adopted technology include SCADA computer technology, multi-media filtering systems, and some chemical treatments. Adopting and-improving technologies from other industries conserves resources and research funds. But this process can mean that advanced management techniques reach the water industry long after they have been implemented in other industries. For example, peak rate or volume rate pricing associated with metering technologies was practiced by only 15 percent of United States' water systems in 1992, up from a mere 8 percent in 1986.[232] In contrast, technologies permitting peak rate pricing have been utilized by the transportation and telephone industries for decades. Most industry analysts agree that technology in the water supply industry has evolved slowly from the 1940's to the present, with the most recent innovations in the areas of computerization and sampling techniques.

B. Economic and Institutional Barriers to Technology Innovation

Economic, political, and institutional barriers have combined to slow the rate of technological innovation in the water supply industry. The industry has had difficulty raising capital funds and R&D funds because most water utilities do not realize economies of scale due to their small size. Their smallness, in **turn,** is a political and sociological product of localism. Federal and state regulations have at times assisted and impeded technological change. The ITS industry can examine the history of the water supply industry to avoid the institutional arrangements that have unnecessarily retarded technological development.

1. The Impact of Industrial Organization on Economics, Funding, and R&D

Because most water systems serve small populations, they cannot realize economies of scale and raise R&D funds. On the other hand, the few large utilities can realize economies of scale and have been able to sufficiently fund technology development and acquisition.

The EPA estimates that the United States water industry contains. approximately 200,000 Public Water Systems (PWS). A PWS can serve residential, commercial, or institutional customers including school systems or hospitals. A subset of PWS systems are Community Water Systems (CWS). Approximately 60,000 community water systems serve year-round populations of residential customers.[233] About 88 percent of the CWS systems are small, serving under 3,300 customers. An additional 7 percent of the systems are medium (serving between 3,300 and 10,000 customers) and 5 percent are large (serving over 10,000 customers). Only 233 and 43 systems serve more than 100,000 and 500,000 people respectively. Although large systems constitute a tiny fraction of all water systems, they serve about 80 percent of the residential customers in the country.

While the overwhelming majority of public and private systems are small, a larger percentage of private systems serve under 3,300 customers. Ninety seven percent of the private systems are small compared to 78 percent of public systems. In contrast, around 22 percent of public systems are medium and large as opposed to 2 percent of their private counterparts.[234] Private systems are owned by investors, homeowner associations, mobile home parks, or individuals. Publicly owned water systems are either an agency in local city and county governments, or districts or authorities with higher degrees of autonomy.

Most water systems cannot accumulate significant funding for R&D or acquisition of advanced technology because they have tight operating and capital budgets. Humphrey and Walker document that operating expenses per unit of production increases by a factor of 5 from the largest to the smallest utilities.[235] The EPA suggests that only large utilities, serving over 10,000 customers, realize economies of scale in operations.[236] In other words, over 90 percent of water systems with customer bases under 10,000 people confront relatively high operating expenses. At the same time, they have difficulty raising capital funds because their smallness limits access to debt and equity sources. Their cost of issuing bonds is high because they cannot float large enough issues to realize economies of scale. Furthermore, their access to bank loans has diminished because of changes in federal bank regulations.[237]

2. Too Little Autonomy

Even though large utilities realize economies of scale, they too have trouble raising R&D and technology development funding. Their status as part of local governments (over 80 percent of large utilities are publicly owned, and most of them are a city or county agency rather than an independent authority) reduces their control over capital funding. Often their budgets are not even distinguished from other city agencies. Since treatment plants and underground water distribution networks are literally hidden from the public view, the water systems' capital budgets are susceptible to raids from other agencies and departments. Political pressure compels local governments to place a priority on visible services and infrastructure such as police or schools, sometimes depriving water systems of critical capital funds. The same dynamic occurs within municipal transportation systems. The capital budget of traffic control centers is sometimes diverted to the repair and replacement of roads and bridges which more visible parts of the system.

Relative lack of autonomy also limits the ability of public utilities to budget for operating expenses by adjusting rates charged to customers. Systems that are part of local governments confront political pressure to keep rates low, often preventing full cost pricing (rates cover operating costs) and marginal cost pricing (peak/off peak pricing and volume pricing). Even if they are large enough to realize economies of scale in operations, their inability to recover full costs from their rate structure may prevent them from accumulating operating reserves that could fund advancements in management techniques or technologies. Furthermore, institutional resistance to peak or volume pricing prevents demand management, that is moderating demand during peak times in order to conserve water and reduce wear and tear on the system.

Evidence suggests that water utilities experience less control over their rates and revenues than other utilities. In a report to the National Council on Public Works, Wade Miller Associates, Inc. documents that annual water utility rates have remained hundreds of dollars lower than electric, phone, and natural gas rates from the 1970's through the 1990's. Wade Miller Associates also report that the more autonomous public systems, water districts and authorities, have been more successful in recovering full costs from their rates.[238]

Private water utilities also experience institutional obstacles to adjusting their rates. In 45 states, the private systems have to obtain approval of public utility commissions (PUCs) for rate changes. The few large private utilities, only 500 in the country, possess the financial expertise to successfully justify rate adjustments and increases. On the other hand, the small private utilities often cannot document in a satisfactory manner why they require rate increases. As a consequence, their applications for rate adjustments are often rejected.[239]

3. Too Much Autonomy

While too little autonomy hampers control over operating and capital budgets, too much autonomy restricts opportunities to merge systems and thus attain economies of scale. Consolidation possibilities are plentiful since about one-half of small systems are located in SMSA's or metropolitan areas often served by larger systems.[240] But because the water supply industry developed small town and city-based systems, public officials jealously guard control over their water utilities. Parochialism thus thwarts attempts to merge local systems into more economically viable regional systems. Private systems also exhibit localism. A large number of small systems owned by homeowner associations or individuals oppose any suggestions that they consolidate with more viable and efficient systems. The transportation industry, like its water supply counterpart, confronts a turf mentality that impedes more economical regional arrangements. Sometimes, local traffic management systems resist entreaties to merge or collaborate in order to improve regional traffic flow.

Instead of consolidations, the most prominent form of restructuring in recent years has been contracting out operations and management by the small systems. This has resulted in economies of scale in operations and management in cases where a contractor manages the daily operations of a number of smaller systems in a geographic area.

4. Who Are the Innovators of Technology?

With tight capital and operating budgets, water utilities have scarce funds for developing and acquiring advanced technology. The large utilities have been able, for the most part, to acquire the latest advanced management technology. However, acquiring advanced technology is often beyond the realm of possibility for the smaller utilities, the great majority of water systems in the country. Technology transfer and dissemination occurs in the water supply industry, but on a limited scale.

The water industry's trade association, the American Waterworks Association (AWWA), operates a research organization, the AWWA Research Foundation, that is funded by sliding scale contributions from member utilities. Since the contributions are adjusted by the volume of annual water production, the large utilities contribute more than the small systems and are, in effect, providing a cross subsidy for R&D. The Research Foundation conducts R&D in all aspects of water treatment and distribution. Its annual research budget averages $6 million dollars. For industry research consortia, this is a relatively small budget.[241] By way of contrast, the microelectronics and semiconductor industries have recently formed consortia with annual budgets of tens of millions of dollars.[242] To some extent, this is an unfair comparison because the water supply industry does not generate R&D funding from profitable operations in domestic and international markets as the microelectronics and semiconductor industries. But it indicates, that even if the water industry restructures itself, it cannot be expected to be a leader in technological innovation.

Although the AWWA Research Foundation has undertaken valuable research, the major source of technological innovation in the industry is the equipment suppliers. These are the private sector entrepreneurs that manufacture and sell advanced management technologies ranging from enhancements for water treatment to computer technology for regulating water demand and supply. As stated above, many of these entrepreneurs are companies in the other industries, such as the chemical industry, that tailored their products for the water supply industry. They resemble telecommunications companies who are eager to apply their technology to the ITS and transportation industries. In addition, market niche companies have been established to develop technologies for small water systems. One such technology is package plants that are manufactured and then transported to the water system for installation. For small utilities, package or prefabricated treatment plants offer a cost effective alternative to on-site construction of treatment plants. Package plants are not the dominant form of treatment plants for small systems, however, because manufacturers have encountered regulatory resistance to them.

5. The Impact of Regulations on Technology Development

Although the water supply industry is one of the oldest public services in the country, government at all levels did not regulate it extensively until recently. One of the major pieces of federal regulation, the Safe Water Drinking Act (SDWA), was passed in 1974, almost two centuries after the first waterworks appeared in this country. On the local and state level, public agencies are responsible for monitoring the quality and safety of drinking water and reporting their monitoring activities to the EPA. The late development of regulations did not endanger the safety of United States drinking water, which is of high quality and safety.[243] However, the regulatory lag contributed to primitive construction of some small water systems and delayed the introduction of advanced technology to the industry.

Simultaneously, the contradictions of too little and too much regulation of different levels of government retarded the technological development of small systems. On the one hand, minimal regulatory requirements prior to the SDWA act allowed small system operators to save expenses by installing skeletal systems. As the EPA report for Congress states, ". ..all that was required was a well, a pump, a tank, and *perhaps* (italics added) a chlorinator" (for disinfection).[244] Many of the small systems operators are developers of residential sub-divisions or mobile home operators who viewed water provision as an ancillary function instead of a main function of their business. Now, that final rules have been issued on the 1986 amendments to the Safe Drinking Water Act, small system operators will have to elevate the priority they place on their water service. The EPA estimates that over half of all small systems will have to restructure themselves and upgrade their technology to comply with the SDWA rules regarding treatment of surface water and the abatement of lead and copper contamination.[245]

For several years, the lack of federal regulations combined with the heavy paternalistic hand of state regulatory agencies to delay the introduction of package plants for small utilities. While the absence of federal regulations eliminated the threat of penalties for using primitive, technology to save costs, state regulators resisted package plants which are considered by the EPA to be safe and cost-effective technology. Wade Miller Associates asserts that state regulators approach technological developments with a conservative attitude, wary of approving new technology for fear that it could endanger the public safety. Also, design engineers that specialize in treatment plants constructed on-site often serve as consultants for the installation of small systems. Generally speaking, they add to regulatory conservatism by opposing package plants as untested technology.[246] Very likely, the conservative regulatory attitude contributed to safety by preventing rapid introduction of untested technology, but it also blocked some safe and efficient technologies.

The EPA has been promoting the standardization of regulations across state boundaries as a method for enhancing technological dissemination and development. While Wade Miller Associates claims that the usual low-bid procurement process prevents equipment suppliers from generating adequate R&D funds,[247] EPA emphasizes that the unevenness of state standards has slowed down the market for new technology such as package plants. A lack of reciprocity (if one state approves a specific technology, states within a region automatically approve it) entails a laborious marketing process under which equipment suppliers have to approach each state separately to seek regulatory approval for new technologies. To alleviate this burden, the EPA worked with Western states to develop the Western protocol, a set of common approval standards that makes reciprocity possible. The EPA's "Small Systems Low Cost Technology Initiative" seeks to promote protocol arrangements throughout the country as well as provide detailed information to states on the safety and reliability of recent low cost technologies.

Now that federal and state agencies are improving the coordination of regulatory standards, it seems as though a combination of regulatory sticks and carrots will speed technological innovation in the water supply industry. States including Alabama, South Dakota, and Connecticut have established regulations and programs that coerce or entice struggling small systems to merge with their larger counterparts so that they can improve their technological efficiency. The Clinton administration has also addressed the chronic budgetary squeeze of water systems by proposing a revolving loan fund that will be available to public and private systems for technology upgrades necessary to comply with the SDWA amendments. To avoid the continuation of financial inefficiencies such as the lack of full cost pricing or autonomous capital budgeting, the EPA counsels approval of loans contingent on financial reforms.[248]

6. Lessons for ITS

The water supply and transportation industries provide infrastructure for distributing services across networks. Thus, both industries employ similar advanced management technologies that promote safety and efficiency in moving goods and people. As one of the oldest industries in the United States, the water supply industry offers instructive lessons as to which institutional frameworks to utilize and which to avoid in the pursuit of technological innovation.

7. Size, Economies of Scale, Autonomy and Accountability

Historically, water systems developed as local service providers. In the eighteenth and nineteenth centuries, one water system per town may have been able to realize economies of scale to generate sufficient revenues. They may not have had to devote any resources to R&D because they may have been able to rely on the local inventor/tinkerer for technological innovations. But as time marched on, it became clearer that larger size and regional collaborations and consolidations, would improve the cost effectiveness of operations to the point where R&D and technology 'acquisition could be funded. Traditions of local control did not give way, in many cases, to imperatives of economics and technology.

In a number of cases, the resistance to regionalism may have been motivated by a legitimate desire to maintain accountability to the public for the safety of drinking water. As the service became regional and control seemed more remote, local political leaders and their constituencies may have feared that community concerns would be overlooked by a distant and autonomous regional authority. Even regional authorities whose board of directors include public officials from participating jurisdictions often appear to be unaccountable.

Although institutional arrangements cannot completely resolve the tension between economies of scale and local accountability, the transportation industry, like the water supply industry, ought to pursue regional entities with as many accountability mechanisms as possible. In addition to establishing board of directors with equitable representation from participating jurisdictions, regional authorities ought to involve the citizenry in the decision making and planning processes. Sometimes, local political officials oppose regional authorities out of a fear that their constituencies would feel that larger service providers will shortchange their needs. Citizen advisory committees, town hall meetings, surveys, and public education campaigns can overcome this political barrier by demonstrating how regional authorities can operate more efficiently and thus provide everyone with better services. Furthermore, these types of citizen participation mechanisms can generate creative suggestions for service improvements from the citizen/consumer perspective, ideas that may not occur to the service provider. Also, politically difficult changes in service, such as periodic rate increases, may become easier to implement if citizens are involved from the start in a consensus-building quest for equitable sacrifices rather than having such sacrifices imposed from on-high by a remote entity.

The water supply industry, like its transportation counterpart, is a recent convert to increasing citizen participation in the decision-making process. Devoting its entire November 1993 journal to discussing and promoting citizen involvement, the American Waterworks Association states that most systems surveyed had established participatory planning mechanisms within the last year or two. The survey indicated that citizen participation created consensus for initially controversial conservation strategies and rate adjustments. One utility reported that citizen input facilitated a bond issue, contrary to the prevailing wisdom that citizens will not tolerate increases in taxation or public funding for services. In the transportation industry, some public and private entities fear that boisterous and contentious citizen advisory boards will attract unfavorable media coverage. But with controversial topics involving new and unfamiliar technologies, it is possible that citizen input as well as efforts to inform (as oppose to manipulate) the citizens, can win public approval for new technologies. Water systems report that the process of creating public consensus can take longer than anticipated, but early results indicate that it is worth the effort.[249]

8. Market Orientation, Opportunities & Technology Development

Usually, the industries whose primary focus are producing goods for private domestic and international markets will have the greatest abilities to generate funding for R&D and technology transfer. Sometimes, these market oriented industries receive a jump start in technology development by large scale government procurements, especially when markets for new technologies or products are in the developmental stage. Using this working hypothesis as a guide, it is more realistic to expect a faster rate of technological innovation in the transportation industry than the water industry. The telecommunications aspects of ITS are more marketable internationally than water supply technologies which are still largely country specific.

While institutional barriers to technology development should be removed in the water supply industry, it is unrealistic to expect the speed of technology development to increase markedly. Historically, the water industry has applied ATMS-like technologies to its operations instead of developing advanced technologies from scratch. Equipment suppliers in the industry have found niches, like the small systems market, that provide opportunities to develop and innovate treatment plant technologies. However, market opportunities for the entrepreneurial pursuit of ATIS-technologies seems limited. Since water rates are still low, residential customers do not have as much an incentive to purchase information systems that conserve water as automobile users of congested roads who perceive a scarcity of transportation services. Again, the water supply industry may offer an ATIS-like add-on to smart home technology that originated from another industry.

9. Regulatory Impacts on Technology Development

An invaluable lesson from the water supply industry is that early and though&l development of regulations and standards facilitates instead of impedes technological progress in industries offering public services. In the water industry, an absence of regulations and standards created little incentive for technological innovations. Flexible, outcomes-based, and coordinated regulations among all levels of government can bolster safety, efficiency, and creativity within an industry. Also, regulations can be accompanied with implementing grants and loans to address funding shortfalls and promoting restructuring that reduces financial inefficiencies.

XV. CHAPTER FIFTEEN — TECHNOLOGICAL INNOVATION IN REFUSE COLLECTION

The transportation industry moves people to work and home; the solid waste industry moves people's trash to disposal sites. During the last several years, increasing rates of suburbanization and population pressure have created congestion on the roads and in refuse collection and disposal. Public attention, however, seems to be concentrated on our clogged thoroughfares. Highway congestion is covered daily on radio traffic reports while land-fill capacity receives sporadic media coverage. Hence, the search for technological innovation for refuse collection has not been as intense as the quest for ITS. Of course, technological innovation has improved refuse service, but innovation occurs over decades. In contrast, ITS-related telecommunications equipment speeds through technology generations within a decade.

Internal organizational aspects of the solid waste industry also explain the slow pace of technological innovation. In the first half the century, municipal public works departments focused their attention on improving management techniques instead of pursuing technological innovations. When they have sought technological innovations, public works departments have discovered that limited workforce skills and technological displacement of workers impede the introduction of advanced refuse collection and management systems.

This case study will examine exogenous and endogenous factors facilitating and impeding technological development and transfer. Exogenous factors outside the solid waste industry include population growth, suburbanization, and the development of consumer products, especially non-durables. Endogenous factors internal to the industry consist of the mix of public and private ownership, the scale of operations, and labor relations. As a nascent industry, ITS, can better anticipate or influence exogenous factors and develop internal institutional structures to speed technological innovation after examining the history of technology development in other industries like solid waste.

A. History of the Solid Waste Industry

1. Evolution of the Industry

During the colonial and the early industrial eras, American systems for refuse collection and disposal developed later than their European counterparts. With an abundance of land and natural resources, public officials and citizens in this country did not perceive a need to establish systematic methods for collecting and disposing solid waste. In contrast, European countries constructed the earliest incinerators and collection systems in response to rapid population growth and industrialization. Most American cities relied on private scavengers to collect garbage. By the mid-nineteenth century, population growth and industrialization were creating filthy, unhealthy tenements in U.S. cities. The first public sector reactions, however, was to establish water supply systems, institute municipa1 street cleaning, and reduce industrial pollution. For reasons not entirely clear, refuse collection did not receive priority attention, perhaps because solid waste buildup was not as visible as dirty water, manure and other street wastes, and industrial emissions.

Cities that implemented municipal refuse collection programs encountered institutional impediments. In the nineteenth century, rural dominated state legislatures would not grant cities "home rule" and also restricted the funding channeled to cities. Thus, over-populated and burdened cities had relatively few resources to construct public infrastructure. Furthermore, city councils often allocated the bulk of their modest revenues to water supply or street cleaning ahead of refuse collection.[250] Managing the earliest refuse collection systems, municipal health departments perceived trash removal primarily as a means to fight infectious disease.

By the early twentieth century, cities started placing a higher priority on refuse collection. Steady population growth and industrial development throughout the late nineteenth and early twentieth centuries intensified the sanitation problem until it could no longer be ignored or dealt with adequately by private scavengers, By 1920, about 90 percent of United States cities had some municipal sponsored or funded garbage collection system. After municipal sponsorship became widespread, sanitation engineers replaced health professionals as the managers of garbage collection and disposal. Health professionals had shifted their disease prevention efforts from trash removal to inoculation and immunization programs. At the same time, city officials believed that sanitation engineers could alleviate garbage buildup by vastly improving refuse collection and disposal technology.

Sanitation engineers instituted significant advances in solid waste management techniques but were unable to revolutionize technology. Borrowing management techniques from the water supply industry, sanitation engineers implemented the first information systems in solid waste management. They systematically collected data on demand for service, thereby increasing efficiency by adjusting service levels to fluctuations in demand. Itemizing costs of equipment and supplies, they improved the ability of public works departments to adjust and minimize expenses. Moreover, sanitation engineers convinced city leaders to abandon the most primitive and unsafe disposal practices which included dumping solid wastes into the ocean and open-burning of refuse.[251]

Interestingly, both sanitation engineers and civic associations advocated public service delivery and opposed privatization. The engineers maintained that managing and planning tasks were much easier if the public works department operated refuse collection and disposal: For instance, it was simpler for municipal employees to collect data on route operations than to monitor the daily operations of private companies. Furthermore, city engineers claimed that development and implementation of long-term planning was more feasible under a regime of public service delivery than under a regime of short-term contracts with several private companies. Citizen groups also opposed privatization because they felt that companies charged usurious rates and gouged the taxpayers. In addition, they believed that public service providers would be more accountable to the voters. As a result of managerial and citizen pressure for public service delivery, municipal control of refuse collection and disposal reached 50 percent by World War I, up from 24 percent in 1880.[252] As the twentieth century progressed, city ownership of refuse services became the dominant form of ownership.

Technological innovation progressed slowly. The private sector had little incentive to innovate since city agencies delivered most of the service across the country. Sanitation engineers in public works departments were the primarily source of innovation, but they focussed on upgrading management techniques as opposed to technologies. However, they paved the way for technological innovation in the later half of the century. If they had not introduced modem management techniques, it would not have been possible or desirable to introduce data collection technologies required of advanced management approaches.

2. Modern Technology

The first technological advancements centered around the trash truck. The garbage collection vehicle changed from horses and carriages, to open body trucks, to closed body trucks, and then to compactors that compressed garbage. By the late 1960’s, trucks were equipped with mechanical arms that dumped the contents of pales and large bins into their truck storage bodies.

Management information systems followed much of the truck innovation. These systems computerize data collection, and facilitate demand management. They are not yet widespread for reasons which will be explored below. For as many economic and institutional factors compelling technological innovation, there seemed to be an equal amount of factors impeding innovation.

B. Factors Motivating or Facilitating Technological Development

1. Endogenous Factors

The solid waste management industry sought technological innovations to combat high costs and low quality of worklife. Melosi estimates that the annual cost of municipal garbage collection and disposal is about $4 billion, an amount that is approximately equal to the yearly cost of operating schools and maintaining roads.[253] About 60 percent of these costs are labor costs, since trash collection is a labor intensive activity. Coupled with these high labor costs are poor working conditions. Not only are trash collection jobs extremely arduous and dirty, the industry as a whole has one of the highest rates of injuries and worker compensation claims.

To reduce costs and injuries, the city of Scottsdale, Arizona pioneered the use of automated trucks, trucks with mechanical arms, in 1965. Today, most of the cities that use automated trucks are on the West Coast.[254] Automated collection cuts costs dramatically as work crews of three to four were replaced by crews of one or two. The incidence of injuries also decreases substantially. The quality of worklife improves as revealed by plummeting absenteeism rates. Moreover, the workforce can be diversified from strong young men to include older men and women.

2. Exogenous Factors

Demographic and economic developments conspired to exponentially increase the volume of trash and to require longer travel times from refuse collection to disposal. The advent of the packaging industry enhanced consumer convenience by creating disposable wrapping materials and products. As disposable products became mass produced, the United States experienced one of its largest population increases, that is the post War II baby-boom generation. More people consumed more disposable products. Even after the peak of the baby-boom generation, trash volume soared. Since 1960, the United States population grew 34 percent, while the amount of garbage has increased 84 percent.[255] Due to suburbanization and lower density residential development, the larger volumes of trash had to be hauled over longer and longer distances to disposal sites. The scale of refuse collection and disposal enlarged from the city to entire metropolitan areas.

Larger volumes of trash and longer hauling distances spurred changes in technologies, industrial organization, and service operations. To accommodate the increase in demand, municipalities started purchasing compactor trucks in the late 1960’s. These trucks had more capacity simply because they compressed or compacted the refuse. As compactors were purchased, municipalities sought to diversify their service operations. Since population and economic activity spread from the central city to the suburbs, regional operations became more economical than operations at a city level. Some city and county governments combined their refuse service or entered into cooperative arrangements. Public agencies also increased their utilization of private sector contractors. Because hauling distances to disposal sites increased substantially, economies of scale could only be realized by a relatively few haulers per metropolitan region. In the 1960’s the solid waste industry underwent a series of consolidations and mergers.[256] The remaining companies were large enough to realize economies of scale. In some cases, cities contracted-out to region-wide hauling companies whose operating costs were significantly lower than the public sector's.

As operations became regional with increasing diversity of public and private operators, it would seem that technological innovation would accelerate. Perhaps, the lower operating costs associated with economies of scale could generate funding for research and development (R&D). Perhaps, larger public and private entities could realize economies of scale in the financial markets and command favorable capital financing due to their increased bargaining power. However, the solid waste literature is silent about the impacts of changes in industrial organization on technological innovation.

Industrial organization does not seem to have a noticeable impact on the utilization of management information systems (MIS). The literature does not include a systematic survey of MIS systems in refuse collection systems across the country. If a survey revealed that larger operators used MIS, then economies of scale would be a critical a factor in the utilization of advanced management systems. On the other hand, the water supply literature talks at length about how economies of scale permit larger water utilities to adopt state of the art technology while small utilities use primitive technologies.

The critical factor explaining the introduction of MIS is rapid population and economic change. For example, Sacramento, a rapidly growing city, relies on MIS. In contrast, Washington DC, a city experiencing population loss, abandoned MIS after a brief period of operations.[257] MIS seems to be more useful to municipalities with dynamic and variable demand for trash removal because continuous service adjustments are necessary to save costs and increase efficiency. On the other hand, cities with predictable or declining levels of demand do not perceive much need for MIS.

It appears that exogenous factors have direct as opposed to indirect effects on technological innovations. The exogenous factor of population growth had a direct influence; that is, population growth motivated service operators to acquire advanced technology. The indirect influence, in contrast, does not seem to be present; we do not have a scenario in which population growth leads to larger scale operations with economies of scale that motivates technological innovation or R&D.

Popular pressure for recycling is another exogenous factor with a direct effect. Citizen advocacy and state legislation pressured local public works departments to implement recycling programs. It was not until the late 1980's that recycling became a national phenomena; the slow pace is partly attributable to a lack of federal legislation or regulations mandating recycling. Service operators could not therefore rely on federal financial or technical assistance to achieve cost effectiveness in recycling. Under pressure from local constituents, public sector operators turned to technology and advanced management techniques to make recycling viable. For example, Pferdehirt, O'Leary, and Walsh document that Evanston, Illinois uses detailed data on demand from a MIS system to devise a cost effective method for combining regular curbside collection with recycling pickup.[258]

C. Factors Inhibiting Technological Innovation

1. Endogenous

The literature does not include detailed discussions of low revenues and high costs as an impediment to technology. Like their water system counterparts, public sector refuse collectors could have constrained financial resources due to a lack of autonomous budgeting. Their revenue streams could likewise be restricted since they may not be charging fees that cover the full costs of service operations.

The most common revenue sources are general taxation or monthly billing to customers. This type of revenue collection does not generally recover as much of the cost as user fees scaled to the level of customer usage. Only a few municipalities have implemented weight-based user fees. Interestingly, advanced technology seems to follow the implementation of weight-based pricing. One commentator mentioned that MIS often becomes necessary to implement weight-based fees since customer demand becomes more variable and unpredictable in a weight-based fee system.

Workforce skills and labor-relations are much more frequently mentioned endogenous factors impeding technological innovation. Often, when a public works department is considering MIS, they cannot implement it because their staff lack the computer skills necessary for operating MIS. Out in the field, labor relations can retard the introduction of automated trucks. Since automated trucks reduce crew sizes, some operators cannot use them economically if union contracts specify minimum crew sizes. Possible solutions to this issue will be discussed below.

2. Exogenous

Perhaps a lack of perceived crisis has relaxed the search for technological innovations. While it is true that population pressure and suburbanization forced technological and industrial changes, the pace of these innovations has been slow. Periodically, the public hears reports about over-burdened land-fills, but national attention has not been focused on innovations in refuse collection or recycling to alleviate land-fill saturation. In contrast, congested highways affect tens of millions of commuters on a daily basis.

As a result of the low level of public concern, the federal government has not been aggressive in promoting technological innovation through regulatory or legislative mechanisms. One of the few pieces of legislation, the Solid Waste Disposal Act of 1965, focuses on disposal, and not on refuse collection or the linkages between disposal and refuse collection.[259] Also, the federal government does not offer financial or technical assistance to refuse collectors. On the other hand, the federal involvement in other industries, notably transportation and water supply, is extensive. For example, recent amendments to the Safe Water Drinking Act will impel water systems to vastly upgrade their technology. In the transportation industry, the federal government has been a major funder of infrastructure and technological innovation (as evidenced most recently by its research consortia with U.S. automakers).

D. Lessons for ITS

1. Exogenous factors

A striking difference among refuse collection, water supply, and transportation infrastructure is the level of regulations. Water supply and transportation infrastructure must adhere to rigorous federal safety standards while refuse collection is not regulated by any major piece of federal legislation. As a consequence, the search for technological methods to protect safety has been more intense in the water supply and transportation industries than it has been in refuse collection. Therefore, if policy makers determine that it is desirable to speed technological innovation, the early development of safety regulations is necessary.

Government agencies must design the regulations with care lest they have the unintended result of retarding technological advances. For example, a flaw in the solid waste regulatory framework is that it is devoted to disposal and does not encourage efficient linkages between collection and disposal. Also, the regulatory framework should specify outcomes such as safety or cleanliness levels, but it should not dictate methods for obtaining outcomes. In particular, regulations should not tilt the economics of the industry to favor either public or private operators. Refuse collection started as a public sector dominated industry partly because the private sector was not as developed in the late nineteenth and early twentieth centuries. Today, the public sector is still the major operator, but the participation of private operators has increased markedly. The optimal mix of public and private operators is an empirical question which will be answered differently across the country. Therefore, regulations must be flexible so that jurisdictions can pursue a variety of service options. Regulations that prohibited flexibility in service arrangements would needlessly retard efficiency and technological innovation.

To preserve flexibility, a regulatory framework must ensure accountability of the service operators. In the early history of refuse collection, the citizenry opposed contracting-out because they felt that private operators would be unaccountable to the public. In the late twentieth century, public sector operators can be as remote and unaccountable as their private sector counterparts. Citizens will oppose any operator if it adopts a haughty attitude, and does not explain service changes which can appear to be irrational or worse. Since citizens pay for public services, they are entitled to services that are accountable, regardless of whether the service provider is public or private. Moreover, citizens will adopt a more flexible attitude about public or private service operation, if the service provider is accountable and responsive to the citizenry. Accountability mechanisms range from citizen advisory committees, townhall meetings, to citizen seats on boards of directors. In the transportation field, the Intermodal Transportation Efficiency Act mandates meaningful opportunities for citizen input as accountability mechanisms. These accountability mechanisms should be viewed as a means of promoting flexibility in service delivery.

2. Endogenous Factors

One of the largest endogenous obstacles to technological innovations in refuse collection is labor relations. Automated truck technology, displaces workers. In some unionized settings, it may be uneconomical to introduce such technology if union contracts mandate minimal crew sizes.

Technology is often a double-edge sword. On the one hand, it enhances the quality of work by reducing worker stress and injury. On the other, its immediate effect is to reduce employment levels. While there is no perfect solution, some municipalities attempt to mitigate the employment loss by re-assigning displaced workers to other city departments. Others gradually reduce employment levels through retirements rather than layoffs. What seems to be absent are major efforts to retrain workers to perform data management on MIS and the other higher order tasks in the field. Another important element is involving front-line workers in decisions about technology upgrades in the workplace. Managers will not only be more likely to gain acceptance of the new technology but also insights about how best to utilize the technology to improve safety and productivity.

Labor relations and technological innovations will be particularly relevant to ATIS systems on mass transit. Bus and train operators should be involved in decisions regarding how ITS technology will impact working conditions and employment levels.

XVI. CHAPTER SIXTEEN — PRELIMINARY CASE STUDY OF ELECTRONIC FUNDS TRANSFER SYSTEMS[260]

Introduction

Automatic teller machines (ATMs) are playing an increasing part in banking and in business, and in their role as point of sale (POS) terminals may eventually rival credit cards in importance. ATMs, along with the automated clearing house (ACH) are a special case of the general technology of electronic funds transfer (EFT), which is central to the operation of the entire national banking system. Since EFT technology is similar in many ways to technologies that have been proposed for use in ITS services, and since many of the public interest considerations that underlie EFT will also be relevant to ITS, the application of EFT technology and the evolution of EFT and ATM services are important to consider in ITS policy planning.

A. Technology

Electronic funds transfer systems make use of a variety of technologies, coupled in different ways to achieve different objectives. The principal EFT technologies are outlined in this section; variations that are used to provide specific services are discussed in conjunction with the discussions of those services.

1. Terminals

In its generic sense, a terminal is a device that accepts information or other inputs from a user; stores, processes and forwards these inputs to a system or network; and conveys certain outputs from the system or network to the user. Most terminals accept inputs by means of a keyboard, coin or envelope slot, or access card reader. The terminal stores inputs by means of a built-in memory unit and/or mechanical device; processes inputs by means of an internal microprocessor or device: and forwards user inputs by means of communications links to a central system facility or office. Finally, the terminal conveys information returned to the terminal by the system or network to the user by means of a display device or an output slot.

The best known EFT device is the basic ATM terminal, which accepts a user's access card and keyboard input, authenticates the user by reading the access card and asking for entry of the user's personal identification number (PIN), processes the requested transaction by communicating with the ATM network, displays the progress of the transaction and prints out the results, and delivers cash to the user via an output slot.

Another common EFT device is the point of sale (POS) terminal, including the electronic cash register, the credit card authorization terminal, and the combined credit card and ATM payment terminal that can be used directly by the customer to pay for groceries or other goods. The electronic cash register scans the bar coded product identifier, adds the prices of the goods purchased, records changes to the store's inventory, verifies checks, and prints a transaction receipt for the customer. Some POS terminals read the customer's card (some require entry of a PIN), communicate with the POS network, validate the access card and the user, and print out a record of the transaction.

Some EFT terminals are designed for home use. The natural evolution of the "telephone bill payer" systems of recent years, that used a plain vanilla pushbutton telephone to check account balances or transfer funds to payees or between accounts, these terminals can be much more sophisticated. For example, one design incorporates a credit card and ATM card reader, a light pen input device to read payee bar codes, and a display to indicate the progress of the transaction.

2. Access Cards

The nearly universal access card technology is the familiar credit card or ATM card that stores certain user account information in a magnetic stripe that can be read by ATM or POS terminals or both. A more recent development is the so-called "smart card," which incorporates a microprocessor chip and a non-erasable memory. This card stores security and identification information that the POS terminal can use locally to perform validation, without the need for communication with the network. Each card is assigned a dollar limit, and the card deducts the amount of each transaction from the remaining stored value and records the name of the seller. Thus in principle the card could contain an internal "cash" value without reference to account identification, and could be as anonymous as cash. Some cards use laser technology to provide for mass storage of information such as medical histories or insurance data. And some access cards include both a magnetic stripe and a microprocessor chip, providing additional flexibility.

3. Switched Networks

> *A network is anything reticulated or decussated, at equal intervals, with interstices between the intersections.*

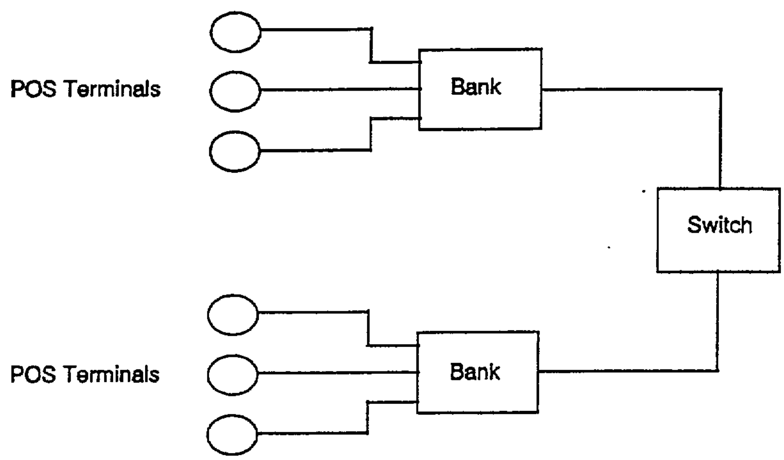
A switch is a computer that is programmed to route messages from their origins to their destinations. The same computer may also process the data in various ways; for example, if the computer is owned by a particular bank it can process transactions locally for the bank's own customers and switch other transactions to different computers for processing.

A switched network consists of two or more transmission links interconnected by one or more switches. Networks can carry information of all kinds, but apart from the public switched telephone network or certain other common user networks, they are typically dedicated to specific purposes. An EFT network carries data that identify particular accounts, that debit certain accounts and credit others, that form the basis for transaction summaries, and that control EFT terminals. A network may be *centralized* (controlled by a single large central computer) or *distributed* (controlled by a number of interconnected smaller computers that share the control function).

An EFT network can operate in an on-line or real-time mode, in which each transaction must be referred to a network computer (whether centralized or distributed) for authorization or for actual completion. Alternatively, the network can operate in *an off-line* or *batch* mode, in which a number of transactions are authorized and/or provisionally completed locally, and then sent in a group to the network computer for completion or recording.

Control of the routing of network information is exercised by a switch. Each time a different computer must participate in a transaction, the appropriate information must be directed to the computer by the switch. Since a particular transaction may involve a number of businesses or financial institutions, each with its own network and computer, a good deal of switching is required for even a simple transaction. For example, if a customer uses his ATM card at an out-of-town bank, the transaction must be routed through a switch from that bank's computer to the customer's computer for processing, and then back to the first bank's computer for control of the terminal and completion of the transaction.

Back End Switch Network



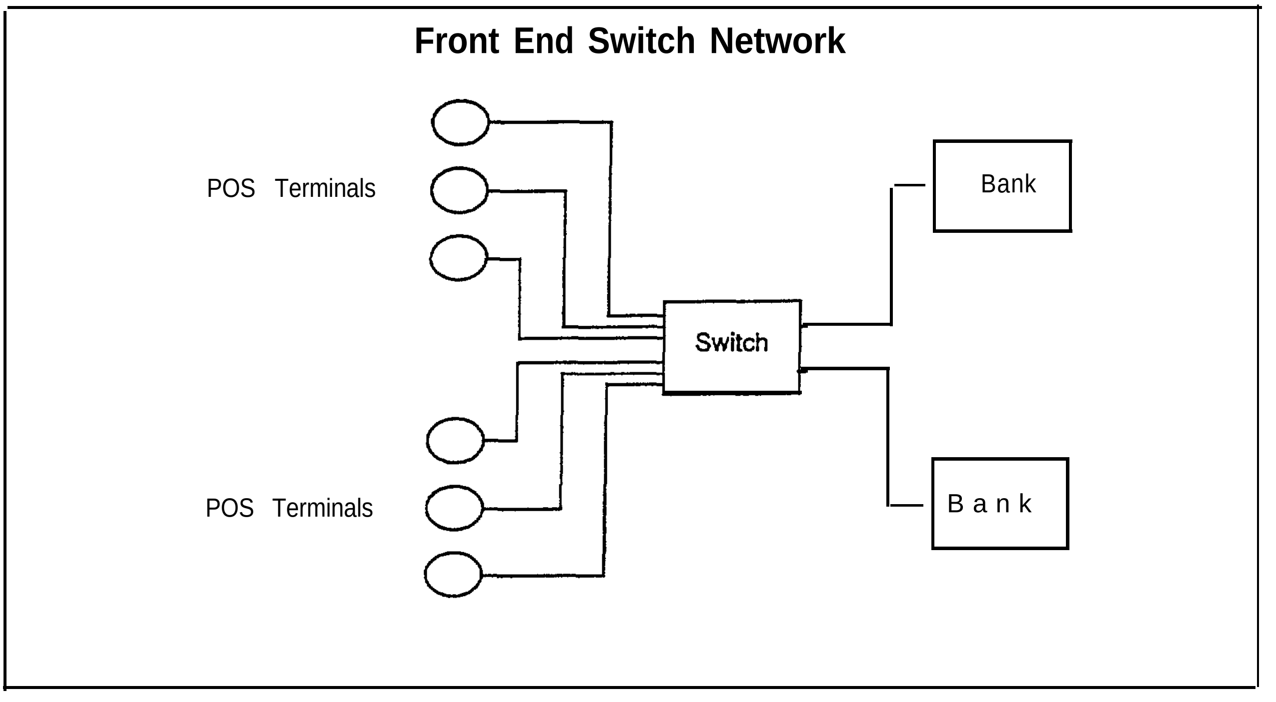
EFT networks are divided into two broad classifications: a "front-end" switch network, in which the switch is placed *before* the bank computers (see Figure 1), and a "back-end" switch network, in which the switch is placed *after* the bank computers (see Figure 2). A back-end switch allows transactions that are essentially "local" to be completed without going through the switch. For example, if a customer makes a purchase from the retailer that issued the credit card used for the transaction, the retailer's computer can complete the transaction without further assistance from the network. Similarly, if a customer uses an ATM card issued by his bank to withdraw cash from his account, the bank's computer has all of the information required to complete the transaction without invoking other computers via the switch. Such transactions are called "on us" transactions in bank parlance; handling them locally is simpler and cheaper, and gives the retailer or bank more control over its own customer's transactions. Conversely, in a network using a front-end switch, all transactions are routed through the switch. All transactions are handled in the same way, but the number of transactions that go through the switch is much greater, leading to higher costs. In practice most networks have both front-end and back-end aspects, but there is a gradual trend toward a relatively standard network design architecture.

4. Databases and Software

Virtually every party to an EFT transaction has a data base that is involved in the transaction. In an ATM transaction, data bases of the customer's bank and (if different) of the bank operating the ATM are involved. In a POS transaction, the retailer's data base can also be involved, for such purposes as inventory tracking and sales analysis. Even the customer may have a data base involved, in home banking transactions using a dialup telephone connection and a personal computer.

The various computer programs must also interoperate smoothly to complete a transaction. The computer operating the ATM must forward information that defines the transaction to the customer's bank in a form that can reference the customer's account file, as well as the bank's service charge and monthly statement processing programs. The latter must be able to return an authorization or refusal of the

Figure 6



transaction in a form that can be communicated back to the terminal for completion of the transaction. And the switch software must permit interconnection between these potentially quite different computers.

5. **Transmission Facilities**

Virtually any type of transmission facility can be used for EFT transactions. Leased or dedicated circuits offer good security and high transaction volume, but are relatively costly. Dialup lines, of the sort used for voice telephone service, are much cheaper for low volume uses. Optical fiber transmission facilities can be used to provide leased lines, and as a practical matter are increasingly used for the long distance portion of dialup circuits. Private microwave systems and commercial satellite systems are also usable for EFT transactions.

6. Security

Security is a potential problem with any activity involving matters of economic value, and EFT transactions and systems are surely included, There are two points of vulnerability in EFT systems, relating to unauthorized customer access and to the security of the system itself.

a. Unauthorized Access

The access card is the principal means to identify an authorized user of an ATM or POS system. The access card contains most of the information needed to identify the customer account, but it is also necessary to verify that the bearer of the card is in fact the authorized customer. With current technology, that is usually accomplished with a confidential personal identification number, or PIN. Such a system is not foolproof, and about one third of the customers victimized by ATM fraud are foolish enough to have written the PIN on the card.

The limitations of these current customer identification systems have led to research on ever more sophisticated technologies, e.g. imaging the translucency of the user's hand; voice prints; computer verification of the customer's hand motions as he signs his name; computer analysis of fingerprints or retinal scans; etc. Perhaps we will soon have to submit to a DNA scan before we can purchase a box of cereal with a credit card. So far only the cost of some of these advanced technologies stands between us and Big Brother.

Other technologies have been developed to help validate the access card itself. Holograms, high quality fine structure printing, and a variety of ways to embed validation data surreptitiously into the card are all in use or under study. The smart card is a promising approach, because it can contain a large amount of validation information that is readable by the same device that reads the basic account information.

b. System Security

The EFT system itself must also be protected from unauthorized access. Physical access to a bank's EFT computer or ATM, to a retailer's computer or POS terminal, or to a network switch must obviously be limited to authorized personnel. Such systems are particularly vulnerable to the programmers that design them, and also to "hackers" that are able to access them via communications lines. When multiple organizations, each with its own computer and operating staff, are involved in a transaction, the opportunity for a breach of security increases significantly.

It is also important to monitor the use of the EFT system to detect apparent fraud. Individual account activity can be evaluated in a number of ways, either by specific monitoring of known accounts with lost or stolen cards or by more general monitoring of accounts exhibiting suspicious patterns of use; authorization of a transaction can be withheld if valid concerns are present. Camera surveillance of ATM or POS terminals can provide information useful to law enforcement personnel in the event of actual misuse.

7. Technical Standards

In addition to these government interventions, the private sector undertook standards activities to improve the interoperability of ATM systems. ATM and debit cards, data formats, and transaction processing were all standardized, and manufacturers developed ATM terminals that could accept a variety of card technologies-as a result, banks and retailers can exchange the information necessary to complete a transaction electronically.

8. Lessons for ITS

Electronic toll collection, an oft-cited potential element in an ITS program, may be considered as a special case of POS transactions; from a purely technical perspective, the only real difference is the need to identify the financial account associated with a vehicle in motion, rather than to capture a transaction involving a relatively stationary credit card and a loaf of bread or box of cereal. Special attention to nationwide standardization may will be important-although EFT usage is primarily local, electronic toll collection may involve a high proportion of motorists at a substantial distance from their homes, and the account information must be readable regardless of the location of the vehicle. As a major party in interest, government has a legitimate role in assuring that such standards are put in place. Although the timing of such a standardization effort may be a matter for debate, the ultimate need for nationwide compatibility seems beyond question.

B. Electronic Funds Transfer Services

Electronic funds transfer (EFT) services differ significantly in their purposes, their operator/user relationships, their technologies and the policy issues they raise. These services have been evolving, and a number of different services are now offered using a single general purpose terminal and interconnected networks. These services and their convergence are discussed below.

1. Automatic Teller Machines and Services

Automatic teller machines (ATMs) were the first EFT devices to come into common use. ATMs began as adjuncts to traditional banking services, allowing customers to obtain their bank balances, transfer funds between accounts, and withdraw cash without the intervention of a human teller. ATMs were initially located only on the premises of the owning banks, but after legal issues relating to branch banking were resolved they became commonplace in retail establishments and other locations as well.

2. Point of Sale Services

The next major step in the evolution of EFT systems was the point of sale (POS) network, which allows a complete purchase transaction to be accomplished electronically. For example, a clerk in a retail establishment can scan a product with a bar code reader, thereby capturing both the price and the product identification; the clerk also scans the customer's ATM card with a different device, and combines the resulting account information with the product information. The combined information is sent automatically to the POS network authorization center, and upon receipt of an electronic authorization the clerk's terminal completes the transaction by debiting the customer's bank account and crediting the store's account. The product identification and price is also used to deduct the product from the store's inventory and to add the price to its daily revenue.

The networks that authorize and complete POS/ATM transactions have more recently been interconnected with credit card authorization networks, access cards have been developed that combine both ATM (debit) and credit card functions, and POS terminals that can accomplish both credit and debit transactions are becoming commonplace. Thus today POS embraces both credit and debit transactions.

3. Telephone Bill Payer Systems

A variation on the early ATMs was the telephone bill payer system, allowing customers to query their bank account records, transfer funds and pay bills by using their pushbutton telephones. Also, more sophisticated telephone bill payer systems are now being offered that permit the customer to initiate purchase transactions from home. Some of the newest terminals have light pen bar code readers that allow the customer to scan product codes from a catalog and complete a purchase transaction automatically with only a few keystrokes.

4. Automated Clearing House

The automated clearing house (ACH) is essentially a wholesale EFT system used for large transactions between corporations and/or banks, and typically operating in an "off line" or batch mode. The Federal Reserve operates a large ACH system, used primarily for interbank settlements, social security payments and payrolls. Commercial ACH systems are also used for interbank transfers.

5. Lessons for ITS

There are numerous examples from the development of EFT services that offer guidance for ITS planners. First, at every step in EFT service development there were considerable delays in adoption of service while customers became familiar with the new technologies. Builders of electronic toll collection systems should be prepared for an extended period of time during which there will be very little return on their investments.

Second, customers are quite adept in perceiving where their own self interest lies. For example, when banks seek to maximize their revenues by debiting a customer's account immediately for ATM withdrawals ***or*** POS transactions, but place a few days' hold on deposited funds, their customers are quick to realize that they lose the "float" they would otherwise have by using paper checks. Also, customers realize that their costs per check are often lower than the banks' charges for POS transactions (or even zero), and that they pay nothing at all for a credit card transaction (depending, of course, on the time at which interest begins to accrue). Thus the growth of debit card POS transactions has been lower than many banks had hoped.

Finally, customers believe that paper transactions give them a clearer record of their transactions than many EFT alternatives, and believe that the paper method gives them more control over their financial affairs.

Change usually comes slowly, and there are many avenues of resistance. If customers are to be . induced to change their accustomed ways of doing business, the advantages to *them* (rather than to the-promoters of the new approach) must be made clear. It doesn't take much of an impediment or mixed message to discourage a customer from embracing change-a greater cost, or greater complexity, or unpredictability, or increased likelihood of being identified and caught for speeding or an expired license plate, or even the vague fear of such effects can be enough to deter participation. Thus the burden is upon the proponent of change to offer the user an unambiguous cost/benefit message.

C. Diffusion/Penetration

1. Factors Affecting EFT Development

Proprietary ATM systems were introduced by large banks in the 1960's to help limit the growth of paper checks, which were costly to process. Initially ATMs were simple cash dispensers, operating off-line, but gradually evolved into multifunction terminals allowing users to check their account balances and perform other routine account activities.

Shared ATM networks began to develop in the 1970's, permitting customers of one bank to access their accounts at ATMs owned by another bank. A number of state governments began to mandate sharing of ATMs to level the playing field for the smaller banks. Also, federal regulators determined that interstate cash withdrawals did not violate interstate banking laws, and the federal courts decided that ATMs did not constitute illegal bank branches. These government actions encouraged the development and inter-operation of ATM systems.

With the legal framework clarified and with the accomplishment of industry sponsored technical standards, regional ATM networks began to develop, and a number of these were soon interconnected into national networks. Within a decade there were hundreds of shared networks: some local, some regional, some national, and a few international.

A variety of systems were developed by retailers and other third parties (e.g., Sears, American Express) and soon these also were interconnected, along with the bank oriented Visa and MasterCard networks.

POS systems developed more slowly than ATM systems, owing to the high cost of placing terminals in thousands of retail establishments and the lack of bar codes on most products. The lack of terminals deterred product manufacturers from investing in bar code labeling, and the lack of bar codes made POS terminals impractical-a classic "chicken and egg" problem. When in 1982 the Department of Defense began to require bar codes on all products it would purchase, the problem was quickly overcome, and "the rest is history"-today one can't buy even a package of aspirin without finding a bar code on the label.

POS is the key to success for EFT services: ATMs cannot generate enough volume to make a profit on the considerable investment in these networks, but POS volume is potentially enormous. The insistence of retailers that all access cards work with a single POS terminal is being accommodated by network operators, and customers are increasingly taking advantage of the POS option. Customer operated POS terminals that accept both debit and credit cards are appearing in supermarkets, and are achieving customer acceptance. Thus customers may choose to effect any specific transaction on a debit or credit basis, with equal convenience; their choices will ultimately be made on the basis of availability of credit, the amount of cash they have in their accounts, the cost of the transaction (credit transactions are "free," as are many check transactions, but banks impose a charge for debit transactions), and the amount of float that customers receive on debit transactions.

2. Growth of EFT Service

Customer interest in ATM services developed slowly, but as shared ATM networks developed in the 1970's both the number of ATM terminals and the number of transactions per terminal were roughly doubled every two years. Many of these networks had hundreds of ATMs connected to them, and some had thousands. By 1984 nearly 60,000 ATM terminals were operating nationwide, with an average of 5,500 transactions per month per terminal.

3. Lessons for ITS

It seems likely that EFT applications in ITS will be largely for purposes such as electronic toll collection, although similar technologies are of course adaptable to such non financial purposes as identification of vehicles in motion. It also seems likely that electronic toll collection will be an essentially local service, for the benefit of a particular toll authority, although uniform technical standards will be essential to allow motorists to use a single access card or identification marker nationwide.

Some unique characteristics of electronic toll collection both constrain the design of such a system and offer the prospect of rapid customer acceptance, e.g.:

- government involvement in the role of "merchant"
- privacy and surveillance issues
- the relatively small amounts collected per transaction and the high cost of network switching of each transaction
- the probable resistance of customers to the potential for identification and surveillance

Taken together, these factors suggest that a debit only, preferably anonymous smart card technology, with a limited stored cash value, may be most efficient and may achieve the highest rate of customer acceptance. The value stored in the standardized smart card could be debited by any toll authority in the country; thus the standard card would benefit from economies of scale in manufacture and could be relatively inexpensive. Moreover, since the individual transactions would be small in amount, the total value stored in the card would be relatively low, greatly reducing security concerns. This would make it possible to sell (or recharge) the cards in vending machines, and the convenience of such a distribution method would contribute to customer acceptance. The lack of a need to store customer account data would make the entire network significantly cheaper, and probably decentralized in architecture (the card would store its own number and its remaining value). Any highway or bridge authority could build its system completely independently of the rest of the nation-only a record of the card numbers and the amounts debited need be stored for subsequent off-line collection from the entity selling or recharging the universal toll cards.

Another approach would be to store the record of purchased value in a nationwide data base that could be accessed by any toll authority. A smart card would not be necessary, only a card or sticker whose number could be read automatically as the vehicle approached. The toll authority could download all card numbers having less than (say) $2.00 remaining value on an hourly basis, maintaining these records locally in a "negative file." If a vehicle bearing such a card number approached the toll facility, an automatic query for an updated value would be made to the central data base to assure that the remaining value is sufficient.

The above are only examples, but they show how citizens' individual needs can be accommodated while avoiding the development of a costly financial "empire" to collect very modest sums of money. This approach would be convenient for motorists, and would not raise extraneous issues that could impede acceptance.

D. Private Sector Economics

EFT systems began with off-line ATMs, with the objective of reducing the cost of checks rather than earning profits. Indeed, even after considerable acceptance by customers the cost of constructing switched ATM networks was high enough that operators could not expect profitable operation.

POS operation is quite different. Once the network has been built the marginal cost of additional transactions is small, and POS can contribute very large numbers of transactions. Thus POS transactions are very profitable on an incremental basis, although many banks are continuing to impose relatively high transaction charges to improve their profits even further. It seems likely that POS will not be fully accepted by the public until the transaction cost compares favorably with alternative means of payment (e.g., checks, credit cards, or even cash).

1. Sources of Revenues

Banks typically make no charge for the use of their own ATMs when operated by their own customers. Despite the cost of the ATM system, the banks find it more expensive to serve customers with human tellers, and thus encourage the use of ATMs by making no charge for their use.

When ATMs are used in a shared network, by customers of another bank, a transaction charge is usually made. This reflects in part the cost of use of the shared network (and of providing a supply of available cash in the dispenser) and in part the fact that the bank owning the ATM has no relationship with the particular customer and hence no opportunity to save money through the use of its ATM.

In POS transactions, either the customer or the retailer must pay the cost of processing. Banks typically discount credit card transactions to offset the risk of failure to collect the funds, and often seek to discount debit card transactions at the same rate even though their risk is substantially lower. Some banks impose a charge on their own customers for use of a debit card in a POS transaction.

2. Lessons for ITS

Customers will pay for convenience, but not large amounts. In the case of debit card POS, the advantages compared to credit cards or checks are unclear, and may in fact accrue to the bank or the retailer rather than the customer. Thus debit cards are a long way from dominating POS transaction volume.

ITS bears a similar burden of proving its value to customers. If consumers must also incur an up front, out of pocket investment cost to be able to benefit from ITS, those benefits must be clear and unambiguous or the service will be ignored. Even electronic toll collection, a very narrow part of ITS, may not achieve critical mass for a long time. To be successful, this technology must offer a clear and unambiguous benefit, and must be inexpensive as well.

E. Role of Government

Government has played a significant role in the development of EFT services, but mostly by getting out of the way. By mandating sharing of ATMs, state governments helped to level the playing field for smaller banks and to increase the value of ATM cards to consumers by making them usable at more locations. By deciding that interstate cash withdrawals did not violate interstate banking laws, federal regulators removed a potential impediment to the development of ATM networks. And by deciding that ATMs did not constitute illegal bank branches, the federal courts removed another important impediment. By deregulating the financial services industry, the federal government greatly heightened competition, thus helping EFT services to graduate from product differentiation to competitive necessity, Finally, by mandating the use of bar codes on products it purchased, the Department of Defense gave strong impetus to the development of a technology crucial to the development of POS.

1. Lessons for ITS

From a policy perspective, the basic financial industry issues of POS have been addressed and largely resolved, but electronic toll collection raises anew some of the most difficult of these. To all of the controversial questions regarding collection and use of personal and lifestyle data in connection with electronic transactions is added the potential for real time surveillance and tracking of motorists. These issues will attract a great deal of attention, and a new "social compact" must be reached that adequately treats the conflicting interests involved.

Exacerbating these issues is the possibility that public agencies will be operating electronic toll collection facilities. A major source of controversy during the evolution of public policy toward EFT was the concern that government might obtain access to personal data collected in connection with EFT transactions. For example, both the Privacy Act of 1974 and the Right to Financial Privacy Act of 1978 restrict the access of government to customer financial records. If government takes on the role of "merchant" in an electronic toll transaction, and seeks thereby to justify direct access to customer data to help it authorize the transaction, new policy tensions will be created that far outweigh the monetary value of these transactions. Available technology (e.g., smart cards) makes possible truly anonymous electronic toll collection, thus making it unnecessary to raise such controversial issues. Such approaches should be considered seriously in the ITS planning process.

ENDNOTES

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3. National Academy of Engineers, Prospering in a Global Economy, p.68 and p.76.

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21. MCC brochures entitled "Corporate Overview and Vision," "ElNet Overview," and "MCC Spin-Offs and Spin-Ins". MCC has its main office in Austin, Texas(telephone 512-343-0978) and another office in Washington, D.C.(telephone 202-347-4799).

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31. Information about the Partnership for a New Generation of Vehicles contained in White House Office of Press Secretary news release of September 29, 1993. Federal effort in the partnership will be led by Dr. Mary Good, Undersecretary of Commerce for Technology.

32. Bob Johnstone, "Reinventing Research: U.S. Consortiums Mimic Japanese Organization," in Far Eastern Economic Review May 24, 1990, p.70. U.S. consortia consume less than 1 percent of total U.S. R&D budget; their Japanese and European counterparts expend 4 percent and 6 percent respectively of their countries' total R&D budgets.

33. Portions of this section have been extracted from a paper written by Archer S. Taylor, co-founder of Malarkey Taylor Associates, for pre-filed testimony in 1989 [see Taylor, 1989].

34. Regression techniques employed include: ordinary least squares, two-stage least squares, linear probability and logit methods in both linear and log-linear equation specifications.

35. Levy, J.D. and PK. Pitsch, (1985): "Substitutability Among Video Delivery Systems," in Noam, p. 65-66.

36. This section draws upon an article by Michael T. Hayashi, "Qube Yesterday and Today," Communications Technology, Nov. 1988.

37. 47 U.S.C. § 153(o).

38. 47 U.S.C. §§ 390 et seq.

39. 1992 Television and Cable TV Factbook, Warren Publishing.

40. 47 U.S.C. § 303(s).

41. 47 U.S.C. §§ 302, 307 and 309.

42. The format of this case study is dictated by the facts that HDTV will not be commercially available until 1995, and that the basic economics of television broadcasting have already been described in our case study of the television broadcast industry.

43. ATV refers to any television technology that provides improved audio and video quality or enhances the current television broadcast system. The term "ATV" includes both High Definition Television (HDTV) and Enhanced Definition Television (EDTV). HDTV systems aim to offer approximately twice the vertical and horizontal resolution of NTSC receivers and to provide picture quality approaching that of 35 mm film and audio quality equal to that of compact discs. EDTV refers to systems that provide more limited improvements over NTSC. 7 F.C.C. Rcd 3340 n.1, 70 R.R.2d 1102, 1104-l 105 n.1 (1992), reconsideration granted in part, deferred in part, denied in part, 7 F.C.C. Rcd 6924, 71 R.R.2d 375 (1993).

44. NTSC is the acronym for the National Television System Committee, an industry committee convened first in 1940 to establish technical standards for the broadcast television system and again in 1950 to establish color television standards.

45. Only the fortuitous intervention of the War Production Board during the Korean War prevented implementation of the Commission's adoption initially of CBS' incompatible color standard. The Board's moratorium on color set production permitted perfection of the compatible NTSC system, which displaced the CBS system. Color Television Transmissions, Docket No. 10637, 41 F.C.C. 658, 10 R.R. 150 (1953).

46. Notice of Inquiry, 2 F.C.C. Rcd 5125 (1987) (First Inquiry); Tentative Decision and Further Notice of Inquiry, 3 F.C.C. Rcd 6520, 65 R.R.2d 295 (1988) (Second Inquiry); First Order, supra; and Notice of Proposed Rule Making, 6 F.C.C. Rcd 7024 (1991) (Notice). For a fuller description of the history of this proceeding, see Second Inquiry, 3 F.C.C. Rcd at 6521-6523 & n.15. See also Notice, 6 F.C.C. Rcd at 7024.

47. The Commission has offered this explanation: "Within the category 'ATV' we include any stem that results in improved television audio and video quality, whether the methods employed improve the existing NTSC transmission system or constitute an entirely new system . . . . Although terminology

varies slightly within the industry, the new systems commonly are referred to either as High Definition Television (HDTV) or Enhanced Definition Television (EDTV). HDTV generally refers to systems that provide quality approaching that of 35 mm film, whereas EDTV refers to systems that perform better than NTSC but not on a par with 35 mm film." 3 F.C.C. Rcd at 6544 n.1, 65 R.R.2d at 298 n.1.

48. The full benefit of HDTV is perceived only on large screens, which occupy a considerable cubage in the viewing room. The theory is that viewers' spouses will be unwilling to cede that much space in the room to a large-screen receiver. Over the past decade the trend instead has been toward personal viewing on small-screen receivers. It is uncertain whether HDTV would reverse this trend and the extent to which HDTV receivers are salable in the absence of such a reversal. It is not safe to assume that small-screen NTSC receivers will be replaced as long as there is NTSC programming available. Black-and-white sets are still in service, and some are still being sold in the smaller screen sizes, although virtually all television programming has been in color for years. By analogy, although touchtone telephone sets have been available for years and are necessary to utilize competitive long distance services and voicemail systems, a large number of the U.S. homes still have rotary dial telephones.

49. The patent issue has arisen in the FCC's ATV rulemaking proceeding. There the Commission is faced with the question of whether, when it officially selects an HDTV standard, it need only condition that selection on the proponent's commitment to "reasonable and non-discriminatory" licensing and sub-licensing of relevant patents, or whether the Commission should exercise "greater regulatory control over a selected system's patent practices." 7 F.C.C. Rcd 3340, 3358, 70 R.R.2d 1102, 1124 (1992). See also Amendment of the Commission's Rules to Establish a Single AM Radio Stereophonic Transmitting Equipment Standard, Docket No. 92-298, Report and Order, 8 F.C.C. Rcd 8216, 47 R.R.2d 244 (1993) and to 196 1 Public Notice, Revised Patent Procedures of the Federal Communications Commission, Public Notice 13948 (December 6, 1961).

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