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Publication Date

2002-02-01

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Lessons in Network Management: Cross-Industry Comparisons, and Implications for ITS Development

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**California PATH Research Report
UCB-ITS-PRR-2002-4**

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration.

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Final Report for MOU 3019

February 2002

ISSN 1055-1425

Lessons in Network Management:

Cross-Industry Comparisons, and Implications for ITS Development

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Report Prepared for California PATH Program

MOU-3019

EXECUTIVE SUMMARY

This report provides an historical and case study analysis of policies aimed toward the management of complex systems, with specific reference to the role of public policy and technology in balancing surface transportation system demand and supply. Three case studies form the crux of the paper energy management, airport management, and Internet growth. Lessons from these case studies are then applied to the circumstance of ITS deployment to manage surface transportation in California.

Following an introductory section (1), section 2 provides an historical analysis of the forces which have combined to place the California transportation on the precipice of paradigm change. The historical factors that undermined the continued efficacy of these past infrastructure choices are easily identifiable: three influences -- the withering of roadway construction funds by general price inflation, a locationally footloose economy facilitating accelerated sprawl, and the rise of environmental regulation -- effectively killed the post-war paradigm of road-building on demand. Yet traditional transportation planning procedures and capital construction program thinking continued to accent a practice of making capacity decisions on a link-specific basis, rather than devising an overall network approach.

This report then outlines the need to enunciate and to implement a new transportation system management strategy. The new paradigm is less fixated on urban highway construction, and more oriented toward better utilization of the transportation network,

using information and technology as part of an integrated approach to the efficient balancing of demand and supply. To demonstrate possibilities and challenge of government efforts in this regard, this report examines two contemporary examples of coordinated government actions which have successfully engaged system management practices for the resolution of private resource supply constraints.

Section 3 summarizes these two case studies. A first case study highlights the process of network optimization which comes from another corner of the transportation sector: This segment discusses the crisis in national airport capacity which faced the Federal Aviation Administration (FAA) in the late 1960 s, and how the FAA was able to make use of its regulatory powers to relieve aircraft congestion at the nation s busiest airports. By limiting the number of flights into the congested airports, and by balancing new airport construction with additional air traffic control system operational changes, the FAA was able not only to accommodate three decades of burgeoning growth in air traffic demand but also to substantially improve on-time performance while doing so.

The second case study then examines the energy supply sector of the 1970 s: how a geopolitical crisis in the Middle East led to an oil supply emergency in the industrial West, and how a concerted response by government to relieve that crisis spurred a comprehensive set of measures to promote increased domestic supplies, manage demand, and effect dramatic efficiencies in energy use, particularly in the realm of electricity demand and supply.

The history of these two major exercises in system management as a direct response to resource constraint crises provide some valuable lessons in the efficacy of network management strategies for surface transportation. First, the operational management techniques used in both the airport congestion and energy crisis case studies showed that system management can be a valuable aid in helping us cope with even the most severe kinds of resource dislocations. Measures to dampen demand and to increase the efficient use of what is already in place proved to be very effective in both instances.

The fourth section provides an analysis of the third case study the rise of the Internet and then turns attention to the related system challenges surrounding the deployment of ITS. That case study is found in the U.S. Department of Defense , and its initiative to create the world's first computer network -- the ARPANET -- and its role in setting the table for the economic, social and cultural phenomenon of its progeny, the Internet. While the rise of the Internet is now contemporary folklore, for the purposes of this study the key lesson is how public policy and investment helped spur the evolution of what would turn out to be a very complex and self organizing system. At this point, some general observations are made for ITS, though the bulk of the analysis is contained in the final section.

The fifth and final section outlines a series of directions and recommendations for ITS. These recommendations include: the need to more fully address customer information needs, the importance of a broaden array of system performance information metrics, the opportunity to create new institutional allegiances in the pursuant of systems

management, and, finally, the need to better understand flexible transportation network management from a theoretical as well as practical perspective.

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1 INTRODUCTION

1.1 Paradigm Change In Transportation

Philosopher Thomas Kuhn (1970) is credited with having defined a groundbreaking re-interpretation of the process of intellectual evolution in the sciences. Noting that extended periods of scientific certainty tended to be punctuated by relatively severe -- and not-necessarily cumulative -- breaks, Kuhn's analysis highlighted the conceptual process of an evolution of what he called paradigms, which he defined as a viewpoint or organized set of scientific views held by a consensus of the eminent scientists of an age for a generation of doctrinal thought. He explored the history of several branches of the sciences to search for clues in this process of intellectual evolution, tracing the initial process of a paradigm's establishment, and then examined the process through which the march of theoretical refinement coupled with experimental testing would ultimately undermine it.

Although Professor Kuhn's contribution was to decipher a new structure for the interpretation of the history of thought in the hard sciences, he also believed that the paradigm concept was easily adaptable to a broader range of research endeavors. Many have agreed. Today, what's good for formal scientific knowledge now conceptually also is widely seen to work in understanding issues in social science and public policy, and even more generally into processes of culture and politics. It is in this sense that the paradigm is a convenient device to use in a discussion of

evolutionary changes in public policy; and we seek to use it in a policy-directed discussion covering the evolution of the ground transportation network in California.

This report was conceived on the premise that the state of the transportation network facing public officials and other transportation network infrastructure planners has led to an unwelcome crossroad. A post-World War II transportation paradigm accenting reliance upon road and highway construction to meet demand has run its course. (Lang , 1999) The severity and regional breadth of our urban traffic congestion clearly indicates that our capacity planning and infrastructure choices are failing.

In fact, our urban surface transportation networks increasingly have come to resemble the former Soviet Union s approach to rationing limited supplies of consumer goods: Like Russians lining up for bread, Americans queue up to the transport line--having the apparent freedom to enter at any time and at very low marginal cost. But without the capacity required to service this level of demand, we find ourselves ultimately captive to congestion and delay.

The forces undermining the continued efficacy of these past infrastructure choices are easily identifiable: growth in major metropolitan areas, low-density development and edge cities, and failure to plan for and fully fund needs to accommodate that growth (and its changing regional distribution) all deserve their full measure of the credit for this turn of events. Air quality considerations force us to spend sparse transportation dollars on investments less concerned with mobility than with the impacts of that mobility. Public works officials throughout the country wrestle with problems simply maintaining what they already have, let alone expanding their

network to the full extent required by expected system needs. And most contemporary observers today realize that we no longer possess either the financial resources or the planning flexibility required to build our way out of our congestion morass. Yet we continue to try to do so. Projects like the Boston Harbor Tunnel and the Los Angeles Subway -- although apparently well-founded in justification-- prove to be vastly expensive, and after the full accounting for cost overruns and system performance, do not always meet the criteria used to justify them.

All of this present us with a powerful need to enunciate a new surface transportation management strategy; yet the ultimate shape of that new paradigm remains opaque. Where, in the past, congestion on a given roadway link was overwhelmingly met with a *pro forma* assumption of need for more capacity via roadway construction, today's prescriptions require an understanding of the entire system, including demand as well as supply, and, importantly, the role of information technologies can play in harmonizing the system.

1.2 Paper Objectives and Approach

This paper uses historical and case study analysis to reflect upon our past experience -- not only in the narrow confines of transportation policy but more generally to issues of major resource constraint in other policy realms. Then, within that context, we analyze a number of new tools available to meet the needs of this new network management paradigm, to suggest their respective roles and provide support for their active inclusion in forming alternative strategies to the selection of our urban mobility infrastructure choices.

One of those broad strategies is to systematically integrate the expanding quiver of advanced information technology tools into the task of transportation grid management. These Intelligent Transportation Systems (ITS) offer new means to in effect boost network capacity through operational changes which ease traffic flow and affect demand. The ITS universe covers a fairly wide range of functions, from traffic sensing to traveler information to electronic pricing. (ITSA, 2000). More generally, a recent workshop by the National Science Foundation (NSF, 2001) has underscored the full scope of the new era in infrastructure management made available by our rapid pace of innovation in information technology. Their central feature, however, is their prospective capability to vastly improve the flow of information to system managers, operators and customers. Looking across systems, they present opportunities for a dramatically new form of infrastructure management for civic infrastructure programs including surface transportation systems.

This report seeks to apply practical lessons from our recent past, and draws upon our historical experiences in system management in other public realms to suggest the new drive to apply ITS methods to surface transportation. In Section 2, we discuss the general question of the yoking of these practices as a major strategy in handling our urban congestion problems. To do this, we initially discuss why we have to -- the historical realities driving the paradigm for urban mobility away from simple capacity expansion and toward operational network optimization techniques. In Section 3, we then discuss how our contemporary history shows that these kinds of civil infrastructure approaches have been undertaken quite successfully -- even in dealing with seemingly intractable resource supply constraints: Using the examples of the Federal Aviation Administration's operational approach to airport congestion and our national response to the

Energy Crisis of the mid-1970s, we show how system management can stretch limited resources -- not only through enhanced efficiency of use but even from tapping available -- but hidden -- sources of supply. Then we discuss the implications of these lessons for the ultimate feasibility of use of these advanced operational tools, and how ITS approaches meet their respective needs. In a concluding section we address some of the innate opportunities and pitfalls in applying a new system management paradigm to regional urban transportation systems.

In Section 4, we narrow our focus to the specific topic of near-term ITS in California. To do so, we begin by analyzing a third historical public policy metaphor -- the Defense Department's effort to construct the first major computer network (the ARPANET) and how successful commercialization of the computer network technology led to the veritable explosion of private sector economic activity which the techniques have enabled over the last two decades. Finally, we discuss the meaning of this parallel for the likely level of success of ITS as a component of our future approach to urban traffic congestion.

In section 5, we integrate the lessons into an overall analysis of the challenges facing ITS in this new information era. The organizing theme for this section is how new information systems present an opportunity for ITS to affect the travel and access needs for a wide variety of customers. Based on this analysis a number of directions and recommendations are outlined. Ultimately, we hope to have lent a historical and cross-industry bent to the discussion of how regional urban transportation systems can be developed which more fully reflect a cohesive system management philosophy, and the supporting role of Intelligent Transportation Systems in doing so.

2 POST-WAR AMERICA AND PARADIGM CHANGE IN URBAN MOBILITY POLICY

The contemporary demographic and economic history of America since World War II is intimately intertwined with the evolution of our ground transportation system. The immediate wake of the post-war era brought a historic level of economic prosperity not seen since the onset of Great Depression. The nation's return to a dynamic peace-time economy would link with rapid growth of family formation and the beginning of the Baby Boom era to launch an era of explosive redistribution of the population from rural areas to the cities, from the country's Northeast to the South and West, and from central cities to the surrounding areas. Ultimately these changes would prove to re-make the national landscape. (Jackson, 1985)

By now, the history of these post-war economic and demographic patterns is well understood. Less well known, however, is the role of the government finance practices of the time; how they facilitated the suburbanization of America, and how they at the same time came to influence our current state of urban mobility. The suburban migration of post-war America, the transportation paradigm which enabled it, and the seeds of further evolution in contemporary regional transportation policy which set the context for our infrastructure decisions today present a fitting first topic in this study of system management's heightened role in our transportation future.

2.1 The Policy Economics of Auto-based Transport

Suburbanization, of course, could never have occurred after the conclusion of World War II without a ready source of general public infrastructure funds: New suburban communities needed to build a wide range of public assets and services required to accommodate the immigrating public, not only local roadways, but also schools, police and fire stations, water and sewer systems, and the like. As a simple cash flow issue, these local government investments were required to be made first, before the induced tax revenue streams from the new homes and businesses attracted to the fledgling communities could begin to compensate governments directly for their infrastructure outlays. For typical non-roadway infrastructure, new construction funds were either directly financed by issuance of new bonds written against future tax revenues of the new community, or funneled by state government from taxes levied upon already-existing areas for redistribution in the form of grants and loans to the new suburbs.

Whichever route was taken, the financing process required relatively healthy local property and sales tax revenues which would ensure adequate funds to fully compensate bondholders, or to allow the new beneficiary community in turn to participate in the state government-brokered cross-subsidy for other, even newer recipient jurisdictions. And these tax rates had to be adequate to concurrently leave every community with adequate revenues to supply their residents own public service needs. For the most part, these funds were readily available in the urbanized regions of the United States after the War, and new growth could be supported without the severe infrastructure charges incurred today by land developers choosing to build in new

suburban zones. With public opinion more favorable to growth than is often found today, these general tax revenue levels allowed older fringe communities to welcome new suburban populations.

Suburbanization also required the ability to finance timely construction of a vast network of new and improved roads. In one important way, the financing requirements for roadways were more difficult to meet than the needs for other more localized types of public infrastructure. Part of this begins in elemental geometry: Because the area of a circle expands by the square of its radius, the increasing breadth of the sprawled urban region forced increasing demands for road building into new areas simply due to this basic geographical reality. In addition, because new suburbs grew largely to serve the housing needs of people employed in the central cities, city and suburb remained economically integrated. This meant that suburbanization required not only extensive construction of local roads within the fledgling suburbs, but also a network of high-capacity roadways linking the two. In this sense, highway finance was especially burdened because of the need to sink even more capital into upgrades into the regional network beyond the community's own boundaries. And for public works officials of the period, extension of the roadway network required large sums of new cash to allow this construction.

Financing for previous levels of road construction had been cobbled together through a complex web of taxes and user charges already in place at both the state and federal levels; yet in the post-war era, government at all levels recognized the need to provide substantially higher capital funding levels to accommodate new growth. The financing vehicles selected ultimately to serve as the major source of new construction money were the federal and state excise taxes on motor

fuels. (Brown, et al., 1999. Chapter 3) This existing fiscal system came to be substantially strengthened in the 1950 s during the Eisenhower administration, in the capital budget planning process for the Defense and Interstate Highway System.¹ The Defense and Interstate Highway Act established the national Highway Trust Fund, and specified the basic permanent process for the allocation of federal fuel excise tax revenues that we still utilize today. Excise taxes flowed into the appropriate selected trust accounts, from which they were drawn upon in a formulaic way to finance construction of network additions on an out-of-pocket basis. By paying cash for new projects, rather than through bond finance mechanisms, interest payments were avoided and hence turn-key costs for each project could be minimized.

These arrangements could hardly better meet the roadway needs of the suburban growth model. Being tied to their specific uses, these trust funds would arrive automatically; and their administrative processes provided relatively flexible dispersal for new projects, with minimal interference by government at large. More vehicle traffic led naturally to more gasoline sales and tax revenue, and ultimately to more money in the capital fund for more roadway capacity. With a steady supply of programmed capital funds for new construction, transportation officials were able to anticipate the needs for additional highway capacity radially from the central city, and could thereby serve -- if not actively promote -- the process of sprawl.

While this system of public highway finance had a salutary effect upon the capacity of the highway network, it included no companion arrangements to provide matching capital assistance for transit systems. In fact, the original legislation financing the fledgling Interstate Highway System specifically ruled out use of federal Highway Trust Fund moneys (i.e., the depository

home for the federal fuel excise taxes) for transit system support.² Similar limitations came to be enacted in law in most states, including California. This appeared to be a logical provision at the time, given the scheme's design goal of using the highway trust funds as engines for a national highway network construction initiative.

When faced with the need to extend transit service out into the evolving suburbs, however, transit systems would find themselves financially ill-prepared for the needed growth spurt. Part of this was due to the financial structure of the transit industry of the time: Up to this point, transit service was generally provided by private firms, running on a for-profit basis under exclusive franchise agreements with their respective host cities. Capital expenditure questions were internalized within the transit firm, generally with little or no direct public sector input in determining them. Firms would invest in equipment as route service demands and available revenue permitted. As the city extended out into the countryside, the bounds of that capital finance system became tested in several ways. Highway finance was automatic and grew geometrically with the expansion of auto use. Transit firms had no companion ballooning revenue base to form the source of the extensive system investments which would have been required for them to keep up. And, at the time, there were no regional planning entities as exist today to promote a balanced growth of the entire transportation network as it radially extended outward. When no complementary dedicated source of capital funds was fashioned to allow transit to grow in concert with the highway grid, transit systems could not respond to the challenge on an even footing.

Ultimately, this quirk in the structure and the differences in long-term investment practices between highway and transit systems combined with more basic market disadvantages for transit in suburban settings to wreak havoc with transit system economics. Decreased population densities and wider geographic dispersal of destination points for many kinds of trips had already severely disadvantaged mass transit as an effective competitor for suburban travel. Many trips had no transit connections of any kind available; and even when a particular suburban trip was possible using transit, long travel times and infrequent service posed substantial disadvantages when compared to the auto. Also starved for growth capital, transit systems found their markets eroding : Ridership nationally in 1955 was less than half of what it was a decade earlier, (American Public Transit Association, 1976) and vehicle ownership per capita soared with the good economic times: In California in 1945, there was one passenger vehicle registered for every 3.6 people in the state; 10 years later, there was a car for every 2.4, and more autos had been added to the state s fleet than the number of adults available to drive them.³

The withering of transit ridership itself would cause a reinforcing bias against transit use: As middle class riders abandoned transit for increasingly affordable and convenient auto travel, transit began to develop an unsavory image as it became increasingly prone to cater only to the needs of lower income patrons. Taken together, these problems severely compromised transit system financial performance, forcing many urban operators either out of business entirely or into consolidations with other local operators. And a transit industry formerly composed of profitable, privately-owned urban firms became transformed into a set of publicly-subsidized regional systems -- all chronically awash in red ink.

Clearly, by the end of the administration of Dwight Eisenhower, a consensus paradigm of urban ground transportation policy and the financial underpinnings for it was in place. That mobility paradigm was centered firmly on the personal use of the automobile and the choice of highway construction over mass transit investment. It was also based upon a general philosophy of building and improving highways on a traffic-demand basis. Infrastructure policy was to accommodate the desires apparent in the evolving patterns of urban growth, rather than to attempt to shape them. The automatic nature of highway funding mechanisms relative to transit investment, coupled with the flexibility to pay cash for incremental highway network additions provided a roadway link-specific focus to capital planning decisions: Rather than asking more basic questions about how to best link specific locations within an integrated multi-modal transportation network, we chose instead to expand indicated corridor capacities with more roadways. And even if some authority had existed with responsibility to provide a balanced approach to urban regional growth between the auto and transit services, the financial stasis of transit system investment funds would have impeded its achievement.

The consequences of post-war suburbanization and the infrastructure paradigm choices to facilitate it about the nation's cities were to prove even more stark in California, due to the state's large growth relative to its pre-war level of population and level of economic development. Particularly to the South of the Tehachapi range, history coupled with the lack of water had conjoined to retard the degree of urban development in California before these larger regional growth factors could take hold. With a healthy network of state and federal highways already built connecting the coastal areas, the agricultural inland valleys and the land-locked

western states, a ready supply of highway capacity already existed to facilitate the early stages of the suburban growth to come.

Further, California already held an impressive directory of national defense interests located within its borders. The state's role as principal national border to the Pacific Ocean only further accentuated its value as a defense asset, given the increasing strategic importance perceived for the Pacific theaters of operation in the wake of World War II and the pursuant Korean conflict. Its weather made it ideal for aircraft testing and fabrication. One of the results of this was early construction of the buttress links of the Interstate network within the southern coastal zone. The Southern California megalopolis which was to become the consensus national example of sprawl and bad air could arise because a roadway infrastructure network built in advance of what would be commensurate with the area's population and economy came to meet a vibrant new post-war economy based upon petroleum, entertainment, aircraft, and a permanent establishment of the national defense industries.

2.2 The Auto/Roadway Infrastructure Paradigm Frays

The reigning paradigm in urban ground transportation began to unravel during the late 1960s, and did so for three distinct reasons:

Inflation, coupled with improvements in automotive fuel economy worked together to compromise the buying power of the highway construction funds provided by the fuel

excise taxes. This had the ultimate effect of withering the financial underpinnings of the system;

Suburban sprawl began to change character and to accelerate as the nature of economic growth changed from one based upon traditional city-centered heavy industries to one highlighting growth sectors characterized by greater locational flexibility; and

New-found alarm due to environmental degradation -- particularly with respect to air pollution -- began to nudge governments at all levels to favor alternatives to the auto -- particularly against the vehicles of single-occupant commuters.

The fuel excise taxes -- both state and federal -- had been selected as the consensus user charges to serve as the primary funding source for roadway network capacity expansion during the 1950 s. Two salient characteristics of them proved to hamper their effectiveness during the following 30 years: First, the taxes were set in a fixed rate denumerated in cents-per-gallon, and were not by law automatically increased with increases in price levels. This meant that as costs for roadway construction naturally floated upward with general inflation, no compensating automatic increases in construction fund revenues arose to compensate for the higher prices. Second, because these taxes were levied only upon the purchase of each gallon of motor fuel, total collections were highly sensitive to changes in fleet vehicular fuel efficiency. Both of these aspects were to lead to cumulative erosion of the buying power of their depository funds after the mid-1960 s. And this in turn would lead to the undermining of the ability of public works officials to maintain their practice of building capacity to meet the demands on the network .

The history of this erosion of the fiscal superstructure of the highway system is traced in detail in a recent and thorough report by a multi-disciplinary research team of the University of California, and published through the auspices of the California Policy Research Center. (Brown, et al., 1999) Briefly mentioning some of the findings of this work will be sufficient, however, for our needs. A hyper-inflation in the general economy arising first due to a very expansive federal budgetary, monetary and fiscal policy during the Vietnam War era was to continue for other reasons into the late 1980 s. Yet during the 1970 s, vehicular fuel economy also improved, largely in response to the petroleum supply interruptions orchestrated by the members of the Organization of Petroleum Exporting Countries. Consequently, cars were able to travel considerably higher distances on each tank: Nationally, between 1970 and 1990, automotive fuel efficiency improved by about half, from 13.5 mpg to about 20, while in California this trend was exacerbated by the early saturation of the new car market by Japanese imports.⁴

The combined effect of these influences was to be a plummeting of the fuel excise tax revenue per vehicle-mile traveled available to build new roads. Over the 20 years between 1965 and 1985, general price levels more than tripled, population had increased by more than half, and total travel on the state s highways more than doubled.⁵ What this meant for the funding of roadways is summarized in Figures 1-1 and 1-2, below. When considered in terms of real (i.e. adjusted for inflation) tax revenue per vehicle-mile (i.e., expressing the constant-dollar tax revenue received for each mile traveled), this is equivalent to a 2/3 drop in revenue over the period. (Figure 1-1) All of this led to a commensurate relative reduction of road-building over the same period: Adjusted for inflation, total highway expenditures for capital projects in

California decreased by more than half. (Figure 1-2) Further, if we note that highway construction cost increases have exceeded those for the general economy -- exacerbated in California by soaring prices for new right-of-way -- these measurements are conservative in portraying the full extent of the capital fund shortfall upon our ability to expand our highway network.

As this erosion of the highway construction funds was unfolding, however, neither the federal nor the state government chose to respond to this situation with proportionate boosts in the fuel excise tax rates to compensate for these factors. At the federal level, a White House generally in Republican Party hands during the period sought to shift the burden for urban highway finance to the states once the federal Interstate Highway System was complete, rather than to attempt to retain a parity in the federal/state fuel tax mix. At the state level, the reaction was mixed: Because of its interests in diversifying the urban auto/transit mix in the State, the administration of Edmund G. Brown Jr. responded to the situation primarily by seeking increased flexibility in the use of available funds to better include transit-oriented uses. His successor, George Deukmejian, chose a return to the greater use of bonds in lieu of continuation of cash financing with increased taxes as a means to cope with the revenue shortages. This had the double-edged effect of allowing a goodly number of ribbon-cutting ceremonies, but largely shifted the burden for paying for those projects to his successors. Because bonds also require interest payments to compensate bond holders for the use of their funds, project costs of those new projects soared with the addition of those interest costs. And the attachment of future fuel tax revenues for payment of already-built projects exacerbated the financing problems faced by future governors unable to use those funds for their own network improvements.

In the end, in California, increases in taxes for ground transportation purposes over this period typically took the form of localized general sales tax additions for major cities throughout the state, to contribute additional transportation funds for local government uses, rather than to ensure inflation-compensating additional revenues to the construction kitty. Particularly after the passage of Proposition 13 in 1978 -- rolling back inflation-indexed increases to the valuation of homes for property tax determination purposes -- both legislators and the Executive Branch alike proved reluctant to raise fuel excises commensurate with inflation despite their common understanding of the evolving crisis in transportation finance. By the middle of the 1980 s, senior CalTrans staff were worried about maintaining what was already in the state inventory, let alone how to expand it. In a speech to Orange County officials in September of 1986, then-CalTrans Director Leo Trombatore put the issue this way: (Trombatore, 1986)

CalTrans has just about completed all of the freeways and highways that California can afford... With this network in place, the major emphasis of CalTrans mission has shifted to highway maintenance, rehabilitation, reconstruction, and to making safety and operational improvements. In short, CalTrans number one job is protecting California s multi-billion dollar highway investment.

It was to take until 1989 for a substantial new revenue package for transportation to be passed by the Legislature and signed into law. Certainly, the help was long in coming, but it proved to be nonetheless insufficient: The University of California research team estimated in 1999 that a

state gasoline tax of 43 cents per gallon would be required to bring tax level per vehicle-mile in line with those historical levels. The current rate is 18.4.⁶

The result has been a truly impressive backlog of needs for additional construction. When the state Senate requested an estimate of the cumulative financial shortfall during the 1998 - 99 legislative session, the California Transportation Commission estimated the level of unfunded needs for roadway and highway projects alone at over \$90 billion. (California Transportation Commission, 1999) And, in the preamble to the Congestion Relief Act of 2000, the California Legislature noted that while California's population has grown by more than 50 percent over the past 20 years, highway capacity has increased by only 7 percent. (California Government Code Chapter 4.5/14556.3)

Recent developments, of course, have shown that the historical under-capitalization of our ground transportation is now well recognized in both the executive and legislative branches of California's government. The recent passage of the Congestion Relief Act coupled with the state's generation of healthy budget surpluses in recent years have given many transportation advocates cause for hope that a serious bipartisan effort to find solutions to our ground transportation fiscal problems could now be at hand.

But even more recent events have thrown a pall over that guarded optimism: No serious long-term proposals are currently in the works to significantly boost fuel excise taxes. Legislative interest in crafting new capital budgeting processes which better assess the state's infrastructure needs and provide for their funding is beginning to appear; but as yet there are few formal

proposals to actually do so. The major economic slowdown which permeates the national news today -- particularly in the information technology sectors which have been so spectacular in driving the state's economy -- places the continuation of budget surpluses in doubt. And the state's need to commit vast funds to limit the damage from our ill-conceived tilt at deregulation of the electricity sector threatens the general health of the state's budget. We may thus have to wait a bit longer for a major initiative to fix our transportation infrastructure delivery system.

2.3 The New Wave of Suburban Growth

The first post-war wave of suburbanization retained a strong economic tie between the surrounding suburbs with the central city. Although residential choices favored the urban fringe, the central cities retained the role as the fundamental source of employment and income from which the new suburbanites took their sustenance. This, too, began to change during the 1960s. Economic diversification tended to shift growth from heavy industry toward light manufacturing and the service sectors, which allowed movement of regional economic activities away from the cities. Retail and other consumer service operations, of course, tended to follow the population away from the urban core. But more importantly, a manufacturing industry evolving toward the production of goods with relatively low weights and volume relative to value favored freight shipment by truck rather than by the traditional bulk shipment means of rail and water transportation. This allowed major employers more flexible location, too, freeing firms to seek suburban or even rural locations; and became a factor in the national redistribution of manufacturing industries in search of cheap labor. As the construction of the Interstate Highway System filled in across the country, these manufacturing establishments could gravitate from

historical rail or water transportation centers to major nodes of the Interstate system. And previously noteworthy, but not strategically-located inland cities such as Charlotte, North Carolina, and Columbus, Ohio, would be transformed into major integrated multi-regional economic centers.

Beginning during the 1980 s, this historic trend came to be accelerated even further by the onset of the so-called New Economy consisting of the computer industry and the other advanced information and telecommunications sectors. From an industry generally known only to accounting professionals of large firms and those involved by accident or by stock transactions with IBM a generation ago, this sector has come to dominate the nation s economy. A full third of the total economic growth of the United States over the last five years is directly due to growth of the information technology sectors, (Economics and Statistics Administration, 2000) and total employment in this industry (including those in the rest of the economy whose job involves using it at a technical level) now accounts for almost one in ten workers in the nation s largest urban areas. Because of its critical early role in these industries here in California, this employment presence is even higher: In the San Jose area (the home of the Silicon Valley), the information technology segment of the economy has grown to provide almost 1 of every 7 jobs in the region. (U.S. Department of Housing and Urban Development, 2000. Exhibit 1-6)

In part due to the ability to work long-distance over vastly improved communications networks, and very high value-to-ship weights attached characteristically to high tech products, major firms in this sector have been free to locate in relatively isolated towns perceived as attractive less due to direct economic linkage than a high quality of life for its officials and employees.

The industry has launched such formerly demure -- if not sleepy -- fringe towns and cities as Cupertino, California (home of Hewlett-Packard and Apple Computer), and Redmond, Washington (Microsoft Corporation) into significant roles in the national and even world economy. In California, we have at least two classic examples of this phenomenon played out on a grand scale: the Silicon Valley area between San Francisco and San Jose, and Orange County. Similar kinds of growth -- only on a lesser scale -- are also in evidence at the outer reaches of the eastern and northern fringes of the San Francisco Bay area, and in the Sierra Nevada foothills to the East of Sacramento.

The important point lying behind the change in economic growth patterns is this: The focus of the first wave of suburbanization retained a regional reliance on the central cities as the economic engines propelling regional growth. This continuing mutual reliance between city and suburb had the effect of serving as a restraint upon the degree to which sprawl could distribute new population -- and hence traffic demand -- across the regional landscape. With the relative decline of old manufacturing and the rise of the New Economy, the footloose character of industry has effectively severed that link to the central city (though not necessarily to the larger metropolitan area), and with it those implicit restraints upon the degree of sprawl. In 1950, growth in land use for single-family housing in the United States increased at the same rate as the growth in population. Now, land use is increasing twice as fast. (U.S. Department of Housing and Urban Development, 2000)

Of course, in theory this situation might have presented a positive result: redistribution of traffic over a wider set of less-densely urbanized regions could be viewed as offering an opportunity for

better use of the existent network by spreading peak-hour traffic over a wider geographic area. And it might well have actually worked that way if this growth had occurred at the same time that we were fully funding the system's evolving needs in those new urbanizing regions. Instead, we have exported congestion into new areas, as anyone recently prone to traversing the Silicon Valley or northern Orange County during rush hour can readily attest. The downstream effects of this accelerated dispersal of population has been to place even further demands for new roadway infrastructure upon a system which has been seriously underfunded for a quarter of a century. Without the money available to maintain highway construction levels on demand, the result has been truly impressive levels of vehicular congestion: In 1999, the state's urban motorists are estimated to have spent over 400,000 hours each day in traffic jams, at an estimated daily cost approaching \$8 million. (Legislative Analyst, 2000)

2.4 The Environmental Ethos -- Air Quality and the Search for Alternatives

Despite the heavy post-war investment in roads and highways, traffic jams -- albeit on a smaller scale than today -- were an almost universal experience across the nation's major cities even relatively early in the post-war era. And with high levels of traffic came the broad public recognition that the automobile was contributing to a decreasing quality of the country's urban air. Environmentalism as a popular mode of thought based upon a common public understanding of the evolving body of environmental science was not to arise, however, until the late 1960s. When it did, it did not take long to intrude into the prevailing infrastructure paradigm, with passage of major legislation at both the federal and state levels: the National

Environmental Policy Act (NEPA) of 1969 and its counterpart in California, the California Environmental Quality Act (CEQA) in 1970.⁷ These measures laid out a process of environmental review and mitigation for new construction projects which came to significantly increase the administrative costs of road-building. Since the Acts also required the identification and resolution of environmental issues before construction could begin, they also added a new and profound source of administrative cost and delay.

Under the best of circumstances, environmental compliance would entail a delay between planning and actual construction of generally two years; but lawsuits based upon these general environmental grounds quickly proved capable of delaying projects indefinitely. For instance, the so-called Devil's Slide project on Route 1 south of San Francisco was first formally planned in 1972: Due to relatively low official priority and a legally canny set of opponents well versed in the provisions of the new environmental laws, it has yet to be built. Nor were the impacts reviewable under these acts confined to a concept of physical environment issues, narrowly defined: The environmental review process for the Century Freeway in Los Angeles ultimately went so far as to require provision for the housing needs of displaced residents.

Whereas NEPA/CEQA proved to be a costly annoyance and source of delay to highway builders, the passage of the Clean Air Act in 1970 (Federal Code Volume 42, /7401 ff) proved to be a more serious threat to the entire regime. The Act's principal early initiatives were centered in regulatory measures to improve the emission profiles of new vehicles; but the longer term regulatory scheme also mandated state and local government actions to effect reductions in auto emissions by changes in infrastructure and land use decisions as well. The Act's legal levers

designed to force the hands of state and local jurisdictions consisted of both fiscal and regulatory sanctions: The Environmental Protection Agency was given the authority to impound earmarked federal highway and sewage treatment plant construction funds for failing to meet the proscribed standards.⁸

And these sanctions went beyond the mere fiscal impacts of such impoundments: The Agency was also given the authority to refuse certification of new major stationary air pollution sources.⁹ Taken together, these regulatory actions would not only crimp state and local infrastructure construction funds, they could indirectly limit a recalcitrant community's ability to grow by strangling its economic infrastructure. When the Agency for the first time proved its willingness to actively use its remedies by withholding funds from the State of Colorado in 1980, state and local officials -- particularly in California -- found themselves facing a real threat.

From the perspective of vehicular air quality impacts, the most serious of these criteria pollutants are ozone, carbon monoxide and small particulates. Although EPA has proven to be willing to grant delays in compliance when faced with good-faith efforts of local authorities to comply with the Clean Air Act's provisions, their patience is not endless: At the present time, six communities nationally are subject to withholding of transportation funds or fighting orders to do so, with Atlanta, Georgia, being the most recent high-profile target of these sanctions.¹⁰ And a number of major California cities are facing imminent deadlines for compliance, with varying degrees of likelihood of their respective ability to meet the requirements: A review of the Environmental Protection Agency's listing of areas in the country which are out of compliance with the Clean Air Act's ozone standard presents an uncomfortably long list of regions in the

state. The ozone problem in the South Coast air basin (Los Angeles) is rated by the Agency as extreme , with only severe violations of the ambient standards being encountered in the Southeast Desert region, and Sacramento. The list of problem areas also includes the southern San Joaquin Valley, Ventura (city) and even Santa Barbara.¹¹

With the EPA s legal sword hanging over their heads, state and regional officials have been forced to scramble to find alternatives to practices of the recent past. California s standards for performance of new vehicles were the toughest in the nation, and it was also one of the first to deploy an inspection program for used vehicles as well. The more operational elements sought to reduce emissions with strategies to lure commuters out of their cars and into carpools and mass transit during peak-hours. This effort has taken many by-now familiar forms: State and local governments began to build high-occupancy vehicle lanes, sponsored carpool and even bicycle-related commute programs. Suburban districts without transit services were supported in establishing them; and state government extended that support for the establishment of commuter heavy rail service as well. In addition, increasingly sophisticated local governments began to make active employer support of carpools and transit use a positive requirement conditioning the issue of land use designations and building permits.

In addition, the need to attack air pollution has also funneled sparse public transportation capital expenditures into purposes which -- however useful they may otherwise be -- have little beneficial effect for enhanced mobility. The national campaign to convert diesel transit vehicles to compressed natural gas, for instance, may be a valuable aid for micro-improvements in local

air quality. It doesn't by itself, however, expand the capacity of systems struggling to provide service levels attractive to prospective patrons who currently drive to work.

2.5 The Search for a Better Network Management

Taken together, these three influences -- the withering of roadway construction funds, a locationally footloose economy facilitating accelerated sprawl, and the rise of environmental regulation -- have effectively killed the post-war paradigm of road-building on demand. And they conjoin to shape the outline of what soon will be a consensus philosophy that will guide the new one. The new paradigm needs to be less fixated on urban highway construction, and more oriented toward better utilization of the transportation network, mixing elements of demand management and multi-modal coordination into an overall network management focus.

This fact may not yet be fully understood by national highway officials, but a long-term commitment to network management -- in both supply allocation and demand management functions -- is no longer merely an option which one can take or leave. In many ways, it is the immediate future of urban ground transportation. We address these issues in context of a broader policy discussion of the role of Intelligent Transportation systems in this new world of advanced network management in Section 3 of this report.

Chapter 2 End Notes:

- 1) Also interesting as a shaping influence is an anecdote retold by Daniel Yergin about Dwight Eisenhower early in his Army career, and his experiences in a cross-country road trip during 1919 to demonstrate the potential of motor transportation and to dramatize an ongoing Defense Department case for better highways. The trip proved trying, and President Eisenhower later came to describe it in his memoirs as a genuine adventure, ... through Darkest America with truck and tank. (Yergin, 1991. pp. 207-8).
- 2) This provision was finally liberalized during the Nixon administration in 1972. But its actual use for transit capital finance has been *ad hoc* and sporadic since.
- 3) Unpublished population estimates for the respective years by age cohort were supplied by the California Department of Finance. Passenger vehicle registration data is from (State of California. 1970).
- 4) U. S. estimates are from (Oak Ridge National Laboratory 2000). Unpublished vehicular fuel efficiency data from California were provided by the California Energy Commission.
- 5) GNP deflators for price level adjustment were taken from the U.S. Department of Commerce Income and Product Account series for the United States. Population estimates are from unpublished data of the California Department of Finance. State

- highway VMT statistics were taken from the Caltrans *Travel and Related Factors* series. Tax receipt estimates were taken from (Brown, et.al. 1999. Figure 4.1).
- 6) (Brown, et al., 1999. Table 5.2) For a complete picture of the current finance system for roads and highways, see (Legislative Analyst, 2000)
 - 7) NEPA, as amended, may be found at Federal Code Volume 42,/4321 ff. The California Environmental Quality act is found in the California Public Resource Code,/21000 ff. The two have largely similar provisions, but as a matter of law NEPA applies when direct federal money is predominantly used, while state and local projects are subject to CEQA.
 - 8) Impounding federal sewage treatment plant construction funds could hamstring an area s future growth, since federal water quality law prevented future sewer hook-ups in the absence of adequate sewage treatment capacity.
 - 9) This, of course, could prevent new facilities vital to local economic activity -- like major manufacturing facilities or electric power plants -- permission to operate. The original act allowed this sanction to be applied only to new stationary sources. When the Act was tightened in 1990, all air pollution permit certificates were changed from permanent to confer five-year operation authority. This potentially threatened all major stationary air pollution sources, not just new ones.

- 10) As of March 15, 2001. Four of these six are due to criteria pollutant violations specifically caused by motor vehicles, and from failure to adopt adequate plans for future compliance. These are cited at the Federal Highway Administration website <www.fhwa.dot.gov/environment/sanccllok.htm>
- 11) Current ozone compliance dates for the major non-attainment areas in the state are: Los Angeles Basin, 2010; The Southeast Desert region, 2007; Sacramento, San Joaquin Valley, and Ventura, 2005; Non-attainment areas for the nation by criteria pollutant may be viewed on-line at: <www.epa.gov/oar/oaqps/greenbook>

3 SYSTEM MANAGEMENT IN ACTION: PUBLIC SECTOR APPLICATIONS TO PRIVATE SECTOR RESOURCE PROBLEMS

There is nothing conceptually new about the use of network management in the transportation realm. In fact, rudimentary network management techniques have been freely used throughout history: A stop sign, for instance, is a tool of network management; so are lane striping, traffic signals and highway signage, airport beacons and marine navigation aids. Right-of-way rules also qualify as system management tools, whether they be encountered on roadways or in context of airborne or maritime commerce. Even weather forecasting provides occasional transportation system management functions, when it leads to travel advisories affecting route selection of aircraft, ships and motor vehicles.

As shown in the preceding section, however, chronic traffic congestion in the nation's urban areas clearly reveal a compelling need for a new paradigm for urban ground transportation, based upon the extension of a more modern array of network management tools. The new philosophy will in large part be committed to the application of advanced techniques of system management, seeking not only capacity enhancement but also optimization of the use of what we already have. These techniques will be technologically sophisticated, and based significantly upon the new capabilities inherent in the rapid evolution of the communication and information technology sectors. They will also present a mix of direct traffic control strategies with simple provision of

better real-time information to give individual travelers more effective choices in their travel decisions.

Before discussing the specifics of applying modern system management practices to contemporary problems in support of our urban mobility, however, it is instructive to show that just these kinds of public sector approaches have been very successful in the past in addressing seemingly intractable resource problems in other arenas. To do so, we examine two contemporary examples of coordinated government actions which have successfully engaged system management practices for the resolution of private resource supply constraints.

Because the conceptual uses of system management in ground transportation contain elements of both optimization of network traffic flow and demand reduction, we present historic case studies which feature both methods: A first case study highlights the process of network optimization which comes from another corner of the transportation sector: This discusses the crisis in national airport capacity which faced the Federal Aviation Administration in the late 1960 s, and how the FAA was able to make use of its regulatory powers to relieve aircraft congestion at the nation s busiest airports. A second case study then examines the energy supply sector of the 1970 s: how a geopolitical crisis in the Middle East led to an energy supply emergency, and how a concerted response by government to relieve that crisis spurred a comprehensive set of measures to promote increased domestic supplies, manage demand, and effect dramatic efficiencies in energy use.

3.1 Airport Congestion, the FAA, and the Landing Reservation

Program:

Our initial policy metaphor in the application of network management techniques is offered from a vehicular congestion problem of another kind, and found in a different realm of the transportation field: the control of air traffic and the methods which came to be applied to relieve congestion at major airports:

3.1.1 The Historical Setting

Particularly by the late 1950s, the deployment of heavy public subsidies to inter-regional highways and airport construction began to tilt the market for intercity travel away from passenger trains and toward automobiles and air transportation. The air system experienced rapid growth, and equally rapid technological advances -- particularly the beginning of the systematic adoption of jet engine technology into the passenger aircraft fleet during the early 1960s. All of this offered speeds of comfortable travel between major cities which would have been truly astonishing only twenty years before, and a golden age of intercity travel based on fast and convenient air transportation appeared certain on a time horizon not very far away.

In these early days of the national filling out of the nation's airline network, the needs of those responsible for ensuring safe flight operations were relatively simple. Air traffic control was rather easily provided by control towers located only at the airports themselves, handling traffic

on a real-time basis, and needing primarily to apply simple formulas providing safe spacing between aircraft, and to ensure that departing and arriving flights be reliably prevented from simultaneous assignment to the same runways. Befitting the relatively spare needs of the control towers of the day, good radar and a reliable inventory of flights scheduled for departure and landing could serve as a reasonable basis for planning the day's operations. Specific movements were tracked and authorized in advance solely by simple person-to-person communication between the craft's captain and the traffic controller. And the Federal Aviation Administration, charged with providing for air traffic safety, neither required nor held regulatory authority covering flight scheduling or related aspects of airline operation.¹

The sheer volume of traffic began to erode this relatively comfortable arrangement in the middle 1960s. Over only four years between 1965 and '69, total traffic at FAA airports nationally almost doubled, increasing by an average of almost 14% per year. (FAA, 1977) And with that growth came the first incidence of congestion at the largest and most integral airports in the national web. By 1966, almost 1 of every 4 scheduled flights nationally experienced delay of over 30 minute duration, (FAA, 1977) and the overwhelming majority of these were found attributable either directly or indirectly to five major eastern airports where traffic demand had simply outpaced the available airport capacity: In the New York City area, these included John F. Kennedy, LaGuardia and Newark airports; in Chicago, O'Hare; and in the Washington, D.C. area, National Airport (now named for former president Ronald Reagan). Worse, in the Jet Age, where higher speeds allowed an extended list of scheduled flight segments per plane daily, delay in any early leg of the craft's schedule caused a cascading daisy chain of delay throughout the rest of the day's operation. The cumulative effect of this indirect source of delay was to

influence other airports, and ultimately to compromise the system-wide ability of carriers to meet their respective schedules.

Nor was the congestion problem to prove to be simply a matter of passenger irritation with unmet schedules and airline inconvenience. Faced with excessive numbers of flights attempting to take off and land at the same time, air traffic control officials found themselves with few options. To handle the overload of flights seeking to land, controllers had no effective alternative to stacking arriving aircraft in cork-screw-shaped landing patterns, in which arriving planes entered the landing pattern at relatively high altitude, and circled, descending slowly at relatively low speed, until each plane in the queue in front had been able to land, and the flight in turn could be cleared for landing.

This arrangement presented a number of very real safety risks as well. With three of the overmatched airports within easy reach of each other in or near New York City, keeping the landing queues separate was not in itself an easy task. In the event of emergency due to in-flight equipment problems or fuel shortages experienced by longer flights, the need to reshuffle the landing pattern to accommodate the stressed plane at the wrong time could cause a fairly complex set of changes to the instructions for each other craft already in the landing pattern. And with the labyrinthine character of the queues, any misunderstanding between pilots and the control tower about these changes could pose dire consequences for multiple aircraft. Nor was midair collision from miscommunication the only danger present in this arrangement: Extended landing patterns at slow speeds in bad weather also exposed flights to well-known (but at the time little understood) dangers from wind shear.

Nonetheless, the system was able to function reasonably well until an extended episode of delay from acute congestion hit New York airspace during Midsummer in 1968. Periodicals of the period decried the situation, using words such as crisis , snarl , and then-creative use of words like swamp and clog as verbs to describe the resulting mess. ² And during the worst episodes of the crisis, FAA officials were forced to utilize up to 11 different holding patterns to handle the traffic. With these developments, the FAA came to know that in airport congestion it had encountered a serious, and even mission-threatening set of problems. And it found itself forced to act.

3.1.2 The Government Response

FAA s response to the airport congestion problem at the five eastern airports featured both long-run planning for airport expansion and advocacy for the money to do so. But it also embarked on a major application of network demand management to mitigate the congestion in the interim. To do this, it established a series of regulations limiting the potential congestion at the five problem airports by simply limiting the number of landings at each.³ It did this in June of 1969 by emergency decree, requiring that each flight landing in the respective airport have a formal flight landing reservation (or slot). Each flight having a reservation for the high density traffic airport would have an assigned hour in which it could land at its respective destination.⁴ Unless the flight into the controlled-access airport had a valid reservation, it was not given clearance for takeoff to that airport. After a transitional period of adjustment and operational practice, the regulations became permanent and fully operational in October of 1970.

By limiting the number of slot reservations given out by time of day to the airport's physical capacity, the FAA was now able to place a check on the number of aircraft in flight to those airports to mitigate congestion problems. It would serve to ensure minimal overall system delay, by both smoothing out landing schedules in accordance with airport capacity and by not allowing a small number of late flights to cause rippling delays to flights otherwise operating on schedule. At the same time, the FAA gained de facto control over departure scheduling of flights into the congested Big Five as well. Of course, congestion did not disappear completely: delayed flights arriving during peak hours would still cause limited back-up at the slot-controlled airports. (More about this topic below.) But now, even under the most extreme delay conditions, any required stacked landing patterns would be considerably less elaborate, shorter in duration and therefore have easier clearance. The results would be both greater flight safety and better on-time performance for the system as a whole.

Later, when the FAA gained the technical capability to process pre-flight plans electronically, it found that it could use that process to further minimize cascading system delay in the event of a congestion episode -- particularly when harsh weather caused problems across the relatively tightly-packed northeastern area of the national airspace system. If a flight with a reservation were delayed so that it could not meet its allotted landing time window, controllers no longer needed to build the landing queue on a first-come, first-served basis. They could instead plan to give landing preference to those flights already arriving on time. The already-delayed flight could then be held at its departure airport until take-off was timely to meet its rescheduled landing slot. This may have been an additional inconvenience, certainly, for those passengers

who were further delayed as they waited longer for clearance to take off; but the result was that other, on-time flights could remain on schedule, to the overall improvement of the system's on-time performance.

Since the slot allocation program was regulatory rather than behavioral in nature, the impact on network air traffic delay due to the resolution of congestion at the target airports was dramatic and almost instantaneous: After rising as high as almost 40% of all flights during 1970, the national percentage of flights subject to significant delay dropped by almost half simply due to the changes in operation at the Big Five. In short, average national delay statistics immediately returned to normal levels experienced before the great crush of airline growth occurred in the late 1960s. (FAA, 1977)

Despite the success of the slot allocation program in resolving the problems of rapid flight traffic growth, this method was to encounter an administrative tripwire on other grounds. The problem was to have nothing to do with the program's goals or its actual operational characteristics: it came instead from the business side of the air carrier industry, a field concerning which FAA had neither jurisdiction nor expertise. The central issue surrounded the industry structure implications of the program -- of who would get the landing slots. Beyond its obvious improvements to smoothed traffic flow, slot allocation also had the effect of determining which airlines could service airports, and the air carriers, the Civil Aeronautics Board (until 1978 the regulatory agency over the routing and business practices of the air carriers), and industry specialists from the fields of finance and antitrust all would have extended remarks concerning the potential role of the FAA's slot allocation process upon the airline industry's composition.

The issue was already a significant one; but it would become even more trenchant if the continued growth of the airline industry were to carry congestion -- and slot allocation -- more broadly across the country.

This issue of how to make fair provision for the allocation of landing slots was already a difficult one. It was to seize center stage, however, with the Carter Administration plan to deregulate the airlines in 1978. (Hardaway, 1986) Before deregulation, competitive implications of slot allocation could be worked out in league with the Civil Aeronautics Board to provide a modicum of balance and control against unhealthy competitive influences due to the ownership pattern of these landing rights. With deregulation, however, the FAA found itself alone in making decisions that would significantly affect the future structure of the airline industry, and without legal jurisdiction to do so. And the effects of these decisions in the future appeared to be unforeseeable, particularly due to the historical corporate fluidity which had been one of its hallmarks of the industry. and its movement from regional carriers toward truly national airlines operating regionally through a now-familiar hub-based business model adopted by the major carriers.⁵ If the FAA could not readily identify the effects upon the geographic distribution of flight pattern demands due to deregulation, it was understandably reluctant to make any programmatic policy with respect to slot allocation which picked winners.

All of this made FAA officials of the time rather uncomfortable. But although the agency would have preferred a less intrusive regulatory approach than a continued reliance upon formal slot allocation, the FAA thus found itself forced to retain the program for the Big Five due to their disproportionately large role in the nation's airline traffic.⁶ It went on to retain slot allocation

authority where it already had it, and approved a permanent slot transfer mechanism in 1986. For the evolving problem of contending with the market forces promoting the spread of airport congestion across the country, it chose instead to rely upon less rigid methods. Because of improved information technology and computer system capabilities, FAA could craft a different answer to the broader spread of airline congestion at airports across the country. This answer was to incorporate a less formal kind of schedule control over a wider network of airports by incorporating that control into the evolving national air traffic control system.

To extend the landing reservation program to other airports, the FAA defined a Special Traffic Management Program plan, which simply provided an administrative and operational method to extend the same type of landing time reservation system temporarily to any other airport in the National Airspace System experiencing abnormal congestion as well. (FAA, 2000) Only instead of treating the slot as a permanent, owned right, as was defined for the Big Five, the reservations made for airports subject to the Special Traffic Management Program were temporary and readily available to any otherwise proper flight scheduled into the congested airport on a first-come, first-served basis. During the control system's flight plan check, if the estimated time of arrival at the target airport indicated the likelihood of congestion upon arrival, the flight would be assigned an arrival time window on a first-come, first-served basis, and, if necessary, delayed in its departure to ensure its timely arrival to meet the landing reservation. In this way, the FAA created a flexible needs-only and reservation-based system which could be created and quickly incorporated into daily operations of the air traffic control system without the more rigid treatment accorded the major congestion-prone airports. The range of circumstances which could now be handled included cases not only of normal congestion, but also seasonal variations

in traffic or weather, special events, or even temporary capacity problems created by airport construction projects.

3.1.3 The Results

In the end, the system worked. In fact, despite the great growth of traffic levels since this landing reservation system was devised, overall system delay has plummeted from levels common during the early 1960 s. Even before the congestion emergency of the late 60 s, on average almost one of every four flights system-wide could be expected to experience a delay of a half-hour or more. Until very recently, that kind of delay was only encountered by roughly 1 flight in 50.⁷ In fact, FAA has considered its delay reduction programs to be so successful that it now finds the historical half-hour delay standard to be unnecessarily long for either system tracking or for the setting of their on-time performance goals for the system. Accordingly, the agency now tabulates its reports on delay and has established its agency planning criteria based upon the use of a 15-minute aircraft delay (rather than the historical half-hour) for its performance standard.

And the restrictions have not been proven overly burdensome for the airlines, either. In fact, the air carriers found that they, too, possessed operational choices which they could use to mitigate the effects of the landing restrictions at the controlled airports: With the hub system of air travel developed over time, the airlines found an ability to assemble passengers destined into the access-controlled airports. Similarly, although they were limited in the number of daily landings, they retained the option to select larger aircraft when appropriate to do so. In these ways,

carriers could compensate for the loss of the number of landing opportunities by boosting the productivity of each landing window which they retained.

3.1.4 Where we stand today

Two final comments must be discussed here to complete this case study. First is a major caveat, highlighting the fact that FAA's operational measures to limit congestion did not have to carry the load alone. However successful the FAA's operational methods proved to be in ending the threat of severe airport congestion nationwide, we must immediately note that FAA's operational jurisdiction over landing slot reservation is not the sole cause for this improvement in system efficiency. This performance could not have been achieved without the National Airspace System's extensive and coordinated airport runway and terminal re-design and construction support coupled with sound network planning to keep those capital improvements abreast of evolving market forces. Nor could it have occurred without extensive financial support, both through direct federal subsidy and through flexible public bond finance mechanisms that allowed local airport operators the capital funds for those needed improvements. Network management through operational control has been a great success, but it didn't meet the challenge by itself.

And second, despite the network's success, recent circumstances indicate that we may be on the brink of a new period of third generation capacity constraints in the National Airspace System. Three high-profile episodes of severe system flight delays at the nation's airports have occurred over the last two years, during the Summer of 2000 and the high-volume winter holiday seasons. The FAA (with good justification) has attributed much of these episodes to bad weather, but

some independent experts and critics believe that the system recently has begun to encounter a new series of capacity ceilings and more vexing growing pains. (Swieringa, 2000) Some of these originate from the continuing redistribution of traffic patterns due to the hub-based airline model. Others are argued to reside in the rapid pace of technological obsolescence found in the information technology industries, and with FAA's computer systems being generally regarded as having lagged seriously behind the state of the art: In the eyes of some serious commentators, this limits the ability of the air traffic control system to perform even more precise integrated traffic control practices. Other issues relate simply to system capacity, one most evident example of this being a shortage of communications bandwidths reserved for the air traffic control system to enable its communication with in-flight aircraft.

But overall the system has worked remarkably well. No simple operational traffic control system, however thoughtfully constructed and operated, can be expected to fully insulate a continuously growing network from delays originating from bad weather, unexpected equipment failure, the hub system's penchant for multi-stage flights, or selective strikes. The airline industry critics questioning the FAA's performance today fully realize this: The current debate surrounding the state of the art of air traffic control is not due to past failure, but concern over the ability of the system as it stands today to handle future growth. (Swieringa, 2001) At a recent hearing of the FAA, DOT's Office of Inspector General stressed the importance of the continuation of an integrated approach to balancing demand and supply over time, with technological solutions being an important part -- but not all -- of the solution. (Office of the Inspector General, 2000.)

Nonetheless, there is no serious question that the operational air traffic control elements of airport congestion control have given us much more productive use of the nation's airport capacity as it exists today and grows from day-to-day. And it has done so significantly through intelligent application of the evolving information technology techniques, both to help real-time dispatching and to fine-tune the routing of individual vehicles across a limited network. In that way, the case offers an obvious demonstration and parallel to the promise of Intelligent Transportation Systems for urban mobility.

3.2 System Management Approaches to The Energy Crisis of the 1970's:

A second major example of a successful governmental initiative in the operational management of demand as well as supply for a critical resource may be found in the case of energy. During the early 1970s, historically high levels of demand combined with an explosive geopolitical environment in the Middle East to create havoc in the industrialized nations through upheaval in the oil industry. The response at the state and federal government levels presents us with an important example of how innovative operational thinking applied comprehensively across a complex system can substantially contribute to mitigating a major resource constraint.

3.2.1 The Historical Setting

There is no question of the importance of energy in the economic and social evolution of the entire array of nations in the world. And during the early 1970s when this case begins, the predominant sources of our energy by far were oil products and other hydrocarbon derivatives from oil. In fact, despite the nation's extensive coal reserves and pioneering commitment to the development of nuclear technology for the production of electricity, 3/4 of the nation's energy demand came in the form of oil and its resident companion, natural gas. (Federal Energy Administration, 1974) Today, our reliance on oil and gas is even higher. In his encyclopedic history of the oil industry, *The Prize*, internationally-renowned energy expert Daniel Yergin described the role of oil in modern life in the following way: (Yergin, 1991)

Today, we are so dependent on oil, and oil is so embedded in our daily doings, that we hardly stop to comprehend its pervasive significance. It is oil that makes possible where we live, how we live, how we commute to work, how we travel -- even where we conduct our courtships. It is the lifeblood of suburban communities. Oil and natural gas are the essential components of the fertilizer on which world agriculture depends; oil makes it possible to transport food to the totally non-self-sufficient mega-cities of the world. Oil also provides the plastics and chemicals that are the bricks and mortar of contemporary civilization, a civilization that would collapse if the world's oil wells suddenly went dry.

By the early 1970s, the United States and the other industrial nations of the world found themselves dependent upon an oil resource which appeared both to be peaking in supply and to be concentrated in the wrong hands. The ultimate source of oil products, crude oil, had come to be increasingly controlled by a small number of nations in the Middle East by dint of its

geographic distribution. These Arab oil states owned roughly 60% of the world's oil reserves, and supplied 70% of the oil in the world's export markets. And as they came to consolidate their control of oil through the development of a cartel, the Organization of Petroleum Exporting Countries (OPEC), the oil states came to view their control of oil not only as an opportunity for great economic benefit, but also as a lever of geopolitical power as well. The United States was to prove vulnerable to the geopolitical use of oil as a weapon because it imported about half of its oil needs; Europe and Japan, however, were much worse off than that. (FEA, 1974) And because the oil states were clients and allies of the Soviet Union, the United States found itself limited in its ability to use diplomacy tinged with veiled military threats to temper the oil states behavior.

Up to 1967, the principal manifestation of power arising from this consolidation of control over the crude oil market was through rising prices.⁸ In June of 1967, however, the Arab members of OPEC embargoed the shipment of their oil to the United States, Britain, and partially to West Germany in response to these nations' historical support of Israel. The embargo was launched as an element of a pan-Arab military strategy beginning what later came to be called the Six-Day War. Assuming that the war would involve a protracted military campaign, the Arab oil producers believed that an immediate embargo of oil supplies to Israel's primary allies would compromise Israel's military resupply, and hasten a favorable ending to the conflict. Israel, however, quickly defeated the Arab forces, and, befitting the length of the war, this first supply interruption proved short-lived. Not only did the war end in breathtakingly rapid fashion, thereby undercutting the reason for the embargo in the first place, but the western oil companies also found it relatively easy to find replacements for the Arab oil. In the end, the embargo was a

failure, in part due to the debacle suffered by the Arab armies on the battlefield, but also due to unforeseen events which mitigated the embargo's impact.

The embargo of 1967 had not been successful, but the exercise had given the Arab oil partners practical insight into the tactical intricacies of wielding oil sales as a weapon. When they chose to act again in conjunction with the beginning of the October War in October of 1973, the results this time were more effective. The developments on the battlefield may have ended with similar results, but the oil strategy was now designed for longer-run strategic diplomatic effect rather than as a direct component of the hostilities. And this time a number of other factors contributed to give the embargo more teeth: Demand was higher and supplies of oil were already tight relative to 1967. Further, the possible leakages had already been revealed: this time the shut-off was conducted in ways calculated to limit the oil companies' ability to reshuffle oil flows which had rendered the earlier attempt impotent. The result in the United States was soaring fuel prices,⁹ long lines of irritated drivers seeking to fuel their cars, and final -- if grudging -- realization in government that something had to be done to neutralize the threat of international blackmail which Arab control over the crude oil market had now been proven to pose.

Other interests conjoined with these international market considerations to form a bipartisan policy atmosphere favorable to strong action toward the conservation of oil products and energy efficiency in general. In the wake of the dynamic expansion of popular environmental concern which spawned the National Environmental Policy Act and the Clean Air and Water Acts, many wanted to curb combustion of fossil fuels for ecological reasons. Oil industry critics railed against the industry's apparent profiteering from the crisis, and argued for greater energy

efficiency as well as more direct government regulation of the oil industry.¹⁰ And an international committee of prominent scholars and government and business officials calling itself the Club of Rome published the results of a comprehensive world resource inventory and demand forecasting study which predicted a virtual exhaustion of the world's oil supplies within 50 years. (Meadows, et al. 1972) Whether for national security purposes, on environmental or economic populist grounds, or worry over our ability to continue on the fossil fuel path due to finite supplies, informed individuals across the political spectrum could now find a base of philosophical reasoning to support an active national initiative to promote energy efficiency and to find viable substitutes for oil. And the greater part of the next decade was to feature an unprecedented and integrated approach to system management in the energy sectors.

3.2.2 The Government Response

The Arab oil embargo of 1973 occurred during the first year of Richard Nixon's second term in the presidency. As Vice President under Dwight Eisenhower, Nixon had been a witness to the nation's diplomatic maneuvering in the Middle East during the crisis caused by Egypt's brief closure of the Suez Canal in 1956, and had a tactical appreciation of the evolving foreign policy concerns surrounding oil supply that the United States was now facing. In addition, he was not hostile to the idea of an activist government in support of resource conservation issues: He had already signed the National Environmental Policy Act, the Endangered Species Act, and both the Clean Air and Clean Water Acts into law.

Convinced that the route to relief from this threat to the nation lay in energy self-sufficiency, the Administration began immediately with the establishment of an ad hoc energy office, which formally joined the permanent agency roster as the Federal Energy Administration in May of 1974.¹¹ The agency's first act was to launch an initiative in support of energy self-sufficiency. That initiative came to be called Project Independence; and its avowed goal was to set the stage for national energy self-sufficiency by 1980. The initial planning mechanism to launch it was a task force comprised of senior officials of 20 cabinet-level departments, independent agencies, and commissions, covering the full spectrum of the ways in which we use and regulate energy production and supply, coupled with the best minds of the federal science and engineering research establishment. The intention of the effort was summarized in the Preface to the Project Independence Task Force Report by FEA Administrator John C. Sawhill as less of an analysis of candidate energy strategies than the achievement of an analytical and informational framework from which an integrated national energy policy could be derived. (FEA, 1974) The agency would go on to study issues raised by the initial task force effort, and to serve as the administrative tool to funnel federal funds to the states for their own energy planning studies and programs.

Although the Project Independence task force had not been impaneled to make specific policy recommendations, their assessment led them to recommend three fundamental different types of strategies for further evaluation and policy development:

Accelerating domestic energy supply: including predominantly expansion of domestic oil production and synthetic fuel production (e.g., oil from shale deposits and natural gas from coal);

Energy conservation and demand management strategies: Predominant elements included:

- > Fuel switching from technologies utilizing oil and natural gas where possible to energy systems based on electricity from coal and nuclear energy;
- > Encouragement of improvements in motor vehicle fuel efficiencies through tax measures and statutory minimum mileage standards for new vehicles;
- > Establishment of tax incentives to spur energy conservation in homes and commercial buildings;
- > Establishment of energy efficiency criteria for major appliances, lighting, and space conditioning equipment;

Emergency curtailment measures: These included:

- > Creation of stand-by oil fuel allocation authority;
- > Development of a general-use oil stockpile for release in the event of supply interruptions;
- > Limited operational changes which would make systemic mitigating reductions in oil use during times of emergency, such as extension of Daylight Saving Time throughout the Winter, reduced highway speed limits, and staggering of work schedules.

The set of policies actually put into place by the Nixon Administration initially included a number of emergency measures with varying degrees of regulatory teeth:

- > Development of stand-by authority for the allocation of petroleum products in the event of future oil supply interruptions;
- > A ban on Sunday gasoline sales (lifted after the end of the embargo in Spring of 1974);
- > A national speed limit of 55 miles-per-hour;
- > National recognition and/or extension of Daylight Savings Time; and
- > Exemplary mandating of more economical and restrictive temperature setting standards for space conditioning in federal buildings.

In addition to these emergency measures, Nixon also began a series of longer -term initiatives as well:

- > Ear-marking of federal funds to the states for energy planning and conservation program development;
- > Approval of a trans-Alaskan pipeline to allow development of northern-state oil deposits;
- > New research and development funds for critical energy production technology in the areas of coal combustion and gasification technology, recovery of oil from western shale, nuclear fuel cycle improvements, and limited investments in tapping renewable resources such as geothermal and solar energy; and
- > Groundwork which was later to lead to passage of two major pieces of legislation which would not be ready for congressional action until the brief term of Gerald Ford:

- > The setting of regulatory floors for fuel economy of new vehicles (the Corporate Average Fuel Efficiency {CAFE} standards) intending to roughly double the gas mileage of American built autos over 10 years; and
- > The establishment of a strategic petroleum reserve for use in times of declared oil supply emergency.

If Richard Nixon had kick-started a major initiative toward boosting more efficient production and use of domestic energy, Jimmy Carter's election in 1976 was to trigger a veritable explosion of public sector activity in pursuit of those goals. Carter had been trained as a nuclear engineer before taking up politics as a career, and his interest was easily drawn into energy planning matters. And, as evidence of the role of the energy crisis in sapping the nation's economic strength came to be fully understood, Carter was quick to demand further action. In a major address to the nation shortly after his inauguration in April of 1977, he set an extensive set of national goals for energy supply and efficiency improvement for the country's well-being. He went on to declare their achievement to require a national will at the level of the moral equivalent of war.

The result of the initiative came forth a year later, in a number of major policy initiatives designed to increase the nation's energy efficiency and to rationalize the market system for supply. Some of these involved bringing the strategic ideas of Richard Nixon's energy planners into reality; others expanded the mission. The policy was contained within a package of four bills which became known as the National Energy Act of 1978.¹² Principal actions of the Carter Administration in its energy policy included:

Extension and enhancement of the Nixon Administration-sponsored energy technology research and development program, to better include renewable energy resources and basic research into alternatives to the internal combustion engine;

Provision of targeted tax incentives for installation of renewables, including solar, wind and geothermal sources, as well as energy conservation investments;

- Energy-efficiency labeling programs for vehicles, major appliances, and new homes;
- An excise tax (referred to as the Gas Guzzler Tax) on any new passenger car failing to achieve acceptable fuel economy performance; and
- Major energy conservation and fuel substitution initiatives of the Act included:
 - > Restricting construction of new major oil-burning facilities, principally oriented toward base-load electric generating stations;
 - > A number of policy changes in the electric utility sector to promote greater diversity of supply and to conserve industrial process energy requirements at the same time (discussed in detail below); and
- Boosted funds distributed to the states for their own discretionary energy program development.

The era of aggressive energy conservation policy development ended abruptly with the election of Ronald Reagan to the presidency in 1980. Long-term technological research and development programs were sharply curtailed or abandoned outright. And the CAFE standards were weakened in two fundamental ways, by giving an exemption to the CAFE standards for sport

utility vehicles from the regulations, and by setting what most program observers believed were unduly low performance targets. Others, particularly emergency-related allocation authorities and the like, were deemed no longer needed. But some of the initiatives from the Nixon - Carter policy development survived, and these alone contain a stellar example of successful system management as a means of assistance to resolve important resource supply restrictions. The greatest area of program success came from two major areas of program development targeted for implementation at the state level: the Public Utility Regulatory Policies Act (PURPA) and the State Energy Program elements to promote general energy conservation by promoting successful energy programs at the state and local levels.

3.2.3 Public Utility Regulatory Policies Act (PURPA)

The Public Utility Regulatory Policies Act of 1978 was crafted to plumb the potentials for energy conservation in the industrial and electric utility sectors by removing economic, regulatory and institutional barriers preventing non-utilities (both private firms and public agencies) from producing and selling electricity in the bulk market. Because electric utility regulation generally is a state -- rather than federal -- issue, the Act was crafted to influence state regulatory practices to enable this expansion of the bulk power market. It did so by requiring that public utilities purchase power from certain kinds of independent generators within their respective market areas so long as the power was reasonably priced. The state's regulatory role was to interpret the policy within context of their own local energy supply, and to establish the fair rates for power which were required to make the sale enforceable upon the utility.

The specific energy supply goals of PURPA were to allow the capture primarily of two kinds of energy savings: The first of these was the capture of thermal efficiencies from joint production of electricity with process heat necessary for a firm's principal line of business, called cogeneration. By generating electricity with process heat, substantial savings of fossil fuel energy inputs could be achieved over separate production of both simply by reclaiming and better using the waste heat.

The second type of capture involved the use of non-traditional fuels and power sources to help supplant demand for the fossil fuels traditionally used for electric power production. Whether by use of biomass fuels such as wood chips and agricultural waste streams, or more exotic sources of electricity such as solar and wind power, geothermal energy (i.e., steam originating from exposure of ground water to volcanic rock close to the earth's surface), or hydroelectric power, this kind of capture was meant to ensure that any party with the ability and resources to produce reasonably-priced power from these non-traditional sources would be guaranteed a buyer for it. This process was designed to mesh with tax incentives also arising from past energy conservation acts and depreciation policy in the federal tax code as a spur to capacity expansion from these preferred energy sources.

The measure's effect was nothing less than the enabling of a major expansion of the number of participants supplying energy in the bulk power market, by ensuring that their independently-generated power could be sold.¹³ And it was to prove phenomenally successful: Between 1980 and 1996, more than one third of the net addition to the nation's aggregate generating capacity

was to come from these PURPA-enabled projects alone.¹⁴ The role of PURPA-enabled generating capacity in meeting local electricity needs was even higher in specific regions with generous opportunities for these sources, such as the Middle Atlantic region (predominantly wood-based biomass from lumber and paper operations), and the South Central and Far Western regions (primarily from cogeneration originating in the oil industry and general manufacturing).

Moreover, the statistics in this realm are conservative: In some cases, when faced with an imminent requirement to buy power from a new cogeneration facility, particularly where the potential independent unit was quite large, utilities sometime chose to build the plants themselves at the proposed site, and sell the process heat required by the customer.¹⁵ The utility capacity statistics, however, do not show these types of facilities as PURPA-enabled plants. In addition, the Act also proved to create favorable regulatory environments for suppliers whose specific situations did not qualify for treatment under it, but whose projects nonetheless could proceed because of the friendly regulatory atmosphere which PURPA helped to create. Adding in those contributions from other non-utility sources, the overall contribution of independents to total capacity growth exceeded 43% of the total system s expansion between 1980 and 1996.¹⁶

3.2.4 State Energy Programs

PURPA, of course, was instituted as a means of boosting the nation s energy supply. A second major companion arena of success for market system management in the energy sector encompassed a broad range of programs instituted at the state and local levels to improve the

efficiency of energy use by its consumers. Supported in sponsorship of the programs by federal funding, the states were provided wide flexibility in how they chose to enact candidate measures or even to expand them based upon their own circumstances and policy inclinations. What came from these cumulative efficiency programs and their local offshoots comprise a second highly successful aspect to system management in the energy industry over the last twenty-five years.

Generally, the programs instituted at the state level fit into one of two broad categories:

- Utility Demand-Side Management (DSM) programs: These were programs for implementation at the local utility level which were designed to expand customer services to help them save energy, and to influence how they use it to promote more optimal use of generating capacity. Major utility programs included:
- Customer outreach to assist customers in evaluating their home and business energy efficiency, and to promote improvements in several ways, from information to subsidy of purchases of more efficient equipment; and
- Load management programs designed to shift demands by hour of day to reduce peak-hour power needs and to promote greater use of generating capacity during low-utilization periods. Examples include interruptible load programs, which shut off air conditioners for short periods during peak hours, and voluntary agreements with large energy customers to curtail usage during peak hour. Some of this is done behaviorally in the commercial sectors through use of formal time-of-day utility rates, some by operational agreements between the utilities and their customers.

- Non-utility approaches to improve the energy efficiency of new buildings and major appliances:
 - > Programs to promote the use of energy-efficient systems in new buildings, in both residential and commercial sector applications: Programs containing at least some mandatory provisions written into local building codes apply currently in 36 states and the District of Columbia. Ten other states have purely voluntary programs which feature information and technical assistance for builders and building owners;
 - > Through direct energy system lending for energy-efficient retrofits and new construction for certain kinds of public and institutional buildings such as schools, hospitals and general government buildings; and
 - > Regulatory and consumer information efforts in support of enhanced efficiencies for major appliances.

Space constraints prohibit a detailed description of the many variants of the initiatives included under the heading of state-based energy programs, but the interested reader may research these programs relatively easily through the Web-based Energy Efficiency and Renewable Energy Network sponsored by the U.S. Department of Energy.¹⁷ And, at present, good estimates of the program benefits of many of these programs are generally not available. However, for 1996, the utility demand side management elements are estimated as having saved approximately 2% of the total national electricity sales, while having successfully reduced the national capacity requirements at peak-hour by 5%. (EIA, 1997)

3.2.5 Where we stand today

As it actually happened, the opening of the North Sea oil field, coupled with significant improvements in energy efficiency in energy consumers' behavior in the marketplace and reshuffling of the geopolitical situation in the Middle East combined to give us roughly two decades of respite from the energy supply constraints of the 1970s. Today, however, as fuel prices at the pump have jumped over the last year and a-half, and as supply shortages appear to be returning throughout the nation's energy system, we can only speculate as to how much better we might have done in diversifying our energy resources and promoting efficiency if the full menu of long-run energy technology support programs had been allowed to go to term.

Nonetheless, the achievements in the utility sectors from these remaining program elements were truly significant. Between the capacity additions spurred by non-utilities under the PURPA guidelines and associated state regulatory practices, and the capacity no longer required due to the successful implementation of electric utility demand side management programs, these electric utility-based initiatives together in the United States provided slightly less than one-half of the nation's total increased electric energy needs between 1980 and 1996.¹⁸ Stated another way, this means that without these new contributions from non-utility capacity additions coupled with the capacity needs avoided by conservation measures, the nation's electric utilities would have had to almost double their net additions to their generating capability over what they actually did over the period to meet our demand for power.

See appendix A for discussion of the current electricity supply crisis in California and its relationship to PURPA.

3.3 Conclusions

A detailed discussion of the implications of these two system management case studies in context of their meaning for the new network management paradigm in urban mobility is made in the final section. Some broad summary remarks are appropriate to make here, however, to complete this segment.

First, the operational management techniques used in both the airport congestion and energy crisis case studies show that system management can be a valuable aid in helping us cope with even the most severe kinds of resource dislocations. Measures to dampen demand and to increase the efficient use of what is already in place proved to be very effective in both instances. Moreover, they are a natural first response to resource problems, because supply expansion generally takes more time for planning and for the administrative processes required for long-run capital outlay. The rapid deployment of purely operational methods is potentially a much faster option than growing the resource in short supply. If these case studies show nothing else, they reveal that system management as a resource crisis intervention method has a comparative advantage of being relatively quick, and at the least, constituting a good start in the resolution of even the most seemingly intractable resource problems.

Within the context of transportation, integrative efforts can both broaden the range of demand and supply approaches. Certainly, the very concept of system management carries with it a flavor of system optimization and efficiency, as seen in the FAA landing reservation program's optimization of airport landing capacity and in the energy establishment's achievements in the area of energy conservation and substitution of other fuels for petroleum. Both initiatives made important contributions in several areas: Both had demand reduction elements, which by themselves took some of the bite out of the existing supply shortages. And both increased efficiency of the system capacity already in place by taking active measures to move excess demand to off-peak periods (and from petroleum-based fuels to less limited energy sources).

But, under the right conditions, we've also seen that operational changes alone can actually lead to boosted system capacity, by enabling a wider band of commodity or service providers to participate in the system. PURPA knocked out traditional market restrictions that gave utilities the sole right to make fundamental decisions about how our local electricity needs would be met, and by whom. By enabling others to participate, and to force the system's distributors to accept a more diversified menu of electricity sources, we were able to boost capacity simply by bringing in a wider range of suppliers with good market incentives to help ease the resource limitations of the system.

Of course, system management did not perform the feats we've seen in a capital vacuum, either. Neither of these initiatives did -- or even could -- have performed as well as they did if they were not married to a companion capital program designed to work in concert with them. At the same time that the FAA's landing reservation program was limiting congestion by regulation, FAA and the local airport authorities were engaged in a broad series of capital improvements, both in new runways, and in terminal and ground improvements designed to facilitate aircraft tending and speeding flight turn-around. In the PURPA case, officials could ease the entry of non-utilities into the bulk power market, but the individual firms still needed to build the plants.

There are also precautionary observations that must be given heed as well: The efficacy of operational system or network management requires help -- both in the matters of inter-jurisdictional cooperation and in complementary investment patterns. For instance, the FAA could do as well as it did in optimizing traffic flows only because it did not have to compete with other jurisdictions to make the necessary changes. For the most part, this is simply not the case nationally in urban transportation planning and operation. The same factors in our historical patterns of urban growth, which have caused urban regional growth to extend across existing boundaries of several local jurisdictions, have in the process often balkanized local transportation infrastructure decision-making. Add to this, of course, the larger issue of friction between local and state authorities, and the institutional ability to perform good regional transportation network management can often be severely compromised.

And no network management scheme, however well conceived, can be expected to succeed if the complementary capacity investments required to work with the program are not made in lockstep with it. Again citing the FAA example, landing reservation allocation did not have to do the airport congestion relief function in a vacuum: extensive long-term capacity and functional enhancement planning and investment had to occur at the same time to help the airport network keep up with system demand. Similarly in the energy sector (and most pronounced, perhaps, in the electricity component), supply expansion -- not just efficiency improvement -- proved to be critical in relieving the stress on the system.

In the end, the successful system management programs shared three major common methods: First, both used a balanced mixture of supply enhancements and demand reduction elements to attack the supply constraints that they were developed to resolve. The FAA forced discipline by ending unlimited access to airports; but having done so, also promoted increases in capacity and other operational efficiency improvements. The energy agencies allowed non-utilities to enter the bulk electricity market at the same time that they promoted efficiency in energy use. And, second, both made use of latent market forces to further their respective goals: The airlines flying into congested airports could compensate for a decreased number of landings by using larger aircraft and through utilizing the hub system to assemble passengers flying there. The energy agencies acted to empower firms and consumers, either by removing market practices restricting their ability to act rationally in their own behalf, or through information to

help them make smart buying decisions. Third, all systems recognized the inevitable growth of the system and devised means for evolving the system to incorporate overall growth within a balanced supply-demand framework

These observations tell us that the decision to embark upon an intensive network management approach to our surface transport mobility problems is not an either/or decision with respect to capital improvements. How this can be done is the subject of the next sections.

Chapter Three End Notes:

- 1) Until 1967, the FAA was known as the Federal Aviation Agency. It covered the safety aspects of flight regulation only. Business regulation of the airlines, in terms of flight service levels between city pairs was performed by the Civil Aeronautics Board, phased out during the de-regulation of the airline industry in the late 1970 s.

- 2) In a truly remarkable, but eminently sensible development, FAA later chose to buttress its financial case to the nation s leaders for more airport improvement capital funds in part by publishing a briefing book compendium of the newspaper and magazine trade press accounts of this episode. See (FAA, 1969).

- 3) The slot allocation regulations are still in effect for four of the five eastern airports, and may be found in the United States Code of Federal Regulations at Title 14, Chapter 1, Subpart K ,/93.12. Because of traffic flow changes and construction, flights into Newark Airport at present have been temporarily exempted from the provisions of the section.

- 4) Due to operational differences in effect at Chicago O Hare, the slot reservation there instead is set at 30 minutes. See (FAA, 2000). An entertaining and informative

- multimedia view of the entire air traffic control process may be seen on the Web at www.atchelp.com.
- 5) This concern remained a critical concern even a decade later. See (FAA, 1990).
 - 6) Currently, the Big Five airports account for about 1 of every 6 flights in the national system. (Bureau of Transportation Statistics, 1998). Data are for Calendar 1995.
 - 7) (FAA, 1977. Figure 3-21). Current and recent historical delay statistics for 1998 - 2000 may be viewed from the Newsroom station of FAA's web site, www.faa.gov.
 - 8) European nations briefly experienced an oil shortage during the Egypt's closure of the Suez Canal in 1956. This shortage was caused, however, not by concerted action of the producers but was a side-effect incidental to the canal's closure. Oil was just another commodity held up when normal deliveries through the canal could not be made. Fear of an ultimate closure of the canal to European oil tanker shipments, however, was a significant driving consideration shaping the response of Britain and France during the crisis.
 - 9) Under Iranian leadership, price levels for crude oil during the crises roughly quadrupled over the last five months of 1973. This translated into price increases at the gas pump on average above 40%.

- 10) Public rage over perceived oil industry price gouging appeared to have considerable justification. Immediately before the crisis of 1973, 7 oil companies were listed in the Top 20 of *Fortune* magazine's 500 Largest Industrial Corporations. Immediately afterward in 1974, the oil sector held 10 of the Top 20 slots, and the Exxon Corporation had supplanted General Motors from its almost perennial spot at the top after a 40-year reign. Most of the added income came from simple re-valuation of the companies' domestic supplies to reflect the new, managed OPEC prices, despite the fact that no change in domestic oil production costs had occurred. These higher prices were also quickly applied to natural gas and coal (on a British Thermal Unit basis) to create a rough equivalency with the managed foreign crude prices. The Carter Administration was subsequently to attack these pricing practices in two fundamental ways: first via general price controls on the output of existing wells oil and gas wells, and then through a tax on windfall profits.

- 11) FEA was elevated to Cabinet-level status and renamed the Department of Energy in 1977.

- 12) The National Energy Act in turn actually was the sum of four distinct pieces of legislation: The Energy Production and Conservation Act (containing new capacity incentive measures and the energy conservation-related elements), the Powerplant and Industrial Fuel Use Act (encouraging and in some cases mandating the use of other fuels for liquid petroleum and natural gas), the Public Utility Regulatory

- Policies Act (see the accompanying section) and the Natural Gas Policy Act (specific provisions affecting natural gas supply and pricing).
- 13) Additional legislation was subsequently required to force utilities to open their transmission networks to allow independent generators greater flexibility in finding customers for their power.
 - 14) (Energy Information Administration, 1997. Volume 1, Table 1, and Volume 2, Table 57). Also (EIA, 1982. Table 7) 1996 is used as the date of comparison here because it is the last year before California's utility restructuring program caused substantial volumes of utility-built capacity to be sold to non-utility owners.
 - 17) For regulated privately owned utilities, this allowed greater profits by internalizing the capital cost of the facility into the utility's rate base. Otherwise, if the project went forward in the form of a non-utility building the facility and selling power under PURPA, the utility would only recoup costs and earn a margin for power distribution and delivery.
 - 18) See End Note 14, above.
 - 19) Found at <www.eren.doe.gov>
 - 20) See End Note 14, above.

4 ARPANET/INTERNET CASE STUDY: TOWARD AN UNDERSTANDING OF COMPLEX SYSTEM GROWTH

To this point, we have focused upon the generic topic of network management and its prospective role in our urban mobility future. We did so from a largely historical analysis: First, we examined our recent ground transportation history and discussed the realities which have conjoined to make system management a necessary central component of our contemporary infrastructure improvement decisions. Then we examined two case studies -- or program metaphors for network management in urban mobility -- in which the precepts and techniques of system management were introduced with great success in two very different public policy arenas: In the realm of spontaneous demand growth, we examined the airport congestion problem of the late 1960 s; and in the realm of resource supply shortage, the energy emergency of the 1970 s. These two cases showed that even the most serious infrastructure crises, if carefully understood and practically considered, can often be ameliorated by operational means to a level which allows us to meet our requirements..

In this fourth section, we consider the properties of dynamic system growth, first by examining the growth of the Internet within the context of complex systems, and then finally, applying these lessons and other lessons (from section 3) to the deployment of ITS systems in California. This DARPA/Internet case study serves as more than a vague metaphor for comparison to ITS. The case of its growth has become a visible example of how complex and distributed systems can

evolve rapidly, and the role of public sector, private sector, and the consumer in propelling its growth.

Consistent with previous case studies, we begin with a brief history of the ARPANET/Internet program, describing what it was, and what it achieved. We then focus upon the lessons of that history, concluding with some principles for considering ITS policy specifically and transportation policy more generally.

4.1 The Public Sector Role in the Birth of the Internet

4.1.1 The Historical Setting

The Advanced Research Project Agency (now known as DARPA) was established as a civilian adjunct to the Department of Defense, instituted during the administration of Dwight Eisenhower. Based in part because of the success of the Manhattan project in developing the atomic bomb during World War II, ARPA was impaneled to facilitate the harnessing of the best engineering and scientific minds in the nation's colleges and universities to issues of military-related technology. By creating a permanent program to provide flexible consultation between the nation's defense establishment and the academic community, ARPA was seen as a means to provide valuable scientific and technological insights into the nation's defense problems. In President Eisenhower's eyes, it would also serve to provide a counterbalance to the private sector's interests in defense technology procurement policy. Given the costs and capabilities of the new weaponry of the Cold War era, the nation's defense procurement policies were viewed

to be too important to be unduly subservient to the proprietary interests of the major defense contractors.

The rapidly evolving field of computer science was one of the logical areas for ARPA's concentrated interest. The earliest computers, of course, had been invented by the military, and in the early 1960s the U.S. Department of Defense was the largest buyer of computers in the world. (Hafner and Lyon, 1996). There was little question that the technology would continue to prove to be of immense value to the nation's defense, both in the realm of nuclear weapon deployment and operation and in conventional arms arenas in the coordinated command and control of forces in the field. And because much of the data entry and ultimate use of the new technology in the field would need to be performed by relatively low-ranking military staff, great strides in user accessibility and ease of use would be required if the military were to derive the full range of the technical possibilities. To plumb these opportunities and to cover the rapidly-evolving field of electronic data processing, ARPA's Information Processing Techniques Office (IPTO) was launched in 1962. Looking back today, it is difficult to find a significant area of critical computer software development that does not have a strong debt to the early efforts of this office: Among the key areas of modern-day information technology which IPTO was to pioneer were computer time-sharing and distributive computing, interactive graphics, and artificial intelligence and expert systems. (Norberg and O'Neill, 1996)

The genesis of the computer networking technology work which was to become the ARPANET network, however, at the time had little connection to the actual long-term technological goals of IPTO. In fact, at the time, no-one knew that it could be done in such a way as to become a

reliable buttress link in the communication network of the armed forces in wartime. (Abbate, 1999). Although few doubted the ability to design computer networks, a daunting problem arose in considering the practical implications of the ebb and flow of war upon the reliability of any network serving as a major military command and control tool. Particularly in the Nuclear Age, any particular node in the network was vulnerable to attack at virtually any time. The critical question was thus whether a network could be devised which would also have the capability to dynamically route communications around nodes lost (for any reason) without loss of information to the network as a whole.

This principal fear was to become a strong motivating undercurrent to IPTO's mission, but the problem which the ARPANET project was initially conceived to solve was considerably more mundane -- the linking of individual computers at the various ARPA-funded research facilities to facilitate a full collaboration between the members of the computer science team. Each research center in the IPTO family tended toward specialization of function, between hardware engineering and several areas of software research and development, and for this reason faced different kinds of computing equipment needs. Almost inevitably, however, sometimes individual tasks could best be accomplished using a different mix of resident hardware and software platforms than the respective center had on hand. A network would allow one center's task to be performed by another's computer when the technical nature of the task indicated a better fit with the equipment. For example, a comparative testing of program algorithms developed at one of the outlying software research centers (a test requiring very high volumes of calculation) could be routed to the system's supercomputer, located at the University of Illinois, rather than operating on the domestic site's less capable equipment.

And software developers, of course, required access to other kinds of system platforms for program testing purposes alone. Having an electronic network would allow better matching of computing tasks with available equipment at the same time that it would allow remote software testing without costly and time-consuming dispatching of key personnel on the road to perform these kinds of tests on-site. Not only would inter-connectivity enhance the ability of researchers spread far and wide to collaborate on common problems, but it would also help to develop a natural symbiosis in the research effort by facilitating the complementary blending of state-of-the-art knowledge in each specialty area. (Abbate, 1999)

And as the intensification of the Vietnam War during the mid-1960 s began to strain the overall Defense Department budget, a networking capability was also viewed simply from its potentials as an economy move -- as a good way to ensure optimal use of the individual computers spread across the nation s research centers. The Defense budget in wartime simply could not afford to fit out each participating research institution with an equal endowment of equipment.

Developing a network in lieu of parallel equipment investment at different centers proved to have another desirable side effect: the avoidance of programmed obsolescence in the IPTO effort. Spreading the current technology widely rather than to distribute new and rapidly-evolving capabilities around the system as these were perfected was correctly seen to contribute *de facto* to the building of technical obsolescence into the research network. The rapid improvement of technology at each installation was deemed to be more important than an even distribution of computing capability across the family of research centers. Hence the desire to

avoid costly duplication of capacity in favor of creation of an electronic network also would have the effect of helping spur a more timely adoption of new technology into the IPTO research family as it became available. (Abbate, 1999)

4.1.2 The Government Design for a Network

For all these reasons, the development of a network inter-tying the various research centers was a logical administrative decision in the evolution of the IPTO effort rather than one of long-term technological development for operational deployment for the military. Of course, if IPTO was going to build a computer network anyway, it made sense to reflect those unique realities of military application as much as possible. In that way, this narrow network assignment could help identify the problems which would accompany a fully operational war-capable network, and to speed the building into it of those unique capabilities which were required. The overall approach to the linking of the specific sites (and, ultimately, to the ARPANET and the Internet as a whole) was first described in the early 1960 s by Paul Baran of the Rand Corporation. His vision for a successful prospective military network required the following characteristics: (Denning, 1989)

- The network would consist of a full distributed network of computers rather than a few computers augmented by simple relay stations;
- The system would be designed with considerable redundancy of capacity, so that the loss of individual links and nodes could be accommodated by re-routing of communications around them without stress upon the capacity of the remaining ones;

- There would be no central control over the network. Individual computers at each node of origin of a communication would designate a message route in real time based upon the working inventory of links and nodes available at the specific moment of message transmission. Similar evaluation of available paths to route the message would be made at each intermediate node in the message's journey to its ultimate destination; and
- To enhance the time sharing capability of the network as a whole, messages would be separated into data blocks of roughly equal size, with each block capable of separate transmission over (if necessary) multiple routes, for reassembly only at the point of destination.

The specific communication technique developed to serve all of these functions was called packet switching, which defined the process through which individual communications were broken up into component blocks of information, bundled with the appropriate identification and routing information necessary to allow the individual nodes in the network to do their work, and ultimately routed by the individual network nodes which the communication needed to traverse to get to their intended destination. (Hafner and Lyon, 1996)

Although the initial concept of ARPANET involved the relatively democratic connection of each computer directly into the entire network, practical considerations of the building, testing and operation of the network ultimately led to the creation of two networks, not one: First, it required the linking of local computers into a sub-network at each respective research site (what today we refer to as a local area network). This local network, beside developing a successful

mini-network at the site to facilitate direct communication between local colleagues, would assemble all local traffic for porting into the second, main network connecting the individual research centers situated across the country. The local networks required the capability to be able to transfer communications that could be handled across diverse hardware/software computer platforms, while the inter-site network could be reserved for uniformly-configured transmissions regardless of the respective type of communication and its size.

A full discussion of the technical history of the ARPANET's development, of course, is beyond the scope of this discussion, although it makes for fascinating reading.¹ Some of the more important milestones in the network's development and deployment, however, deserve mention here, to give a brief view of the major benchmarks along the way, and the relative speed with which this remarkable stream of technical innovation was actually completed: The first contracts were let in 1967, with the consulting firm of Bolt Beranek and Newman selected as the overall project coordinator. The first four network nodes were successfully connected in 1969, and the initial cross-country nodal link was completed during the following year. E-mail was invented in 1971, almost as an afterthought -- an otherwise unremarkable capability added as an in-process crutch to facilitate remote testing of the network software.² By Fall of 1972, there were 29 nodes utilizing three different cross-country communications corridors, and the first public demonstration of the network's capabilities was made in Washington, D.C. at the International Conference on Computer Communications.

Soon afterward, the first successful establishment of a local network using radio waves rather than a hard-wire connection was completed at the University of Hawaii, and the ability to

complete a reliable long-distance linkage by satellite was demonstrated in 1975. Overall, the success of the enterprise surpassed if not overwhelmed the expectations of the best-informed observers; and by 1975 -- a scant eight years after the effort began -- the technology was demonstrated and deemed to be sufficient to meet the military's needs. ARPANET was declared to be operational, and organizationally was folded into the Defense Communications Agency of the Department of Defense. By the late 1970s, ARPANET was in full deployment mode; and the purely military functions were separated for security reasons from the original computer science research centers in 1983. By 1990, the military network alone (i.e. not including the private sector offshoots which were collectively to become known as the Internet) had grown to over 60,000 sites. (Denning, 1989)

The subsequent steps leading from a flourishing ARPANET to what we now know as the Internet were to occur as the computer research wing of IPTO was released from military security and became free to carry the technological fruits of the ARPANET project into the private sector, adapting them for use by a broader audience and for a vastly expanded set of uses. Yet here, too, the visionary view of the major participants in the ARPANET project, coupled with the willingness of DARPA to support network software development in light of its civilian as well as defense-oriented uses, combined to form the basis of this shift.

The principal way in which the ARPANET team was able to finish the technological construction necessary for the rapid diffusion of computer network technology into the private sector was by its financing and completing the generalized transmission protocols necessary for inter-networking. (Abbate, 1999) From the perspective of the defense establishment, this inter-

networking capacity was required to allow contact between ARPANET sites and defense-oriented sites overseas which were themselves connected by other networks -- principally fledgling national networks established by the individual member states of the North Atlantic Treaty Organization. Yet the development team was allowed to proceed without attempts to limit deployment of network capability within the military sphere of influence alone. In fact, it was encouraged to confer widely with private sector interests, both here and abroad, in collaboration to develop protocols capable of serving as an international standard for network communications. By insisting that this standard be released freely into the public domain, its IPTO-sponsored developers ensured that individual firms could not seize control of private network markets by establishing proprietary rights over the network infrastructure. (Hahn, 1994)

4.1.3 The Rise of Distributed Networks

The capability of communications to cross multiple networks meant that no one institutional party needed to take responsibility for development of a single, all-inclusive national or world computer network to reach the universe of network sites. Individualized networks could begin and grow independently, whether by locational, professional or organizational affinity (e.g., a municipal, corporate or university network) or by private sector network service providers selling connectivity to individual computer users (e.g., national consumer networks such as *CompuServe* or *America Online*). With the inter-networking capability, members resident to different networks could communicate freely with each other, without having to be physically connected to both networks to do so. In the end, this development allowed any computer directly

connected to any one public network to freely traverse others, effectively greatly expanding the available directory of potential contacts.

In 1980, the evolution from ARPANET to the development of the Internet began in earnest with the establishment of an independent, parallel network of other computer research centers ineligible for inclusion in ARPANET due to their lack of federal defense contracts. The new network, CSNET, was based freely upon the ARPANET technology, but operated separately by five universities under the auspices of the National Science Foundation (NSF). From there, non-military application of computer network technology exploded: private and geographically-localized networks arose quickly, catering to more general interests than the narrow realm of computer research as well. Given the existence of a technical capability to connect these individual networks and the clear benefits of inter-networking for all, NSF ultimately agreed to form a backbone net (NSFNET) connecting them in 1985. Four years later, the computer science remnants of ARPANET, cast off by the Department of Defense as the network became operational, joined with the new NSFNET, and the conversion of network development from a purely military to a largely civilian enterprise was complete.

The technical and institutional foundations necessary for the growth of the Internet were in place. The completion of the site presentation, multi-media display capabilities, and navigation software necessary to build the conveniences required for the rest of the Internet edifice and to make it attractive to a wide range of users were to be supplied by a new cast of characters; armed with the considerable achievements of the ARPANET project, but outside of the direct IPTO sphere of operation (Abbate, 1999). In this regard, it is important to recognize the role that

the research and private sector played in commercializing the Internet, especially with regard to developing user-friendly interfaces and applications. Without the early work by Tim Berners-Lee in devising the protocols for the worldwide web (e.g. url, http), and the browser advances by Mosaic and then Netscape, the Internet might still be a communication vehicle for hard-core network designers and administrators. By developing an intuitive and graphically-based system for searching and communicating, the benefits of the network became available to wide segments of the population, producing the now renowned Metcalfe's Law on network effects (e.g. the usefulness, or utility, of a network equals the square of the number of users.) (Segaller, 1998)

Unfortunately, the budgetary details needed to fully quantify the government's expense in establishing the ARPANET have never been tabulated and made public, being lost in the reporting limitations generally applicable to items in the Defense budget. The principal technological developments and testing which ultimately revolutionized communications technology, however, were done over the first 10 years of the ARPANET development project with the price tag of a paltry \$25 million. (Bolt Beranek and Newman, 1981)

4.1.4 Program Achievements: The Internet of Today and its Implications for ATIS

Few informed observers today doubt the notion that ARPANET's progeny -- the Internet -- has proven itself to be a defining technological, economic and even cultural development on the global scale over the last decade. Its impact is stunning not only in the breadth of its

reach and in the ways that its availability has touched the lives of those who have reached out to tap its capabilities, but in the relative speed with which it has done so. The technology was able to progress from a wistful gleam in the eyes of a small group of dedicated cybernauts to a proven technology poised and capable of the feats which we see today in less than twenty years. And today, over 400 million people world-wide are already connected to inter-linked computer networks. (NUA, 2000). In the United States alone, it is estimated that over 166 million people -- almost 60% of the nation's population -- live in a home which is connected to the Internet. (Nielsen, 2001).

From a purely functional perspective, the Internet has greatly influenced how people conduct their daily business and domestic chores, extending even to how they find employment. For many it also serves as a new entertainment medium, and for the establishment and conducting of purely social interactions as well. It vastly expands effective consumer choice: For major purchases, prospective buyers can partake in such basic tasks as comparison shopping without leaving home. And it provides powerful capabilities as an informational medium as well, ranging from use as a research tool to a new medium augmenting traditional electronic and print media for the receipt of general news and current events. With such a wide range of possibilities now available from a computer screen, the Internet may be seen to provide a substitute for travel for trips of many kinds. Just how this technology effects travel demand, and what it will mean over the long run in the aggregate for urban congestion, will be a topic of considerable research in the years ahead.

As a purely economic phenomenon, the role of the Internet as an element of the national economy is virtually exploding. Its users are rapidly increasing the pace with which they are buying goods and services on-line: In fact, a recent survey of Internet-connected adults found that 81% of them -- almost half of all adults in the United States -- have utilized that connection to purchase a good or service on-line. (Nielsen, 2001). And although the measurement of that activity is seriously impaired by definitional quirks in the way that we have historically measured our economic activity by industry and by class of expenditure, the true magnitude of the purchase of goods and services over the Internet is nonetheless beginning to emerge.²⁰ The narrowest measure available -- Internet sales by retail firms (i.e. by establishments reselling products to final users) -- is estimated by the U.S. Department of Commerce, in its Monthly Retail Trade Surveys: Total retail trade by Internet transaction for 2000 was estimated to be \$25.9 billion. (U.S. Department of Commerce, 2000). These transactions represent approximately one quarter of the total sales of all mail order outlets over the same period, and by year s end accounted for slightly more than 1% of total retail spending. (U.S. Deptment of Commerce, 2000).

This may appear to be small at first glance, but becomes remarkable when one considers that the retail sector includes several very large sectors of personal consumption spending, including such things as groceries, eating places, and gasoline service stations, which do not readily lend themselves to remote purchases. And these Internet sales are growing rapidly: Fourth quarter sales in 2000 reflected a full two-thirds increase beyond those of the same period in 1999. (U.S. Dept. of Commerce, 2000) Further, because of

the accounting convention problems, these retail estimates are grossly incomplete, excluding two large components of the dot-com economy that have served as noteworthy leaders of the e-commerce wave -- on-line sales of travel service providers and financial brokerage houses.

If a more practical definition of retail e-commerce is created to fully include estimates for these kinds of transactions, and also to include direct business-to-business purchases on the Internet, the University of Texas Center for Research in Electronic Commerce (2001) estimates the total volume of Internet-based product sales during just the first half of 2000 to be \$127 billion, and increasing rapidly. In fact, Forrester Research (2000) has recently predicted that by 2004, direct business-to-business Internet sales alone will soar to more than \$ 2.5 trillion. Truly, the ARPANET project has done more than merely to leave us a new medium of communication in its wake. It has conferred upon us a new stage upon which a substantial share of our economy will soon be conducted.

Of course, not all of this activity can be attributed to the Department of Defense role in supporting the ARPANET. Certainly, computer networking as a technology would have occurred eventually even without it. But the public sector effort unquestionably hastened its achievement by decades, and ensured that computer networking capabilities would be available with maximum connectivity across the entire spectrum of prospective users. *In the absence of the commonly-derived and standardized set of communication protocols bequeathed to us by the ARPANET project, the computer network market would resemble more closely the software industry or even the early European railroads with their*

incompatible gages -- each network supplier doggedly holding on to their own proprietary equipment and methods, their business model predicated upon the protection of their own economic health by preventing others from easily gaining access to their customer base. Connectivity would have been highly segmented within blocks segregated by major competing network provider, with cross-platform communications available only with the complications of meshing intentionally-designed equipment incompatibilities and extended fees. And with this fractionalization would have come not only higher costs for network services, but also natural limits upon the range of content which would be available due to the lack of a unified and universal potential market.

(Hahn, 1994)

4.2 Precedent for the ITS Success

The invention and deployment of the Internet is bound to join the automobile and electricity as one of the major technical achievement of the 20th century, and in this sense its success is at a very different scale than ITS. Yet, there are core characteristics of the ARPA Internet experience that have import for ITS systems in California. Before addressing these lessons, it is useful to revisit the context for the ITS systems in California.

Some of these are rather common sense factors left from the state's urban history. As noted at length in Section 1, California's major urban areas are products of the post World War II era, with their respective growth patterns highly influenced by the primacy of the automobile as the transportation method of choice. The extent of low-density sprawl and the sheer size of the state's major urban regions make them both very freeway dependent and very complex. For example each of the four major urban systems (Bay Area, Los Angeles, San Diego) is roughly equal to many state systems, not to mention the numerous inter-linkages among these systems and across the vast rural areas that comprise the central (and very northern) part of the state. Moreover, the state has multiple overlapping transportation elements pursuant to a number of economic, social and environmental goals: a strong airport and port system for intermodal delivery of goods; several transit systems for urban, rural, and special populations; and several urbanized light-rail and heavy rail systems in major urban areas. In terms of the sheer scale, the transportation system in California is by far the most extensive and complex.

A second circumstantial factor recommending the fast adoption of ITS is the unique importance of the information technology sectors in the domestic economy of California, and what the development of ATIS technology might mean for the state's economy as an economic stimulus. Certainly, California firms have dominated the Internet infrastructure industries since its inception. In fact, many of the principals involved in the development of network technology -- both equipment and software -- migrated to California after completing their service on the ARPANET project. They did so largely seeking to join with the state's already extensive computer hardware and software

industries and to make their personal fortunes commercializing the technological ideas they had developed in the cause.

As a consequence of these efforts, California is both the leader in Internet technology development and, at a more modest scale, the leader of ITS industry. Based upon a corporate survey of the major firms in the field, the research team at the University of Texas Center for Research in Electronic Commerce (2001) estimates nationally that the Internet-specific equipment, software and ancillary expenditures to run the various networks together comprising the Internet accounted for over \$210 billion in the first six months of 2000 alone. California represents the largest domestic market for the ITS industry. A recent report estimated that the total market for ITS good and services represent a \$10 billion dollar industry (Hagler and Bailey, 2000).

Table 4.1: California ITS Market by Segment, 1998-2010

Market Category/Segment*	Cumulative Market, 1998-2010 (\$ millions)*
<i>Transportation Management Systems</i>	<i>\$895</i>
Freeway Management	\$470
Arterial Management	\$330
Road Weather Information	\$5
Transit Information	\$35
Railroad Grade Crossings	\$15
Emissions Monitoring	\$50
<i>Electronic Payment Systems</i>	<i>\$170</i>
Electronic Toll Collection	\$100
Parking/Access	\$65
<i>Commercial Vehicle Regulatory Systems</i>	<i>\$30</i>
Commercial Vehicle Regulatory	\$30
<i>Fleet Management Systems</i>	<i>\$2,490</i>
Commercial Fleet Management	\$2,380
Emergency Fleet Management	\$30
Transit Fleet Management**	\$70
Maintenance Fleet Management	\$10
<i>Traveler Information Systems</i>	<i>\$4,385</i>
Navigation	\$1,155
Mayday	\$1,315
IVIS	\$1,030

Market Category/Segment*	Cumulative Market, 1998-2010 (\$ millions)*
Traveler Information	\$890
<i>Advanced Vehicle Control and Safety Systems</i>	<i>\$2,885</i>
Adaptive Cruise Control	\$885
Driver Drowsiness Warning	\$155
Vision Enhancement	\$440
Hazard Warning	\$580
Automated Vehicle Control	N/A
Crash Management	\$675
Collision Avoidance	\$160
<i>TOTAL CALIFORNIA ITS MARKET</i>	<i>\$10,850</i>

This market size is not surprising given the dominance of California as a percentage of the US population, economy, and automobile ownership. Yet, it does serve to underscore several major points. The first is that the California system is quite complex and multifaceted. The second is that the magnitude of private sector participation is considerable yet under-realized. While these will be taken up in summary fashion in Section 5, several lessons from the Internet for ITS are worth mentioning at this juncture. Several specific lessons include:

Managing Complex System Growth

The California ITS program needs to be as the IT element introduced into this complex infrastructure as a means to balance supply and demand. As such it follows the broader trends occurring in infrastructure management. Drawing upon their NSF study of US Civil Infrastructure systems, Zimmerman and Cusker (2001) have noted: We are at the crossroads of change in our infrastructure whether it is road, transit , air travel, electric power , water supply or wastewater treatment. Critical evaluations for professional societies, special councils and public opinion polls have rated the quality of infrastructure as generally low across the board. In order to meet public expectations, information technologies create the opportunity for aligning supply and demand, for example through the immediate detection capabilities for infrastructure quality and capacity and the provision of consumer services (p. 1).

The Performance Measurement (PEMS) system being devised by PATH/Caltrans has provided insight into the challenges and possibilities of using information systems to manage as complex a system as surface transportation. This system uses a combination of historical and current data to provide real-time estimation of freeway conditions. While focused principally on the freeway system, the project has demonstrated several important principals of system management previously unrealized or under-appreciated. For example, it appears that system degradation occurs rather dramatically at freeway speeds under 60 mph, and that restorative time is longer than at first estimated. Moreover, it also appears that much of this excess demand could be managed by ramp-metering, but this would invite a parallel management of other systems. As the study authors put it: The calculations of these reductions in delay from metering and excess demand can be the starting point for the rational operation of a regional transportation systems, because the calculations reveal the fundamental tradeoffs between freeway delay, queuing delay, and the distribution of demand over time and modes. A quantitative evaluation of these tradeoffs can help assess the effectiveness of different transportation options: additional ramp storage capacity, an extra lane on a link, transit improvement, providing traveler information, etc.

The implication is that complex systems should be managed like the Internet or other complex systems (Sussman, 2000). As investigated by the Sante Fe group and other noteworthy scholars (e.g Arthur), several overriding considerations of managing a complex system include: adaptability permitting the system to grow and evolve rather

than over prescribing, feedback encouraging mechanisms for self correction and growth; self-organizing appreciating how systems can combine to find unique scale-appropriate solutions.

In this matter ITS carries with it an implicit recognition about the complexity of the transportation system and the needs to manage all aspects of it. That is, a simple capability orientation is quite insufficient (see Richmond, 1997). As Weissenberger notes ITS is a complex and assembled technology, involving the integration of many sub-subsystems, specific technologies, and institutions, and with critical knowledge distributed over many individuals and organizations. Learning networks and learning by doing and using are particularly critical ingredients for the deployment of such systems (p.6).

The challenge to ITS deployers is to devise a system that has the various features of interoperability while respecting the regional and even sub-regional differences that can occur in the transportation system, including the use of information. A guidepost in devising these solutions is to follow the needs of the user, just as the Internet has successfully benefits from killer apps (e.g. email) to propel its organization and architecture. Indeed, within highly decentralized system the user plays a critical role as in many ways it is the most dynamic part of the system.

Attracting Consumer Support

Information technology is fundamentally affecting the role of the user in infrastructure systems. In the case of air travel, for instance, the dis-intermediation of the travel agent via online booking is creating an active and aware consumer (Wilson, 2000). Gone are the days where consumers passively made airline reservations under a set rate structure through a travel agent; increasingly consumers are sorting out their own travel options, and acting in a highly responsive way on the information they receive about price, travel delays, etc.

As will be presented in greater detail in the next section, ITS plays a critical role in bringing information to the consumer. Empowering the consumer is therefore a strategy that can propel growth and evolution of the transportation system. Drawing again upon the Internet analogy, there is no doubt that the astonishing rate of consumer growth has been a key factor in its phenomenal deployment rate. But to do this, the information has to be credible, reliable, timely, and differentiated (for a complete list of factors, see Lappin, 2001). To date the systems approaches to traffic management have developed systems for use by traffic managers vis a vis travelers. To consider the airline analogy, the types of information systems developed are more typical for to the air traffic control graphics than to the customized interfaces of the airline/e-tailers.

4.2.1 From Operations to Performance

The provision of information raises expectation for performance. To stay with the air travel analogy, on-time performance rankings have become a key part of airline operations. They are now not only reported monthly, but available to the consumer on a per flight basis. The informed traveling consumer now expects this type of information. The air -traveling consumer now not only has general information about an airlines flight performance, but detailed information about performance for specific routes.

But, as several reviews have recently noted, the performance expectations for the surface transportation system have been secondary to the overall capital orientation of the industry. The most cited statistic in terms of performance is the annual TTI reporting of congested area, which regularly makes the news when it is released (especially with regard to the rankings) of cities (see Schrank and Lomax, 2001). While useful in making broad comparisons across metropolitan areas, it is a static number and hence does little to direct operational management of performance.

The Caltrans Transportation System Information Program--along with the aforementioned PeMS systems--is making headway in this regard. For example, the prototypical report contained performance measures on four elements:

- Safety/Security - Minimizing the risk of accidents, death, injury, or property loss

- Mobility/Accessibility-- Reaching desired destinations with relative ease within a reasonable time, at a reasonable cost with reasonable choices
- Reliability --The level of variability in transportation service between anticipated (based on scheduled or normal travel) and actual travel
- Environmental Quality --Helping to maintain and enhance the quality of the natural and human environment.

A prototype report has been developed that begins to implement these measures. While this effort is laudatory, it is beholden to the quality of information available. Currently, for example, real time data on system performance is only obtained a few times a year, roughly akin to measuring only a measuring flight performance only a few times per year. Consequently, developing a PeMs sytle system that can provide robust, timely, (and multi-modal) information is critical to achieving a stronger performance orientation.

At the national level, this movement from a construction paradigm to an information driven operations paradigm is represented by the National Dialogue on Operations and related efforts to institutionalize an operations focus into national policy and legislation. From a national perspective, this suggests the federal role is moving from assistance with the capital elements of the program, to assistance with (if not planning regulatory oversight) of the overall performance of the transportation system. As has been outlined by US DOT, the overall intent is to create a dedicated funding stream for assisting localities with operations related expenses, one element of which would be ITS style information systems.

4.3 Summary

The history of the Internet provides an important lesson about how initial public policy support followed by strong consumer demand can unleash rapid growth of a complex technological system. ITS systems can, in this light, be seen as transportation analog where the public policy support has provided the first leg of support, and now the development of strong customer-based information services become critical. Drawing upon the Internet analogy, the key element here is to develop and build upon customer use to communicate about system performance relative to customer needs. While as a concept, customer relationship management (CRM) undoubtedly has a strong dose of hype due to the consulting firms that practice in the area, it nonetheless has a powerful underlying premise: technology permits highly complex information to be delivered in a highly personalized manner to customers throughout their lifecycle with a product or service. Hence, Amazon.com can recommend books based on a customer's buying habits, can track orders, and can handle billing problems all uniquely identified to an individual customer. In a similar vein, Dell Computers, (the emblem of mass customization) maintains complete records on each individual computer that can be accessed to provide customized real-time service. The overall notion is to focus on deputizing individual travels to the maximum extent possible, so that they can become active elements in the overall operations and then to construct a backend system that caters to the regional and local capabilities.

In short, the time is right to reconfigure transportation institutions to better plan, manage, and disseminate information relative to surface transportation performance. And the traveling consumer is a good place to start specific findings and recommendations in this regard are taken up in the final section.

5 BRINGING ITS TO THE CONSUMER: LESSONS, RECOMMENDATIONS, CONCLUSIONS

The previous sections have provided an historical and case study analysis of how three systems air, energy, and Internet have developed. In this final section, we turn to ITS system and lessons from these case studies on its development and deployment, both generally and within the state of California. While the case studies are interwoven into the analysis, the point of departure to considering system development in ITS is the role of the traveling consumer and how that affects system development. The section concludes with specific recommendations.

5.1 The Promise of Information Intensive Transportation Systems

Robert Crandall, the late and colorful Chairman of American Airlines, once remarked that his Sabre information system was one of the most important advances in travel over the last thirty years. While no doubt laced with the same self-confidence that propelled him to transform an industry, the comment is not without merit: the Sabre system served as the information system that facilitated discounted flights, customer loyalty (e.g.

frequent flyer) programs, and new hub-and-spoke service designs that translated the concept of yield management into reduced fares and increased service.

Besides an antidote on Mr. Crandall's business acumen, the explosion of the information dimension of the airline travel business has an important message for surface transportation professionals: the consuming public is ready, willing, and able to take charge of its transportation choices. But, just as the Sabre information system needed to be in place before the benefits of yield management could be realized, the challenge for surface transportation professionals is to create timely, useful, reliable, and interpretable information systems that the consumer can use to guide their choice of the mode and their time and route of travel.

Over the last decade, the Intelligent Transportation System (ITS) program has positioned itself as the provider of information systems for surface transportation system users. Consequently, transportation planners, policy makers, engineers and service providers associated with ITS need to consider how these systems can best accommodate the needs of various users of the nation's highway, transit, pedestrian, and bicycle systems. Using the case studies as a point of reference, this section draws upon recent consumer related ITS research findings to suggest a next generation of information system design and use.

5.1.1 The Infrastructure-Customer Connection

At the risk of over-simplifying a multifaceted research and demonstration program, it is fair to say that the original vision of ITS envisioned a public-sector led platform of information that would serve as a data-repository for numerous consumers, who would in turn be served by the private sector. As noted in early reports such as Mobility 2000, the publicly supplied information system would be designed to provide the backbone information for the traveling public, who would then use this information to avoid congested freeways (Mobility, 2000). And similarly early ATIS systems generally looked to the private sector to provide information into the vehicle or the driver.

However, a major lesson from demonstrations and deployments over the last decade is that *the relationship of the consumer to the infrastructure is more complex than at first envisioned*. This is both in terms of the direction of the information flow between the infrastructure and the customer, and perceived value and use of this information across consumer groups.

Starting with the direction of the information flow, several early demonstrations have provided important hands-on experiences with the challenges of getting accurate and reliable information about transportation system conditions. During the mid-1990 s, perhaps the most visible demonstration was the Travinfo project in San Francisco. Travinfo endeavored to create a state of the art public-sector led platform for providing multi-modal information to travelers. In this highly visible case, the public sector information system became hampered by institutional and technical limitations in being able to deploy a quality sensing system in a timely matter (Yim and Deakin, 2000).

These limitations in traffic condition availability have led to an interesting change in the flow of information. As a result of the Travinfo demonstration experience, the Metropolitan Transportation Commission is now evaluating new *public-private partnerships in the production of traveler information*; for example from data emitting from wireless probes. That is, the consumer is moving to be a part of the information production, not just consumption. A similar though perhaps less stark pattern is occurring throughout metropolitan areas in the U.S.; through cell-phones, call-ins and probes, the travelers and the cars they are in are emerging as an active part of the information system.

As noted above, the original view was that the traveler information would be perceived as valuable and therefore the private sector resellers would play the key role in customizing the information for users. While various market niches are still being pursued, a more sober finding is emerging: while travelers perceived value to the information, this has not yet translated into a strong willingness to pay this had been a consistent finding across a number of demonstrations, such as in Boston, Phoenix, and Washington, D.C..Against this backdrop, the deployment of this national traffic information number (511), can be seen as an astute branding and marketing approach to increase awareness of available traffic information. However, this does not translate into a ready paying market for this information. For the foreseeable future, it appears that baseline traffic information will continue either as a publicly- subsidized service or a service cross-subsidized through other services and to some extent advertising. Again, this is a more complicated information (and financial) flow that originally envisioned by ITS.

5.1.2 Broadening the Consumer View

While traveler information demonstrations suggest a limited private market for broad-based traveler information systems, this does not mean that various consumer groups do not perceive value in the information and that there is not a way to structure a business model around this perceived value. For example, in the model deployment initiative in Seattle, several different users were identified and different travel information sources were views as appropriate (Jenson, et al, 2000). There is a continuing interest, for example, in television-based video feed information services for those who are techno-adverse, and on the other hand, there is a high-end need for web-based information among the facile Internet users who in this case tended younger and, more often than not, male.

Findings from Seattle and other sites points the way to a more detailed understanding of market niches for traveler and system information. For example, a recent summary on lessons learned from national ATIS field tests identified three market segments: control freaks , web-heads and information seekers (Lappin, 2000). The former two, for example, are often market leaders in new ATIS services, and e-services generally. But, as this synthesis notes, it is the less technological agile, information seeker that represents a critically large segment. And within that domain, this would include market niches such as the alternative-mode traveler as well as what I would dub the flexible traveler .

The alternative-mode traveler has been vital constituent in the transportation system, yet it has been difficult to provide reliable and timely information to this segment. As bus and light rail information systems become more integrated, this should provide a useful data source for travelers interested in bus and rail information. However, the alternative mode traveler information need not stop there. There are a variety of niches and circumstances where alternative transportation modes excel as a means of travel. These would include special transit systems in recreational and national park areas, car-sharing programs in university towns, and jitney systems to airports. As bandwidth becomes more available to primary (and secondary) residences, there is a new opportunity to bring information about innovative systems to the attention of the interest alternative mode traveler.

In this regard, the Smart Trek demonstration in Seattle is telling. While travel condition information is available through a variety of sources, the web site is by far the most extensive information source. It features information rich segments of various modes, including highway, rail, car-sharing and ferries. It was ranked as extremely valuable among residents that used it. Moreover, as an information platform, it is several important features. First, it is quickly customizable to the consumer needs, both in terms of types of information and platforms upon which the information is delivered. The types of information run the gamut both in terms of mode (e.g. highway-bus, light rail, and ferry) and communication means, (e.g. video, graphics). With this attention to detail, it was not surprising the SmartTrek evaluation found a high degree of user satisfaction with the

website. Over 90% of respondents thought it delivered useful information and that it affected their commute trip either in terms of time of travel or means of travel (Jenson, et al, 2000).

While sites like Smart Trek can go a long way toward engaging the personal traveler in playing an active role in the transportation system, there is growing evidence that the commercial travel is a vital part of the system. Over the last decade, local commercial delivery has grown exponentially. A recent study has found that commercial truck travel increased by more than 37 percent from 1990 to 1999, from 96 billion miles of travel in 1990 to 132 billion miles of travel nearly a decade later, with some 72 percent of the estimated \$7 trillion worth of goods shipped from sites nationwide is transported on trucks (Road Information Program, 2001). An additional 12 percent being transported by courier services, bringing the total to 84 percent of all goods shipped that travel over roads. Congestion is impacting the performance of this delivery system.

Consequently, the commercial operators are major stakeholders in urban and rural transportation, yet only nascent systems exist for integrating these systems across time and space. For example, there is just now thought being given to developing flexible working hours to improve the intermodal hand-off from shipping to freight, as well as thought to devising innovative shared-space reservation and pricing systems to reducing the impact of local deliveries on urban and downtown environments. While, the original version of commercial vehicle operations rightly testing the technical dimensions of smoother commercial operations (particularly across state lines), this rise in more

dynamic small delivery systems is, once again, creating a more complex relationship between the users and the system.

Another ITS target market for enhancing system is the critical role played by the flexible traveler the flexible traveler is perhaps the unsung hero of the transportation system. The flexible traveler has not been studied as closely, yet might provide an important ingredient to a bringing yield management to transportation systems. The flexible traveler is one who, as the name implies, could and indeed would change there traveler time if they could have a more reliable (and quicker) transportation. The Washington , D.C. system uncovered that ATIS systems were as valued for improving the reliability of service as it was for improving the timeliness of service. That is it is important to know with certainty that one can make, for instance, a 9:00 a.m. meeting as it ease to perhaps save a few minutes on that commute and arrive, say at 8:35 a.m. While the transportation-telecommunications literature has closely examined the impact of formal telecommute programs, from a day-to-day management perspective, the impact of formal and informal flexible arrangements are arguably as important if not more important to the smoothing out spikes in travel demand.

The clientele is there, as for example, a recent study found that even in the slowing economy, flexible work arrangement remain critical (Hewitt, 2001). Based on a survey of over 1000 employers, Hewitt Associates, found that seventy-three percent of businesses offer flexible work options. The most common arrangements offered are flextime (58 percent) and part-time employment (48 percent). Other popular programs include work at

home options (29 percent), job sharing (28 percent), compressed workweeks (21 percent) and summer hours (12 percent). Flexible travelers can adjust their work hours depending on any number of factors, one of which is perceived commute time. This form of partial telecommuting-flextime can be enhanced by accurate ATIS information on estimated travel time for alternative departure periods.

Flexibility can also be a part of the commercial traffic solution as well. This shift away from the peak has already occurred to some extent in the commercial industry and through proper use of transportation information could be encouraged even further. Commercial delivery services will often wait until the perceived peak period travel is over to deliver products and goods to congested urban areas. However, a recent conference on e-freight revealed that additional traffic and parking information could make the commercial delivery availability more efficient.¹ With the growth of small delivery services, there has been a related growth in customer interest in on-time delivery, often around the peak travel time (e.g. business morning delivery). New systems that provide additional certainty for both consumer and delivery while not occurring during peak periods could have benefits for the entire system.

5.1.3 Flexible Yet Demand Predictive Systems

A common theme among the case studies air travel, energy, Internet, and now, ITS is the emergence of information-intensive systems that are highly dynamic, user specific,

and demand responsive. That is, more like the consumer use of the air travel system today. However this is not to say that there is not some predictability of performance. As described elsewhere in this report, there are impressive new developments in using data on prior performance to devise near real-time estimates of route-specific travel time and delay and this can only enhance transportation choice (in terms of time, and where applicable, mode) for those that have easy access to such information over the Internet.

Of course, economists have long argued that pricing provides the most efficient mode of information about demand relative to supply. When demand increases relative to fixed supply (e.g., peak-hours), the price rises and when it demand falls relative to supply, the price will correspondingly fall. Travelers readily accept that when they weigh their air travel choices price sales occur off peak and price premiums occur during business days. Yet, for most parts of the United States congestion pricing or value pricing remains a problematic option. Where Electronic Toll Collection (ETC) has been introduced, however, it is providing demonstrable savings to customers. For example, the evaluation of New York's EZ Pass program found high acceptance among users and strong consensus that it saved travels time and aggravation at the toll center, though there has been some frustration with the customer support billing side of the operation (Vollmer, 2001). It is not surprising, therefore that, this EZ Pass system is becoming a defacto standard for many states in the mid Atlantic-- some seven eastern states now use the E-Z pass system. These systems are providing necessary transactional platforms for a more dynamic and information-based transportation system.

However, in light of continuing policy concern about the equity issues of High Occupancy Toll (HOT) Lane pricing, research might next consider the value of AVI technology is facilitating reserved use of transportation system that is combining what is known about the value of certainty with the availability of flexibility. That is, like the virtual queuing used by other yield management schemes (e.g., Fastpass at Disneyland), in this situation a computer-based system provides for just in time access to spread demand across peak-period and avoid unnecessary and unproductive time in the queue. Under this scenario, a portion of the remaining demand vacancies would be made available (via the Internet reservation auction, and tied to a pre-registered AVI). Travelers on the system could post interested in any time band and these would be honored on a first come, first serve basis. A secondary market of auctioning these off (e.g. congestion pricing) would not be prohibited, but cornering the market would. High occupancy (HOV) users would not need to have any reservations. These and other more mainstream approaches have recently been considered under the rubric of managed lanes the key point being raised here is the importance of designing such lanes in a way to that takes advantage of the demand for performance certainty and uses this demand to help stabilize system.²

5.1.4 Devising Emergency Use Partnerships

Emergency and non-recurrent information needs also occur in the system, particularly in the arena of safety. This service represents a distinctively different usage of information

in the transportation system, and one is which the value of time (especially response time) is extraordinarily high. It is instructive to note that the advent of private sector telecommunications and cellular service has played a pivotal role. The rise in cellular telephones has played an important role in telecommunications services. Between 1990 to 2000, the percent of 911 calls from mobile devices exploded from 20,000 to 120,000 *per day*. The role of mobile telematics in providing safety services has become substantial, and a network has developed to develop innovative service and delivery architectures for these services.

Indeed, the advent of the new e-911 mandate (for being able to determine location based on cell-phone call) will usher in a new era of mobile related emergency service. The recent demonstration in Minnesota of Mayday Plus demonstrates the possibilities for enhancing access to emergency services. This demonstration, conducted over the last two years, integrated cellular communications, Global Positioning Systems (GPS) satellite technology and a special emergency response communications system installed at Mayo Clinic and Minnesota State Patrol emergency dispatch centers. The Mayday Plus system provided authorities with automatic collision notification, and information such as location and crash severity from in-vehicle devices. Over 100 vehicles in the Rochester region were outfitted with an automatic crash notification device. The evaluation included both technical and user elements and found that the system had identified and responded to a perceived safety concern among rural travelers. A full 75% of evaluation respondents noted its perceived value in enhancing rural safety, a belief that generally held throughout the testing period. (Castle Rock, 2000).

Beyond this demonstration, operations such as the ComCare Alliance have created new institutional alliances that can form partnerships to help ensure critical services are delivered within the narrow golden hour between an accident and the arrival of help. With a large percent of fatal accidents occurring in rural areas, the new e-911 requirements) provide an important tool for delivery these critical safety services. Moreover, they highlight the innovative types of partnerships needed to deliver ITS across a broad range of users. In this case, it involves a new form of partnership with healthcare providers, emergency service providers, and the state police.

5.2 Cross- Case Study Conclusions

While the final analysis of this cross-industry case studies leads, appropriately enough, the key role played by the consumer in driving technology systems such as ITS, the cases provide more general lessons about the policy context in which these systems evolve. There is a growing literature on the way that systems evolve, based in part though not exclusively on the experience on Internet and related technology industry growth. As noted earlier, the complexity school has analyzed how networks grow and develop. Several features include historical situation and allows for early choice, the need for systems to self organize, the role of historical accidents, as well as problems such as lock-in to early and inferior technologies. This final section provides a set of general observations about this system growth, which then leads to concluding recommendations.

We believe that there are valuable lessons from these three successful public sector forays into system management and growth can be readily applied to today's problems in urban mobility. These lessons pertain to both our need for a new general approach to congestion in the nation's cities and to the possible role of ITS in helping to implement it. These system examples are presented as they demonstrate the ability to introduce system-wide optimization schemes in a manner that preserves market forces (and the choice implied) while obtaining performance advantages. Within the context of surface transportation, ITS is currently being considered as a means to enhance performance of the system. Efforts such as the National Dialogue on Systems Operations have brought to the fore the potential of performance enhancement through attention to information and operational improvements.

5.3 Recommendations for the Next Generation of ITS

A new federal 10-year ITS Program Plan is under development, and the state of California is refining its long range vision as well. In the current version of federal ITS plan, the importance of the consumer is explicitly recognized in the vision. The relevant section states the ITS program should focus on: providing effective, end-to-end, seamless, multi-modal transportation services for people wherever they live, work, and play regardless of age or disability. Opening employment and recreation opportunities and helping make travel time more productive, by flexibly enabling more travel choices for more people. (ITSA, 2001). The challenge is to deliver a system that will indeed produce this easy and seamless experience. The following are promising research and policy directions for achieving this challenge.

5.3.1 Promote Personalized Transportation Information.

Even the prescient Robert Crandall could not have foreseen the extent to which consumers would take control over their travel choice. The Sabre system was originally designed for the travel agent. But, of course, the World Wide Web changed all that, making the travel agent one of the many functions to be disintermediated. In the spirit of these times, the Sabre system gave birth to Travelocity, which has since become a shining star in the otherwise darkening sky that constitutes the e-commerce galaxy.

Among those enterprises that continue to shine, a fundamental principle is the dedication to a consumer focus, alternatively termed mass customization (e.g. Dell), personalization (e.g. Amazon), or, more generally, customer relationship management (CRM).

For the transportation professionals generally and the ITS program specifically, the corresponding challenge is to devise and execute an information system that can engage the individual traveler and affect overall system choice and performance. Against the general backdrop of highly customized e-services, the surface transportation system seems to cater to a one size fits all. The lesson from CRM approaches (and the longer history of customer-centric management models), is that information systems can allow for both highly tailored relationships with customers while generating overall system efficiencies through a large number of customers. In this vein, the ATIS, ATMS, and AVI systems need to become an integrated means by which travelers can develop customized traveler plans and these plans can ostensibly benefit from archival and predicative information on system performance. This begs the development of a more flexible transportation management network that can respond to personalized information and choice.

5.3.2 Broaden Range of System Information (including Pricing).

Both the energy and air traffic systems strongly rely on information systems to monitor the balance between supply and demand of the system. Particularly for air traffic control system, information plays a key element in the realistic determination as to the impact of

(excess) travel demand on system performance. A similar level of information appears to be missing from the surface transportation system. While ITS has increasingly allowed information to be available to consumers, it has not achieved the level of user friendliness as the estimated-actual arrival time information has air travel.

However, there is abundant reason to believe that choice enhances system efficiency. In surface transportation choice has been constrained due to a number of policy, market and technological circumstances. However, there are an increasing number of modal options being pursued in metropolitan areas transit, light rail, car sharing, and telecommuting. The role of the ITS system should be to access choice of these modal options, and this should include priced travel options, as well as alternative- time travel options.

As for real-time transportation system management, there is a need to develop information systems that can enhance real or near real time knowledge of how these systems are performing everyday. One way ITS can help improve system performance is in providing the information tools for managers to measure actual performance in real time, all of the time. The next step would be to publish information on system performance that can help build awareness and use among the traveling public (Skabardonis, 1999).

Evaluations of ITS systems accumulate on an ongoing basis, so the picture of system performance is still unfolding. However, as seen within the goal of balancing supply and demand of the transportation system, some trends are emerging. The most notable trend

is that ITS plays a vital role in serving as the information backbone for tactical transportation management, yet is viewed as playing a moderate role to play within the overall strategic balancing supply and demand. What is needed is a strategic approach that integrates supply, demand, and the power of information technology to manage the system both tactically and strategically. In the future, is it conceivable to think that information will become as important to all travel constituents as it is currently the commercial delivery business such as Fed-Ex where the information about where the package is as vital as the actual location of the package?

5.3.3 Devise and Demonstrate Benchmarks for Performance.

Particularly in the case of air traffic controls, benchmarks (such as on time performance) provide a succinct metric for assessing performance of the transportation system. ITS could play an important role in providing a similar benchmark for the surface transportation system, including but not limited to the throughput of the roadway system. Benchmarks related to on-time performance (building off on indices such as the Texas Transportation Institute) can enhance public awareness of system performance. In terms of performance management, recent research has advanced a number of algorithms that can be used as management benchmarks. For example, findings of the PeMS research suggests that there are significant performance thresholds for freeway speed degradation, and this might provide new insight into the ramp meter timing.

In California, demonstration projects such as FETSIM provided early evidence for traffic management benefits, while related projects demonstrated demand side contributions. FETSIM overall program results for eleven years and 163 cities: 14% delay reduction, 8% travel time savings, 8% fuel efficiency gains (similar for emissions). Note that FETSIM projects were generally (traffic signal) network wide in scope, and therefore, the results are essentially at the system not link level.³ There should be an effort to continually update and disseminate system performance (and performance gain) results.

5.3.4 Create New Institutional Allegiances

Underlying the tension in moving to an operational focus is the institutional challenge of day-to-day operations. This challenge has rightfully received attention in the National Dialogue on Systems Operations. The customer-driven focus suggested in this report adds yet another dimension to this discussion that dimension is the need to link information systems in support of operations directly to the customer interests and needs. Transportation managers have little to fear of being dis-intermediated (as say the travel agents have); in fact, they have much to gain from an informed traveler who will use the information to alter travel time or mode to enhance their personal mobility and by consequence enhance system mobility. While this objective may be laudable at a very general level, actually finding the precise style of institutional partnership can be more challenging. The next generation of systems do, however, promise to bring partnerships along travel-service, navigation, electronic tolling, safety, mayday, and related

dimensions in a manner that was hoped for but not executed in the first generation of ITS deployment.

For some, the recent retrenchment in the technology sector has given rise to justifiable concerns about reliance on the private sector in providing information systems and services to the public. What happens when private sector partners cannot receive adequate return of investment to justify participation in ITS programs? For over a decade, the ATIS industry has struggled to establish itself as a profitable sector, and it now appears to function as a segment of larger database, mapping, and radio advertising market segments. Similarly on the ATMS side of the industry, the major private sector participants often are strongly rooted in public sector contracting, which can lead to an orientation around obtaining and maintaining public contracts as well as fulfilling the needs of the end-user.

These uncertainties in achieving a strong customer focus underscore the need for a strategic technology focus regarding the role of information in delivering value to the users of the surface transportation system. The venue to articulating this strategic focus is the transportation planning process. But, the focus on performance of complex systems and customer-driven services can affect the nature of the planning apparatus. As a great deal of the transportation planning priorities are a function of regulatory requirements, the move toward a performance-based transportation system would need a planning requirement analog. While the regional ITS architecture conformity requirements could be viewed as a starting point for this function, such requirements layout a rather general

architecture process rather than focusing in on specific data needs and means to derive appropriate data. The next generation of information-systems for surface transportation needs to provide clear planning objectives for the nature and quality of information expected for users of the system.

5.3.5 Understanding Flexible Transportation Network Management.

It is clear that managing complex system like the surface transportation system relies on a set of principles and knowledge at the interface of several fields: transportation, engineering, economics, social science, and with ITS, information systems. Yet we are only beginning to understand how these systems perform. The PeMS system described underway is PATH is an example of the next generation of archival-predictive model that holds promise for using traffic data combined with management control means. It suggests a new level of operations management that needs to be integrated with policy, financing and engineering approaches to transportation management

An interesting parallel is the recent DOD-EPRI research on complex and adaptive systems. Recognizing the dynamic nature of energy systems, this \$30 million-5 year program will develop a fundamental understanding of how energy management can learn from complex system dynamics and, as a consequent, devise more reliable and adaptive energy systems (Amin,2000). A similar effort may be need in surface transportation; that is, a research program that draws upon advances in complexity theory, user-driven systems, and ITS lessons and developments to hence enhance the body of research on information intensive surface transportation infrastructure. Such an effort would be

consistent with a recent National Science Foundation sponsored workshop that highlighted the need for better theories and principles on IT and infrastructure performance.⁴

5.4 Conclusion : The Challenge of Complex System Evolution

By looking at the history of the energy, air traffic, and Internet systems, we can see the performance value that can occur from bold actions to develop network efficiencies.

First, it suggests the importance of an evolutionary approach to systems development and policy. For example, while it can be an important process to develop a regional system architecture, the nature of technology growth and change can affect the implementation of that architecture in fairly substantial ways. As noted in early in chapter 5, the early plans for ITS placed strong reliance on the role of the public sector in devising the basic ATMS system and through this system producing data that would then be used by private sector ATIS systems. Yet, over the course of several demonstrations and evaluations, it is becoming clearer that in some instances the private sector may be a more reliable partner to obtaining traffic flow information (using innovative wireless means) and the public sector is emerging as an important stable force in the provision of traffic information. The overriding lesson to avoid, to the extent possible, early lock-in on technological and inferior technological and institutional relations.

Second, like the air traffic and energy systems, the surface transportation system is strongly influenced by consumer demand operating through a free market (though not fully priced) market system. And like the energy and air systems, the supply network is a capital-intensive infrastructure that requires significant investments over time. The demand characteristics of surface transportation appear closer to the energy system than to the air traffic control system the demand occurs on a day-to-day basis and has a strongly spontaneous (is not regular action). While the level of participating agents (travelers) dwarfs the air traffic system on any given day, the slot allocation program does provide a useful insight---reserving demand slots can reduce unnecessary delay in the system. While such as system (such as noted above in the possible use of the HOT lane scenario) would not easily be controlled by a master reservations operator the beauty of the distributed systems approach is that each region (if not sub-region) can begin to introduce system demand approaches that can then be loosely coupled to adjoining systems.

Third, a dynamic, customer-driven system requires a strategy for integration. Like the other two systems, there is often a lack of integrated strategic approaches to transportation infrastructure management. Traditional transportation planning procedures and capital construction program thinking accent a practice of making capacity decisions on a link-specific basis, rather than with an overall network emphasis. Although ITS would clearly help ease traffic conditions on individual congested links, the way in which it would do so is inherently difficult to predict in terms of benefits to specific congested

links; and this uncertainty -- in a period of tight capital budgets -- works against selection of the ITS-centric approach.

For transportation, the lack of an integrated approach has often meant that transportation project delivery takes precedence over integrated system management. For example, the recently enacted California transportation legislative package contained very little ITS related integration projects, and featured instead a backlog of capacity enhancements.

Finally, it is worth noting that it is often a state of crises that facilitates such an integrated approach. Sadly but inevitably, crises often perform a function of erasing obstacles to paradigm changes. Both the air traffic control and energy management systems enacted change within the context of very visible crises. While each event resulted in unfortunate personal and business costs, one positive outcome is that these events helped galvanize the public to understand the adverse implications of inadequate systems management. Surface transportation does not typically have such crises to galvanize changes. Perhaps the closest to a crises is when unbalanced systems progress so far that the federal government intervenes to restore balance in the systems approach such as the federal government did recently when it ruled the Atlanta transportation program to be out of compliance with the Clean Air Act. Because of this lack of crises, basic systems management approaches, such sending clear information signals on supply limitation and using pricing to manage demand, have typically been used in a piece-meal fashion.⁵

Recently, an unprecedented crisis has occurred in New York and Washington, D.C. a crisis that will likely result in a number of infrastructure policy changes, particularly in the airline industry. Other policy and technical changes --either as a result of this crises, or because of the continuing march of technological advancement--cannot be predicted. And hence, there is some uncertainty about the priority that will be given to the prevailing problems in surface transport. What is known is that the surface transportation system remains at the center of our ability to move around freely for economic and social interaction. Devising an effective ITS system that aids in balancing demand with supply, and permits sustainable growth of the nations cities and metropolitan areas remains a vital activity even in these troubled times.

Section Five End Notes

1 See summary of E-Freight Transportation Conference; Portland, Oregon; See www.fire.org .

2 For more information on the managed lane concept, see
<http://www.wsdot.wa.gov/mobility/managed/>

3. For a summary of these individual sanctions, see Congressional Research Service, Highway Fund Sanctions and Conformity Under the Clean Air Act, October 15, 1999.

4 A summary of the NSF/ICIS Information Technology and Infrastructure Workshop can be found at <http://www.nyu.edu/icis/itworkshop>

5 Skabardonis, A. Evaluation of the Fuel-Efficient Traffic Signal, Management (FETSIM) Program: 1983-1993, Berkeley, CA: Institute of Transportation Studies University of California, Berkeley, Research Report - UCB-ITS-

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¹ See summary of E-Freight Transportation Conference; Portland, Oregon; See www.fire.org .

² For more information on the managed lane concept, see

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⁴ A summary of the NSF/ICIS Information Technology and Infrastructure Workshop can be found at <http://www.nyu.edu/icis/itworkshop>

⁵ For a summary of these individual sanctions, see Congressional Research Service, Highway Fund Sanctions and Conformity Under the Clean Air Act, October 15, 1999.