Regional Architectures: Definition and Integration into the Strategic Transportation Planning Process

by

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ABSTRACT

The advent of Intelligent Transportation Systems (ITS) has had two important impacts on the transportation world. First, it has created an information-rich environment, enabling managers of the transportation system to have a more informed view of the "state of the network". Second, it has provided transportation managers with some tools for controlling the performance of the transportation system, thus enabling transportation systems to be operated and managed on a regional scale. These two impact point toward the need to construct a framework that can (a) guide the distribution of information and (b) govern the deployment of services on a regional scale. The framework proposed by this thesis for achieving these tasks is a regional architecture.

The analysis in this thesis has two basic components. The first component is the definition of the term "regional architecture". A basic definition for the term is proposed, and the basic components of a regional architecture are discussed. An illustrative case study is provided, proposing a systematic method for constructing a regional architecture. A sample "regional architecture" concludes this discussion, and various ways of presenting the regional architecture are proposed.

The second component of the analysis is the description of a framework for integrating regional architectures into the strategic planning process. Regional architectures are proposed as one of two fundamental outputs of the planning process. The regional architecture document—describing regional provision of transportation services—is seen as complementary to the "regional infrastructure" document, which describes regional provision of physical transportation facilities.

Three key ideas are advanced in this thesis. First, it argues that regional architectures should govern the provision of all types of services, both ITS and non-ITS. Second, it makes the point that technical systems cannot be effectively integrated unless the institutions that operate these systems are also integrated. And third, it contends that regional architectures are an effective tool for addressing some of the observed shortcomings in strategic transportation planning.

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Preface

The research for this thesis was done within the framework of an MIT research project called ReS/SITE: Regional Strategies for the Sustainable Intermodal Transportation Enterprise. This project aspires to developing a new framework for regional strategic transportation planning. It has identified various shortcomings in that process through analysis of current planning efforts, and has worked to establish a new process to overcome those weaknesses. It builds broadly on the concepts of scenarios and regional architectures as fundamental to this new generation of regional strategic transportation plans.

This thesis has examined the regional architectures component of this framework. It defines the term "regional architecture", it proposes a method for constructing a regional architecture, and it argues that a regional architecture can and should be a fundamental output of the strategic transportation planning process.
Chapter 1
Introduction and Overview

1.1. Background and purpose of the thesis

Constructing a regional strategic transportation plan is a difficult task. Urban citizens, facing increasing congestion and longer commutes, cry out for more roads. At the same time, environmental groups lobby against the idea of “building our way out of congestion.” Rural citizens simply want someone to maintain their existing roads. Business travelers want more convenient access to regional airports, and they want more travel options at the airport. The perpetually strapped transit community promotes the environmental and equity benefits of public transportation. Manufacturers want to get their goods to market, swiftly, cheaply, and reliably. And rail buffs yearn for the day when high-speed passenger rail finally is an option across America.

As the transportation community attempts to deal with these diverse and contradictory voices, it must also confront a litany of other issues that are placing increased demands on the transportation planning process.

- The virtual completion of the Interstate system, as well as growing public resistance to the construction of new urban highways, calls for a new approach to surface transportation.
- The advent of Intelligent Transportation Systems (ITS) requires new ways of thinking about how the worlds of transportation and information technology should interact.
- Increasing interest in intermodalism—that is, the convenient transfer of both passengers and freight between modes—requires planners to think of how the various transportation modes should be integrated.
- A growing recognition of metropolitan-based regions as the critical units of economic competition requires planners to reconsider the appropriate scale on which transportation planning should be conducted.
These challenges often combine to highlight the shortcomings in the traditionally fragmented world of transportation planning. In fact, addressing each of these challenges requires confronting some fundamental institutional barriers. For example, a new approach to surface transportation will not be forthcoming unless institutions overcome their resistance to change. ITS will not be implemented on a broad scale unless institutions are willing to experiment with technology and collaborate with each other. The growth of intermodalism will be limited unless the institutions that operate the modes demonstrate a willingness to cooperate. And planning on a regional scale will not be a reality unless institutions demonstrate a willingness to cooperate and share responsibility for the operation of the regional transportation system.

The purpose of this thesis is to provide transportation planners with a framework for systematically addressing some of the institutional problems related to transportation. That framework is a regional architecture. We argue that a regional architecture is an output of the transportation planning process that recognizes the need for institutional coordination in the provision of transportation services. A regional architecture recognizes that good transportation planning practice requires one to explicitly address interactions among transportation-related institutions. The task of a regional architecture is to provide a specific response to a basic question: How can regional transportation institutions more effectively interact in order to provide higher quality transportation services to the public?

1.2. Motivation for the Thesis

There are essentially two motivations for this thesis.

- The first motivation stems from the ISTEA reauthorization legislation that is currently making its way through Congress. This legislation, it appears, will follow in the footsteps of the original ISTEA legislation and sustain significant Federal involvement in the development and deployment of Intelligent Transportation Systems (ITS). However, it is expected that the upcoming legislation will attach a new string to Federal ITS funding. That is, the reauthorization bill will likely require regions to develop “re-
gional architectures” that are “consistent” with the National Architecture. This re-
requirement raises an important question: What exactly is a “regional architecture”? This thesis proposes an answer to this question.

- The second motivation stems from prior research on strategic transportation plan-
ning. Over the past two years, a research team from MIT has analyzed numerous state and regional transportation plans. In doing so, the team has identified various shortcomings in the regional strategic transportation planning process. Therefore, a second goal of this thesis was to explore the “regional architecture” concept as a useful tool for addressing some of these shortcomings. The next section will discuss the broader context for this research in more detail.

1.3. The ReS/SITE Framework

The research for this thesis is done within the framework of an MIT research project called ReS/SITE: Regional Strategies for the Sustainable Intermodal Transportation Enterprise. This project aspires to address some of the aforementioned shortcomings in the planning process by developing a new framework for regional strategic transportation planning. This new framework is depicted graphically in Figure 1-1.
This framework (which is discussed in detail in Chapter 7) provides a broad overview of the strategic planning process. It builds broadly on the concepts of scenarios and regional architectures as fundamental to the development of a new generation of strategic plans. This thesis will focus on the "regional architecture" component of the framework. It will argue that (a) developing a regional architecture constitutes good transportation planning practice, and (b) regional architectures can serve as an important output of the strategic planning process.

1.4. Overview and Structure of Thesis

As Section 1.1 mentioned, this thesis is aimed at providing transportation planners with a framework for addressing some of the institutional issues related to the provision of transportation services. This framework is a regional architecture, and as the previous section mentioned, it represents a new output of the transportation planning process. Its purpose is to describe how institutions should interact with one another in support of
the provision of transportation services. Its goal is to support the operation and management of the transportation system at a regional scale.

The need for the development of a regional architecture is motivated by the following four principles:

1. Transportation activity is inherently regional in nature. That is, certain areas experience greater transportation activity than others, and these areas do not readily conform to political jurisdictions. Therefore, transportation planning is done most effectively at the regional level.

2. The goal of transportation planning should be the development of a regional transportation system which, from the user’s perspective, functions as a coherent and unified entity. A regional transportation system consists of two core elements—transportation infrastructure and transportation services.

3. The transportation services of a particular region are typically provided by a wide variety of institutions. The quality of these services can be improved if the institutions that provide these services agree to share information and, if necessary, control.

4. Recent advances in information technology have provided regions with the ability to manage transportation on a regional scale. The effective deployment of these technologies can enable transportation services to be implemented in a mutually supporting manner.

A regional architecture is a planning document that is responsive to these three principles. It is regional in scope; it supports the provision of transportation services; it describes institutional relationships; and it supports the effective deployment of transportation technology. A regional architecture is unique in that it broadens the view of transportation planning, requiring planners to examine the underlying “institutional infrastructure” that owns, operates, and maintains the more visible physical infrastructure. In short, although it is a relatively new addition to the planning process, a regional architecture addresses some of the fundamental requirements of an efficient transportation system.
• The first objective was to define the term “regional architecture”. This was the subject of Chapters 2, through 4, as well as the first three sections of Chapter 5.
• The second objective was to describe and illustrate a procedure by which a region could construct a regional architecture. This was the subject of Section 5.4 and Chapter 6.
• The third objective was to describe how a region might integrate regional architectures into the strategic transportation planning process. This was the subject of Chapter 7.

This thesis intends to achieve three basic goals. The first goal is to define the term “regional architecture”. The thesis will describe some of the important functions of a regional architecture, and it will illustrate what a regional architecture might actually look like. The second goal is to describe an approach for constructing a regional architecture. This thesis will pursue this goal by (a) presenting an illustrative three-city region that wishes to deploy a set of services, and (b) constructing a sample regional architecture. The third goal is to describe regional architectures might be integrated into the transportation planning process. The thesis will propose a new framework for strategic transportation planning, and it will propose a role for regional architectures to play within that framework.

The thesis will proceed in the following manner:
• **Chapter 2** will begin the thesis by analyzing the term “architecture”. It will trace the usage of the term, from its origin in the construction domain to its usage in computer systems realm to its adoption by the world of transportation.
• **Chapter 3** will analyze the term “regional” as it relates to “regional economies”. The premise underlying this chapter is that transportation planning should be conducted on the same geographic scale as economic activity. The chapter will consist of basically two parts. The first part will summarize the key characteristics of a region as discussed by four key contributors to “regional thought”. The second part will review some of the major “regional designations” currently employed by the Federal government.
• **Chapter 4** will review the National ITS System Architecture’s treatment of regional architectures.¹ This chapter will perform three basic functions. First, it will summarize the National Architecture’s proposed definition of a regional architecture. Second, it will review and examine two examples of regional architectures presented in the National Architecture document. Finally, this chapter will critique the National Architecture’s treatment of regional architectures.

• **Chapter 5** will propose a definition for a “regional architecture”. In doing so, this chapter will build on the foundation laid by Chapters 2 and 3, and it will extend the ideas presented by the National Architecture as summarized in Chapter 4. Most of this chapter will be devoted to an illustrative example, in which a regional architecture will be constructed for a fictitious three-city metropolitan region.

• **Chapter 6** will take a critical look at the regional architecture development process proposed in Chapter 5. It will examine some of the implications of the proposed process, and it will suggest some ways for dealing with practical problems that may arise during the process of developing a regional architecture.

• **Chapter 7** will take a step back and examine how regional architectures fit into the broader transportation planning process. This chapter will pursue two basic objectives. First, it will provide a conceptual structure for strategic transportation planning, explaining the role that regional architectures play within this structure. Second, it will discuss how the regional architecture concept addresses some of the observed shortcomings in strategic transportation planning.

• **Chapter 8** will summarize the thesis, identify the key contributions of the thesis, and suggest some areas for future research.

• **Appendix A** will conclude the thesis by providing an overview of some of the more technical aspects of the National Architecture. It will also address an important question—How much do transportation planners really need to know about the National Architecture?

• Finally, **Appendix B** will discuss some principles that can help answer another question—What does it mean for a regional architecture to be “consistent” with the National Architecture?

¹ This paper will routinely use the term “National Architecture” as shorthand for “National ITS System Architecture”.
Ultimately, the goal of this thesis is to advance the state-of-the-art in strategic transportation planning. It endeavors to do so by introducing a new element into the strategic planning process—the development of a regional architecture. The balance of this thesis is committed to this objective.
Chapter 2
Defining “architecture”

One of the difficulties in arriving at a definition for “regional architecture” is the fact that the term means different things to different people. For example:

- To a “real” architect, the term refers to the style of buildings that characterize a particular geographic area. New England, for example, might be said to have an English colonial “regional architecture”, reflecting the area’s European heritage.

- To a defense contractor, the term “architecture” refers to the manner in which components of complex defense systems interact. The use of the term “regional”, however, is confusing.

- To a computer scientist, the term “architecture” refers to the allocation of computer processing power among various computer systems. His view of the term “architecture” is much different than that of the “real” architect, and—like the defense contractor—he is also confused by the term “regional.”

- The term may be a little more familiar to the systems engineer, who recognizes the need for an architecture to guide the deployment of complex systems. However, his concept of the term “architecture” has a very technical orientation, and his concept of the term “regional” is foggy.

- Finally, to the transportation planner, the term “regional architecture” is quite mystifying. The planner may be familiar with “regional development,” and he may be familiar with the concept of “regionalism” as it applies to economic activity that crosses multiple jurisdictions. However, the term “architecture” is quite foreign. It seems to imply something technical in nature, which the planner might not be accustomed to dealing with.

The purpose of this chapter is to sort through the various notions of architecture. It will look at how the term “architecture” has evolved over the years, from its original construction context, to its use in the world of computer systems, to its adoption by the transportation community. This chapter will highlight the ways in which the usage of the
term has changed, as well as the ways in which it has been consistent. The ideas established here will serve as a foundation upon which further notions of "regional architecture" will be built.

The chapter will proceed in the following manner:

- **Section 2.1** will begin the chapter by briefly summarizing the origin of the term "architecture".
- **Section 2.2** will describe how the term "architecture" came to be applied in the realm of computer science. This section will introduce the term "system architecture", defining it and describing its basic components.
- **Section 2.3** will review how the "architecture" concept came to be adopted by the transportation world. This section will introduce the reader to the fundamentals of Intelligent Transportation Systems (ITS), and it will provide a brief overview of the National ITS System Architecture.
- **Section 2.4** will compare and contrast computer architectures and ITS architectures. This section will highlight the important role that institutions must play in the deployment of an ITS architecture.
- Finally, **Section 2.5** will summarize the efforts of the National Architecture to integrate institutions into the general framework.

### 2.1. The Origin of "Architecture"

The term "architect", derived from the Greek word *architekton*, first appeared in the English language around 1563.² The prefix *arch* meant "chief" or "principal", while the root word *tekton* meant "builder." Therefore, the original meaning of the word "architect" was "chief builder" or "master craftsman." The term "architecture," therefore, referred to characteristics of the work done by the chief builders of civil structures.

It is interesting to note that, though people had been constructing buildings and monuments since ancient times, the word to describe such builders did not arise (at least in

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the English language) until the 16th century. It appears that the emergence of the term “architect” reflected a renaissance idea that reason could be applied on a large scale. Many of the earliest uses of the word refer to God. As scientific understanding grew during the Renaissance period, it was accompanied by an appreciation and awareness of the orderliness of the universe. This sense of order manifested itself in the ascribing to God of a new title: “the original architect.”

Thus, although the word “architecture” had its etymological origin in construction, its fundamental meaning resided in a notion of coherency and order on a large scale. By identifying the underlying architecture, one could learn to understand and appreciate complex structures and systems. From its origin, people used “architecture” to identify the unifying form or structure in both historical buildings (built by human architects) and nature (built by a divine architect).

2.2. “Architectures” and computer science

The 1960’s witnessed the genesis of the development of the modern digital computer. The early designers of computer systems recognized the need for an underlying structure to govern the operations of these complex new machines. Thus, they adopted the architecture concept and integrated it into the computer science lexicon.

2.2.1. A Brief Definition of Computer Architecture

In computer science, “architecture” is a very general term referring to the structure of all or part of a computer system. In fact, the 1997 edition of Webster’s dictionary has inserted this additional definition for “architecture”: “the manner in which components of a computer system are organized and integrated.” Broadly speaking, a computer architecture identifies (a) the major components of the system; (b) the roles of the various components and the locations of major processing capabilities; and (c) the method by which information will be distributed throughout the system.

\(^3\) Hine, Thomas, as quoted in *The Academic Press Dictionary of Science and Technology.*

A typical PC can be used to illustrate this use of the term “computer architecture”:

(a) The major components of a personal computer are: (1) the central processing unit (CPU); (2) the memory (both main memory and video memory); (3) various input devices (such as a keyboard, a mouse, a floppy drive, and a hard drive); and (4) various output devices (such as a screen or a printer).

(b) In the typical personal computer architecture, all processing capability is centralized in one place—the CPU. The rest of the components either send information to or receive information from the CPU.

(c) All components are connected to one another by a set of wires referred to as a bus.

A simplified schematic of a PC Architecture is depicted in Figure 2-1.

![A Simplified Modern PC Architecture](image)

Figure 2-1: A Simplified Modern PC Architecture

It is important to note that a computer architecture does not specify the technology that is contained in the system. For example, a PC architecture will not specify the speed of the processor, the amount of RAM, or the size of the hard drive. These are computer

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5 Dellarocas, Chris. Lecture Notes for Information Technology I, Lecture 3. (http://web.mit.edu/15.564/www/slides/nlec03.ppt)
design considerations, not computer architecture considerations. In other words, a computer design is a specific functional form of a computer architecture. The architecture describes the framework around which the various components of the system operate, while the design prescribes the specific technological capabilities of each component. A single architecture can manifest itself in many different designs.⁶

2.2.2. Architectures that govern multiple systems

As telecommunications technologies progressed, individual computer systems were routinely linked together via some communication medium. This linkage had three important impacts.

- First, it allowed the sharing of information. Data that previously had to be hand-carried between computers could now be distributed virtually instantaneously.
- Second, it allowed the sharing of resources. Multiple computers could now access a common printer, plotter, or scanner.
- Third, it allowed the sharing of control. Multiple computers could now collaborate to perform services that were formerly performed by a single computer.

A major implication of this development was the need to develop a higher-level architecture—a system architecture—to govern the interactions among various computer systems. The purpose of the system architecture would be to coordinate the actions of multiple computers. This coordination would enable the computers to function as a “system of systems,” unified in purpose and coherent in operation.

The major elements of a system architecture are essentially the same as those of the PC architecture noted earlier. That is, a system architecture must identify (a) the primary systems involved in providing a particular service; (b) the major functions that each system will perform; and (c) the way in which information will be communicated through the network.

An ATM machine provides an illustration of this higher-level system architecture. In simplified terms, the system architecture for an ATM could be described as follows.\footnote{Two notes are in order for this illustration. First, in reality, a single ATM can communicate with several different banks. This example assumes that each bank will have its own ATM machines, with no interaction with other banks. Secondly, this example assumes that the only type of transaction that occurs at the ATM machine is a cash withdrawal.}

(a) The major components of the network are the ATM machine itself, the bank’s central computer, and a wire line that connects the components.

(b) Very little processing takes place at the ATM machine. This system simply gathers information, forwards it to the bank, and receives instructions from the bank. The major processing capability takes place at the central computer, which verifies the password, processes the transaction, posts the transaction to the account, and directs the appropriate response to the ATM machine.

(c) The two components are linked together directly. A bank’s network of ATM machines is configured like a “star,” with multiple remote machines each directly linked to the central computer. Figure 2-2 depicts a star network configuration.

\begin{center}
\begin{tikzpicture}
  \node[draw, circle, thick] (atm1) at (0,0) {ATM};
  \node[draw, circle, thick] (atm2) at (2,0) {ATM};
  \node[draw, circle, thick] (atm3) at (0,-2) {ATM};
  \node[draw, circle, thick] (atm4) at (2,-2) {ATM};
  \node[draw, circle, thick] (central) at (0,-1) {Central Computer};
  \draw[->] (atm1) -- (central);
  \draw[->] (atm2) -- (central);
  \draw[->] (atm3) -- (central);
  \draw[->] (atm4) -- (central);
\end{tikzpicture}
\end{center}

\textbf{Figure 2-2: Star Network Configuration}

The ATM system is an example of a \textit{client/server architecture}. This type of system architecture splits functionality into two pieces. The client, generally speaking, is the sys-
tem with which the user interacts. The responsibility of the client is to receive and forward requests to the server for access to the network's resources. In this case, the client is the ATM machine, and the requested resource is access to account funds. The server is usually the more powerful of the two computers, and it is typically located at a remote location. The responsibility of the server is to respond to requests and, as appropriate, provide the clients with access to network resources.⁸

A simplified ATM client/server architecture is depicted in Figure 2-3:

![Figure 2-3: Simplified ATM Architecture](image)

Several points are worth noting from the ATM architecture in Figure 2-3:

- A system architecture supports a particular service. In Figure 2-3, the service was processing a transaction and dispensing money to a customer.
- A major component of a system architecture is the identification of the information that must flow between the subsystems.
- Compatibility and interoperability are important issues with system architectures. For example, the information that the ATM machine forwards to the central computer must be in a format that the central computer can understand and process.
- Users are not considered to be "inside" the architecture, although the information that they provide is part of the architecture.

• A system architecture does not specify technologies, nor does it specify communications media. However, architectural decisions will shape these choices. In the ATM architecture, the fact that very little processing takes place within the ATM machine will mean that the machine will not require a very sophisticated computer.

• Furthermore, the availability of technology can shape architectural decisions. As computer processors become cheaper and transmission media become faster, it is possible that the ATM's of the future will contain more functionality.

2.2.3. A look at alternate configurations

One way to develop a better understanding of the architecture concept is to consider alternate configurations that could achieve the same result. For example, a number of different architectures could be used in order to process a withdrawal request. Two such possibilities are detailed below:

• One alternative would be for each ATM machine to store each customer's password in its memory. Each ATM machine would then verify the customer's password on the spot, refusing to forward any invalid requests to the central computer. This alternative would retain the client/server orientation of the architecture, but it would push more functionality out to the client.

An advantage of this configuration would be that it would decrease the demands on the central computer. It would no longer need to verify passwords, and it would process fewer requests. One disadvantage would be that it would require a significant amount of additional memory to be placed within each ATM machine; this could be a costly change. Furthermore, if a customer changed his password, the change would need to be immediately distributed to every ATM machine within the bank’s network.

• A second architecture alternative would be to eliminate the central computer altogether. In its place would be a fully functional computer at each ATM machine, with each machine possessing the account information formerly stored in the central
computer. When a user made a withdrawal, the entire transaction would be handled locally.

The main advantage of such an architecture would be that it would speed up each transaction. All processing would occur at one computer, and no information would need to travel over a wireline. However, this architecture has two major disadvantages. First, it would be much more expensive to implement, given that it would require several powerful distributed computers rather than one powerful centralized computer. And second, it would be more difficult to control, given that a change in account information at one computer would need to be immediately distributed to all other computers within the network.

2.2.4. Architectures and Communication Networks

An interesting aspect of this second alternative is its implications on the communication network. If a bank were to switch its method of ATM operations and adopt this second alternative, it would need to radically alter its communications network. Instead of the star network noted in Figure 2-2, it would likely need to switch to an alternate configuration.

Two possibilities for alternate configurations are noted in Figure 2-4:

![Figure 2-4: Possible Network Configurations for ATM Architecture](image)
These two alternate configurations each have a different set of advantages and disadvantages. The primary advantage of the ring configuration is its cost. Because all machines are linked to a common medium, the amount of communication line needed to support the architecture is minimal. However, the speed of communications between any two machines would be slower in the ring configuration would be smaller. This is because of possible “network congestion” that results as simultaneous transmissions between various machines throughout the network vie for limited communications capacity.

The star network, by contrast, requires a dedicated line between each machine. This would tend to drive up the cost of constructing the network. However, the speed of transmitting information between any two machines would be much faster, since simultaneous transactions between other computers would not interfere.

The main point of this discussion is that architecture decisions impact both technological requirements and communications requirements. When one makes a decision regarding how to deploy technological systems, one must also think about the tradeoffs involved in determining how the various systems will interact with one another.

2.2.5. Summary

The following points summarize the discussion of computer architectures:

- “Architecture” is a term that originally implied the presence of order in the midst of complexity. The adoption of the term by the computer industry follows naturally from its original usage. Recognizing the inherent complexity of computer systems, the system designers sought to impose a coherent, underlying structure that would govern computer operations. The framework that provided this structure was the “computer architecture.”
- In the computer realm, the term “architecture” can be applied in multiple contexts. At one level of detail, “architecture” refers to how individual elements interact in order to
function as a single system. At a higher (i.e. less detailed) level, it describes how multiple systems interact in order to function as a coherent “system of systems.” An architecture that is applied at this level is referred to as a “system architecture.”

- A system architecture exists in order to provide a service (or set of services) to a user.
- Broadly speaking, a system architecture is composed of two physical elements: individual subsystems, and communication lines that link the subsystems together.
- The information that these subsystems exchange with one another is also a part of the architecture.
- Because information is passed between different subsystems, compatibility is a big issue with architectures. Although an architecture will not specify a set of compatible technologies that a system design should adopt, it will nevertheless highlight the major areas of operations in which compatibility will be an issue.
- Technology and architecture alternatives are closely related. The range of feasible architecture choices available to the designer is constrained by the availability (and cost) of technology.
- A system architecture is defined purely in “technical” terms. Although people interact with and use the systems, the people are considered “external” to the architecture.
- Tradeoffs are a fundamental part of making architectural choices. In general, an architecture that is designed to provide greater service to the customer will be more costly, both in terms of its technological requirements and in terms of its communications requirements.

With the advent of Intelligent Transportation Systems, the architecture concept expanded into the transportation world. The next section will describe how the definition of “architecture” has expanded still further in this new context.
2.3. Architectures and the World of Transportation

2.3.1. Background

In 1986, a group of academics, federal and state transportation officials, and representatives of the private sector began to meet informally in order to discuss the future of surface transportation in the United States. There were three basic motivations for these meetings.

- First, the group recognized that, in 1991, a new federal transportation bill was going to be enacted. This bill would be unique in that it would be the first major transportation legislation in the post-Interstate era. In previous years, transportation vision had been driven by the goal of completing the $130 billion Interstate System. Now, a new vision would need to take its place.

- Second, the group recognized that several transportation problems remained despite the presence of the Interstate System. For example, rush-hour traffic congestion continued to mount, and the number of highway fatalities stubbornly refused to drop. It seemed that the ability to “build one’s way out of congestion” had reached its limits. Moreover, the lengthening of commuting times also represented a loss of economic productivity—a dangerous phenomenon in an increasingly competitive global marketplace.

- Third, the group noted growing societal concerns with environmental and energy issues. The combination of increasing numbers of automobiles and increasingly congested roads translated not only into longer commutes, but also into growing volumes of emissions and environmental pollution.

- Finally, the group noted that many of America’s economic competitors in Western Europe and Japan were developing various technologies designed to enhance their posture and productivity. Many of these technologies had direct application to the field of transportation.9

This informal group not only foresaw a challenge, but also an opportunity. Their vision was one in which transportation problems were dealt with through the application of in-

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formation technology to infrastructure. The group identified four basic technological innovations that had the potential to dramatically improve the performance of the transportation system. These innovations, which subsequently became known as the “ITS-4” technologies, were:

(a) The ability to *sense* the presence and identity of vehicles in real time through roadside equipment;
(b) The ability to *communicate* large amounts of information quickly, cheaply, and reliably;
(c) The ability to *process* large amounts of information; and
(d) The ability to use this information in real time to manage the transportation network.\(^10\)

This notion of applying technology to transportation on a national scale had three dramatic effects. First, it provided a new vision for transportation, a vision that could potentially fill the void left by the nearly completed Interstate System. Second, it presented a viable alternative to new construction and the negative environmental impacts that often accompany it. And third, it presented a huge potential market in which US industries could compete. The group noted that the international market for these technologies could well possibly be in excess of $1 trillion over a 20-year period.\(^11\)

Of course, the idea of applying technology to transportation was not exactly new. Street crossing signals were in use in London in 1868, nearly 20 years before Daimler and Benz rolled out the first gasoline-powered automobile called the “Benz Patent Motorwagen”. In 1912, the first traffic control tower was constructed, in which a centrally located policewoman manually changed traffic signals at a busy intersection in Paris. Later that same year, Lester Wire installed the first modern-style traffic signals in Salt Lake City. Five years later, “intelligent transportation” had its true genesis, as six of these signals were linked together in order to provide signal coordination for traffic travelling at 20 miles per hour.\(^12\)

\(^{10}\) Ibid. 116.
\(^{11}\) Ibid. 117.
However, in one respect, these older technological applications were fundamentally different from what this informal group envisioned in 1986. The name that was given to the series of technologies that comprised the new vision—Intelligent Vehicle-Highway Systems—reflected this difference. These transportation professionals envisioned a whole new concept, in which vehicles and infrastructure functioned together as a coherent system. The notion of using computers, communications, and sensors to link the previously independent vehicle and infrastructure components of surface transportation was an insightful breakthrough.\textsuperscript{13} Although the name was later changed to Intelligent Transportation Systems (ITS) in order to reflect a broader set of transportation interests (such as transit and rail transport), the basic idea of linking vehicles and infrastructure remained.

It was at this point that the “architecture” concept became relevant to the world of transportation. Just as a computer architecture was needed to govern the interactions between multiple computer systems, so would an ITS architecture be needed to govern the interactions between vehicle and infrastructure systems.

\subsection{2.3.2. ITS Architectures: A natural progression from computer architectures}

An electronic toll collection scheme can serve as an illustrative example of the need for an ITS architecture. Consider a situation in which a turnpike authority would like to implement an electronic toll collection system. Because of the complexity of such an enterprise, the authority would need to develop a system architecture that would outline the roles and responsibilities of each component of the system. Following the “computer architecture” framework that was established in the previous section, one could describe an architecture for electronic toll collection as follows:

(a) There are three major systems involved in this transaction: (1) the vehicles which travel on the turnpike; (2) the roadside infrastructure (i.e. tollbooth) that detects and identifies the vehicles; and (3) the central facility that processes all the toll transac-

tions. (In order to clarify terminology, these systems will be referred to as “subsystems.” The collection of the three subsystems will be referred to as the “toll collection system.”)

(b) Each subsystem would play a different role. The vehicle subsystem would simply need to supply some sort of identification. The roadside infrastructure would need to detect the vehicle as it enters and exits the toll highway network, and it would need to pass on this information to a control center. The control center (which would perhaps be located at the turnpike authority’s headquarters) would record the transaction and process the tolls.

(c) The system would have two basic communication requirements. The first requirement would be a wireless link between the vehicle system and the tollbooth. The second would be a communication line running between the tollbooth and the control center.

Of course, the level of detail in this description would not be adequate to support a full-fledged electronic toll collection system. Nevertheless, it illustrates how ITS architectures followed naturally from computer architectures. Both perform the same tasks: they identify the major subsystems, they assign roles to the subsystems, and they identify the communication links that must be in place in order for the system to function. Additionally, both identify the types of information that must be exchanged over these communication links, and both exist in order to provide services to a user.

2.3.3. An additional level of complexity

In the example above, the architecture was designed to provide only one service: electronic toll collection. However, the vision for ITS was not simply a series of independent, technology-driven services. Rather, the founders of ITS envisioned a national system in which multiple user services were interwoven. This adds another level of complexity to the architecture concept. It requires an architecture in which numerous “systems of systems” interact in order to create a coherent and unified “intelligent transportation system.”
To illustrate the importance of such an architecture, consider again the electronic toll collection (or ETC) example. The turnpike authority that deploys the ETC system has a wealth of knowledge at its fingertips. First of all, it knows how many vehicles have passed through its tollbooths over a given period of time. This would be of great interest to transportation planners, who could use the information to help determine where to make future investments. Second, it knows how long it takes vehicles to pass through its system. This would be of interest to any agency (such as a radio station) that provides traffic information, since it gives an indication of average speeds on the highway at a given point in time. Moreover, if the authority noticed a sudden decrease in average speeds, then it would have an indication that an incident of some type had occurred. This information would be of interest to the state police, emergency rescue teams, and any other agencies that share responsibility for clearing highway incidents.

Thus, one can see how information from one ITS service could provide important information in support of other services. This sort of information exchange, however, is much more complex than the simple exchange of information between individual systems. Before, individual systems shared information in support of a service; now, individual services must share information in support of the transportation system as a whole.

2.3.4. The development of the National System Architecture

The need to govern this complex exchange of information was noted in the 1992 Strategic Plan for Intelligent Vehicle-Highway Systems. The Plan noted that:

Effective integration of the various components of IVHS requires a system architecture – its design will take time and must draw from multiple disciplines. It must be an open architecture, able to accommodate different system implementations in diverse settings.\(^{14}\)

The effort to construct a national system architecture got underway in 1993. After three years of effort and more than 50 stakeholder meetings, briefings, and workshops, the

\(^{14}\) Strategic Plan for Intelligent Vehicle-Highway Systems, Executive Summary, pg. 18.
effort was largely completed by June of 1996.\textsuperscript{15} The National Architecture (or NA) was the fruit of a joint effort of Loral Federal Systems (now Lockheed Martin) and Rockwell International, and was comprised of 16 documents totaling over 5500 pages.\textsuperscript{16}

The \textit{Mission Definition} document provided the most concise definition of the term, stating that “The [National] ITS Architecture is the framework of interconnected subsystems which together provide the ITS user services through allocated functionality and defined interfaces.”\textsuperscript{17} Five important aspects of this definition are worth noting.

- First of all, the architecture is a \textit{framework}. It describes how the system should operate in general terms, with specific technology decisions being left up to the system designer.
- Second, the architecture exists for the purpose of providing \textit{services} to users.
- Third, the architecture involves the assignment of \textit{functionality} to various components of the system.
- Fourth, the architecture is comprised of \textit{subsystems}. Each subsystem is assigned some functionality, and each has a role to play in providing the set of user services.
- Fifth, the architecture identifies the \textit{communication links} that must be present in order to connect the various subsystems.

All of these aspects are consistent with the characteristics discussed in the section on computer architectures. The primary differences lie in the number of different subsystems involved and in the number and variety of different user services supported.

\textit{The last four characteristics—user services, functionality, subsystems, and communication links—will now be discussed in more detail.}

\textsuperscript{16} See "National Architecture Documents", an overview of the NA available from the USDOT’s web site (http://www.its.dot.gov/architecture/DOCUMNTS.html)
\textsuperscript{17} National ITS System Architecture, Mission Definition. Executive Summary, pg. 1.
2.3.4.1 **User services.**

The designers of the NA came up with a set of 30 user services that the architecture would be required to support. These services were subsequently divided into six different “user service bundles,” as indicated in Figure 2-5 below. The designers of the NA used extensive public outreach to develop these user services, and they considered them to be the foundation of the Architecture Development effort. However, they also noted that the list of services was neither exhaustive nor final. The developers realized that the Architecture would need to be a living document, expanding in scope as the demand for new services arose.

<table>
<thead>
<tr>
<th>TRAVEL AND TRANSPORTATION MANAGEMENT</th>
<th>COMMERCIAL VEHICLE OPERATIONS</th>
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<tbody>
<tr>
<td>• En-Route Driver Information</td>
<td>• Commercial Vehicle Electronic Clearance</td>
</tr>
<tr>
<td>• Route Guidance</td>
<td>• Automated Roadside Safety Inspection</td>
</tr>
<tr>
<td>• Traveler Services Information</td>
<td>• On-board Safety Monitoring</td>
</tr>
<tr>
<td>• Traffic Control</td>
<td>• Commercial Vehicle Administration Processes</td>
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<tr>
<td>• Incident Management</td>
<td>• Hazardous Materials Incident Response</td>
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<tr>
<td>• Emissions Testing and Mitigation</td>
<td>• Freight Mobility</td>
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<td>• Demand Management and Operations</td>
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<tr>
<td>• Pre-trip Travel Information</td>
<td><strong>EMERGENCY MANAGEMENT</strong></td>
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<tr>
<td>• Ride Matching and Reservation</td>
<td>• Emergency Notification and Personal Security</td>
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<td>• Highway-Rail Intersection</td>
<td>• Emergency Vehicle Management</td>
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<tr>
<td><strong>PUBLIC TRANSPORTATION OPERATIONS</strong></td>
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<tr>
<td>• Public Transportation Management</td>
<td><strong>ADVANCED VEHICLE CONTROL &amp; SAFETY SYSTEMS</strong></td>
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<td>• En-Route Transit Information</td>
<td>• Longitudinal Collision Avoidance</td>
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<td>• Personalized Public Transit</td>
<td>• Lateral Collision Avoidance</td>
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<td>• Public Travel Security</td>
<td>• Intersection Collision Avoidance</td>
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<tr>
<td><strong>ELECTRONIC PAYMENT</strong></td>
<td>• Vision Enhancement for Crash Avoidance</td>
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<td>• Electronic Payment Services</td>
<td>• Safety Readiness</td>
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<td>• Pre-crash Restraint Deployment</td>
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<td>• Automated Highway System</td>
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Figure 2-5: User Services Supported by National Architecture

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19 ITS Architecture Executive Summary, pg. 2.
2.3.4.2 **Functionality.**

After selecting the set of user services outlined above, the National Architecture’s designers defined all of the functions that ITS would need to perform in order to execute these services. These functions, as well as the data flows that supported them, were mapped out graphically. This process resulted in what the designers termed the *Logical Architecture*. A simplified, high level logical architecture is depicted in Figure 2-6. Each user service is supported by a designated set of “functions”. The circles in Figure 2-6 represent these functions. The boxes represent external entities that are supported by the various functions, and the arrows represent data flows. The functions in this figure are broken out in further detail on subsequent diagrams in the National Architecture document.

![Simplified Top Level Logical Architecture](image)

**Figure 2-6: Simplified Top Level Logical Architecture**

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20 Extracted from *ITS Architecture Executive Summary*, pg. 4.
2.3.4.3 Subsystems.

Once the designers identified all of the functions that were required to support the user services, they began to translate the functions into the physical ITS entities that would be responsible for carrying them out. This was essentially a three-step process.

- First, the functions were mapped into physical entities termed equipment packages. This mapping translated the abstract functions into a physical set of equipment that one could actually purchase.\(^{21}\) In all, the NA identified 111 different equipment packages that would be needed in order to perform all of the functions identified in the Logical Architecture.

- Second, each equipment package was grouped into one of 19 different subsystems. The names of these subsystems correspond loosely with the various transportation entities that one encounters in real applications, such as “Traffic Management” or “Commercial Vehicle.”

- Finally, the subsystems were grouped into four distinct classes, or systems, that shared basic functional, deployment, and institutional characteristics.\(^{22}\) The four systems identified by the NA were Traveler, Center, Roadside, and Vehicle.

Figure 2-7 identifies the 19 subsystems and their corresponding systems. To illustrate this diagram, consider the electronic toll collection scheme discussed in section 2.3.3. This scheme involved three different subsystems, each of which was part of a different system. The automobile would, of course, be considered a vehicle subsystem, which in turn is part of the vehicle system. The tollbooth would be considered a toll collection subsystem, which in turn constitutes part of the roadside system. Finally, the turnpike authority’s central office would be considered a toll administration subsystem, which is part of the center system.

\(^{22}\) National ITS Architecture, Physical Architecture, pg. 2.3-20.
2.3.4.4 Communication Links

Finally, after identifying (a) the user services that the architecture needed to support; (b) the functions that supported these services; and (c) the subsystems that would perform these functions, the NA described the types of communication links that would be needed in order to connect the subsystems. Five basic media types were selected in order to support the Architecture’s communication requirements:

(a) Wide-area broadcast, such as that provided to a radio receiver in an automobile. This is a fixed-to-mobile communication medium.

(b) Wide-area two-way wireless, which—in contrast to a radio—permits interaction between two entities. This is also a fixed-to-mobile medium; a cellular phone provides an example of this mode of communication.

(c) Dedicated short-range communication (DSRC), such as the wireless vehicle toll tags alluded to in the ETC example. This is another example of fixed-to-mobile communications.

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23 Extracted from *ITS Architecture Executive Summary*, pg. 6.
(d) Vehicle-to-vehicle communication, which, while not yet fully developed, should provide some collision avoidance and route guidance capabilities in the future. This is an example of a *mobile-to-mobile* communication medium.

(e) Wireline communication, such as a common phone line. This is a *fixed-to-fixed* communication medium.  

Figure 2-8 illustrates how these communication links interact with the physical subsystems. It is important to note that the Architecture does not specify communication design (i.e. “FM radio link” or “digital PCS”). Rather, it simply highlights the *types* of communication media that should be used to connect any two subsystems.

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**Figure 2-8: ITS Architecture Subsystems and Communication Links**

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Figure 2-8 is known in the National Architecture document as the “Physical Architecture”. The Physical Architecture will be explained in more detail in Section 2.5.

2.4. Comparison: Computer Architecture vs. ITS Architecture

As the discussion in the previous discussion illustrates, many of the principles of defining a computer system architecture also apply to the definition of an ITS Architecture. For example, both involve identifying major components of the system, assigning roles and responsibilities to each component, and linking the components together by some communication medium. Moreover, computer architectures and ITS architectures both exist in order to support a set of user services.

Given these similarities, one can understand why the advent of ITS introduced the transportation community to the architecture concept. However, the National Architecture not only applies the concept of computer system architectures; it is also extends the concept. This section will discuss three of the ways in which the NA “pushes the envelope” of traditional system architectures.

2.4.1. The National Architecture involves more complex interactions among subsystems.

This characteristic was the subject of discussion in section 2.3.3. At one level, an ITS architecture functions identically to a computer architecture. For example, just as the “ATM architecture” coordinates multiple systems (an ATM machine and a central computer), so does an “electronic toll collection architecture” coordinate multiple systems (a vehicle toll tag, a roadside tollbooth, and an administrative control center). In both cases, the coordinated systems are designed to perform a coherent service to the user.

However, the National Architecture (of which the “electronic toll collection architecture” is a part) takes this a step further. It also coordinates interactions among multiple services. For example, the subsystems that perform the electronic toll collection service could also provide traffic information to an information service provider, as well as incident information to an emergency management center. In other words, the National Ar-
architecture attempts to also unite the various user services in order to facilitate the development of a “national transportation system.” This is a much broader objective than most computer architectures are designed to support.

2.4.2. **Compatibility is a more critical issue with the ITS architecture.**

Section 2.2.5 noted the importance of compatibility with respect to computer architectures. Any time that different computer systems exchange information, one must ensure that the information is transmitted in a form that both systems can understand.

However, the compatibility and interoperability issue is much greater in the realm of ITS. There are at least three reasons for this.

(a) The scope of user services involved in the NA is much broader, as is the quantity of subsystems needed in order to deliver these services. With 111 different “equipment packages” (see Section 2.3.4.3) sharing information with one another, the possibilities for system incompatibility are very high. The architecture thus plays an important role in identifying the many different communication links over which compatibility may be a problem.

(b) The National Architecture routinely calls for the integration of public and private systems. For example, integrating an ETC scheme into the broader transportation system would require the turnpike authority (a quasi-public entity) to distribute information to both public entities (such as the State Police) and private entities (such as a radio station providing traffic information). Given that public and private systems are typically developed independently, compatibility can be difficult to achieve. This type of problem is much less predominant in the computer industry, since the system architects tend to be very closely tied to the system designers.

(c) Institutions play a much more prominent role in the deployment of the National Architecture. Often, the *technological* problems involved in distributing information among disparate systems pale in comparison to the *institutional* problems. The example above noted the need for public and private systems to be able to exchange information. However, this is only part of the “compatibility” problem. Before such technological issues can be addressed, these public and private agencies must first
agree to share the information. Coming to such cooperative agreements can be a significant challenge.

2.4.3. Issues of control are more complex with the ITS architecture

Many of the user services supported by the National Architecture require planners to make difficult decisions about matters of control. For example, consider some of the questions that would arise surrounding the deployment of a metropolitan-wide traffic control system.

- Should each city and town make its own decisions about traffic control, or should one central traffic control authority make all decisions on a metropolitan-wide basis?
- If a central traffic authority makes the decisions, should individual jurisdictions have the right to override them?
- Who should comprise the central authority? Should it be operated by the state? Or by the largest single city in the metropolitan area? Or by a coalition of representatives from each jurisdiction in the metropolitan area?
- To what extent would the central authority exercise its power? All the time, or only during emergencies?

Computer system architectures also deal with issues of distributed versus centralized control. However, these issues are usually dealt with by a single institution, and the primary issues are operational efficiency and system cost. This is not the case with ITS. Although efficiency and cost are important considerations, perhaps the most important factor is institutional cooperation. When an ITS deployment involves multiple institutions, everyone must come to agreement concerning how decisions will be made. This adds considerable complexity to the process of architecture development.

2.5. The National Architecture and the Institutional Challenge

The previous section highlighted the principal point of departure between traditional computer architectures and the National ITS Architecture. That point of departure is in-
institutional involvement in system deployment. This issue, which was virtually non-existent in the computer realm, stands at center stage in the ITS realm. This section will review the method by which the National Architecture integrates institutions into its general framework.

In recognition of the important role that institutions play in the ITS deployments, the designers of the National Architecture introduced the concept of an “institutional layer”. Figure 2-9 depicts, in graphical form, the place that the “institutional layer” assumes in the overarching National Architecture framework.

Figure 2-9: National Architecture Framework and the Institutional Layer

Figure 9 encapsulates the basic structure of the National Architecture. Each of the components of the diagram are explained below:

- The **Logical Architecture** is the portion of the National Architecture that describes the functions that must be performed and the data that must be exchanged in order to provide the 30 ITS user services. A high-level view of the Logical Architecture was presented in Figure 2-6.

- The **Physical Architecture** takes each of the functions defined in the Logical Architecture and assigns them to one of 19 subsystems. Each subsystem performs a
set of related functions. Additionally, the Physical Architecture identifies how these subsystems must communicate with one another in order to perform their assigned functions. A high-level view of the Physical Architecture was depicted in Figure 2-8.

- In order to provide some conceptual clarity to the physical architecture, the designers of the National Architecture further subdivided the Physical Architecture into three "layers": a transportation layer, a communication layer, and an institutional layer.

  - The **transportation layer** is comprised of the 19 functionally defined subsystems, as depicted in Figure 2-7.

  - The **communication layer** is comprised of the 5 different communication media that connect the subsystems to one another, as discussed in Section 2.3.4.4.26

  - The **institutional layer** provides the context in which the other two layers must operate. According to the National Architecture, the role of the institutional layer is to "introduce the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers [i.e. the transportation and communication layers] of the architecture."27 The institutional layer is depicted graphically in Figure 2-10.

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26 The Physical Architecture diagram only explicitly identifies four types of communication media: wide area wireless, wireline, vehicle-to-vehicle, and dedicated short range. However, "wide area wireless" actually includes both one-way and two-way communication. This brings the number of media types to five.

27 National ITS Architecture, Implementation Strategy, pp. 2-1 and 3-1.
To summarize, the National Architecture is actually comprised of two “parallel” architectures—a Logical Architecture and a Physical Architecture. The Physical Architecture consists of two basic elements—a group of 19 functionally defined subsystems (represented by the transportation layer), and a series of communication links that tie the subsystems together (represented by the communication layer). These two elements are funded and deployed within a particular institutional context (represented by the institutional layer). The technical details of the National Architecture are described in more detail in Appendix A to this thesis.

Figure 2-9: The Institutional Layer

As the previous discussion reveals, the National Architecture makes a concerted attempt to give institutions a prominent role within the overall framework. However, this attempt does not fully recognize the important role that institutions play in ITS deployments. The National Architecture appears to come up short on two counts:

- **First**, it does not assign institutions a key role in the day-to-day operation of the ITS services. The document asserts that institutions provide the *context* for the technical layers, but it does not explicitly mention the role of institutions in *operating* the technical layers.

- **Second**, the National Architecture does not explicitly consider the implications that the architecture concept has for institutional relationships. The decision to implement certain services, for example, might require centralized control (see Section 2.4.3). However, the architecture does not say anything about the need for regional institutions to interact in order to make such decisions.

The broader issue at stake here is this: *The National Architecture does not consider how the architecture concept might be used proactively to facilitate institutional change.* As this chapter has demonstrated, the National Architecture calls for the integration of numerous technical systems. However, it does not take the next step and call for the integration of the institutions that operate these systems. In fact, coordination of institutional efforts should be considered a prerequisite for coordination of technical systems.

This is not meant as a criticism of the National Architecture. Rather, it simply highlights the need for a mechanism through which these issues can be addressed. The regional architecture, as defined later on in this thesis, can provide this mechanism.

In summary, this chapter has worked toward defining the latter half of the term “regional architecture”. The ideas presented in this chapter will be developed further in Chapter 5. The next chapter, however, will shift gears and work toward defining the former half
of the term “regional architecture”. It will address one basic question: What is a “region”? 
Chapter 3
Defining “region”

The term “region” enjoys a wide diversity of usage. People talk of the “New England region”, the “Midwest region”, and the “Appalachian region.” One hears about the thriving economy of the “Sun Belt”, the decline of manufacturing in the “Rust Belt”, and the political conservatism of the “Bible Belt”, with “belt” being synonymous with “region”. Travelers complain of chronic congestion in the “New York City region”. National television networks broadcasting football games advertise “regional coverage”. Meteorologists on the Weather Channel warn of hurricanes that will batter the “Southeast region” of the United States. Newscasters provide reports of earthquakes that rattle the “Pacific coast region”.

As these phrases reveal, the term “region” is applied in a wide variety of contexts, from weather to geography to religion to sports to traffic. Moreover, the term covers a wide range of geographic areas, from a metropolitan area to a coastline to a collection of states. This leads to an important question: What do all of these various uses of the term “region” have in common? The answer: They all characterize some event or activity that doesn’t necessarily fit neatly within political borders.

3.1. Political borders versus “regions”

The geography of the United States is typically subdivided into four different sets of political borders—national, state, county, and local (i.e. town or city). These borders are convenient ways of describing political and community activities. For example, one hears of “national drug policies”, of “state fairs”, of “county courthouses”, and of “town meetings”. One votes in national, state, and local elections, and one pays taxes to national, state, and local governments. Every spring, political leaders provide the electorate with “State of the Union”, “State of the State”, and “State of the City” addresses. In
short, many of the activities and events that play a prominent role in American life happen within, and are governed by, political boundaries.

Adding to the prominent role of political borders is the need for national defense. One of the fundamental roles of a national government is to provide for the safety of its citizens. One way to provide this safety is to raise and train armed forces, which are committed to defend the nation's borders from foreign invasion. In this sense, national boundaries serve as a figurative wall of safety, within which citizens can move and act freely, as long as they abide by the laws of the nation.

However, there are a host of other important activities and events that do not fit neatly within the confines of political borders. As the introduction pointed out, neither economic activity nor religious devotion nor athletic competition nor natural disaster conforms very well to political boundaries. In fact, as far as most of these activities are concerned, political borders are purely arbitrary territorial subdivisions. A hurricane pays no heed to state or national boundaries, although certain jurisdictions have a higher risk of being damaged than others. Likewise, religious commitment is not governed by political subdivisions, although certain jurisdictions tend to demonstrate stronger devotion than others.

In other words, many of the activities and events that are part of everyday life are blind to the presence of political boundaries. Although they tend to be clustered geographically, these clusters do not generally conform to political jurisdictions. Thus, an “intermediate” term is needed to describe the geographic scale at which these non-political activities occur. The general-purpose term that is quite frequently used is “regional.”

3.2. Transportation: The Need for a Regional Approach

Economic activity and transportation are intrinsically linked. Manufacturers depend on the transportation system for the delivery of raw materials and the distribution of finished products. Retailers depend on the transportation system for the prompt delivery of their
products. Merchants of all types depend on the transportation system to provide their customers with access to their facilities. And industries of all types depend on the transportation system to provide their employees with a way to work.

One way to view transportation activity is as a mirror of economic activity. For example, high volumes of traffic in a particular area may be a reflection of intense retail activity. Heavy rush-hour traffic volumes may be a reflection of extensive employment in a region. Numerous double-parked delivery trucks in a downtown area may be a reflection of significant commercial activity. Regional traffic congestion that lasts all day, especially during the summer months, may be a reflection of extensive tourist activity. And heavy truck traffic on main arteries may be a reflection of substantial manufacturing activity, as industries receive inputs from other regions and deliver finished products to other regions. In short, heavy usage of the transportation system, both within a region and at the gateways that serve as points of entry into the region, often reflects the presence of extensive regional economic activity.

One could characterize the relationship between transportation and economic activity in the following way: Economic activity relies on the transportation system in order to thrive, and thriving economic activity is reflected in a heavily used transportation system. In fact, the two activities tend to rise and fall together. If manufacturing, employment, and retail activity increase, then traffic (whether it be rail, truck, auto, or transit) will also increase. On the other hand, if these economic activities decline, then transportation activity will also decline.

One inference that can be drawn from this symbiotic relationship between transportation and economic activity is that both activities should be planned and managed on approximately the same geographic scale. Therefore, if one can accurately define the geographic scale at which economic activity occurs, one can simultaneously define the appropriate scale at which transportation planning should occur. The question is—At what level does economic activity occur? Is it concentrated within the boundaries pre-
scribed by political jurisdictions? Or does economic activity happen at a less clearly defined “regional” level?

3.2.1. The Traditional View

Many politicians and economists today tend to suggest that political jurisdictions (or “polities”) and economic systems (or “economies”) coexist geographically. Their view is that the nation is an economic entity, and that national boundaries coincide neatly with political boundaries. The following points illustrate the dominance of this view:

- A single currency is used throughout the entire country;
- Periodic reports from the Federal government attempt to characterize the strength of the “national economy” by citing the national unemployment rate, the national inflation rate, and the Gross Domestic Product;
- The prime rate is controlled at the national level by the Federal Reserve Board;
- Income taxes are debated and implemented nationally;
- The US index of leading economic indicators attempts to predict changes in the overall level of the national economy;
- National political debates rage over the issue of the national economy. During the 1992 presidential campaign, the Democratic Party coined the phrase “It’s the economy, stupid” as a reminder of the importance of addressing the sluggish national economy.

All of these points carry an underlying assumption—that the nation is an economically homogenous entity. Adherents to this view believe that (a) there is such a thing as “a national economy”; and (b) the borders of this economy are aligned with the borders of the nation. This view is deeply embedded in American culture, and it carries with it two important implications.

The first implication is that all political boundaries encompass “economies”. If national boundaries circumscribe a national economy, then it follows that state boundaries must circumscribe a state economy, and local boundaries must circumscribe a local econ-
omy. In other words, the national system of “political federalism” must be accompanied by a parallel economic structure. This implied structure is depicted in Figure 3-1.

![Figure 3-1: Perceived Alignment of Polities and Economies](image)

Figure 3-1 illustrates the prevailing view that political jurisdictions are aligned with economic systems. According to this view, the borders that enclose the “national economy” correspond to the jurisdictional boundaries of the Federal government. Therefore, it is appropriate to give the Federal government the responsibility of developing national economic policy.

The assumption that political and economic borders coincide with one another extends logically to the state and local level. According to this view, state borders circumscribe “state economies”, and local political boundaries circumscribe “local economies”. This perceived alignment of polities and economies is manifested by the presence of economic development departments in many states, and by the crafting of economic devel-

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opment plans by many cities. Each level of government is responsible for developing the “economy” that exists within its borders.

The second implication of the “nation as an economy” view is that regional differences within the nation are minor. After all, if national figures are to be meaningful, then they must closely describe all parts of the country. For example, if the national unemployment rate were 12%, then one would expect this figure to be indicative of employment levels throughout the country. If one-fifth of the country had an unemployment rate of 52%, while the rest of the country had a rate of 2%, then the “national” rate would be relatively meaningless as an indicator of employment levels within the nation.

Moreover, if a national policy (such as adjusting the prime rate or reducing the amount of currency) is to be effective, then it must work in a relatively uniform manner throughout the country. For example, the Fed often considers raising interest rates in order to hedge against “national inflation”. In order for this policy to work effectively, most of the nation would need to be experiencing economic growth. If many parts of the country were actually in recession, then the use of a national instrument such as the prime rate could act as a real barrier to economic growth in these regions. In other words, for national economic “tools” to be effective, the country must be economically homogenous within the nation’s borders.

3.2.2. Problems with the “nation as economy” paradigm
The view that nations are the fundamental economic entities of the global economy is coming under increased scrutiny. At least two reasons for questioning the paradigm stem from the discussion of the previous section.

First, it is interesting to note that the aforementioned implications of the nationalist paradigm are inherently contradictory. To illustrate this, consider the second implication of the “nation as an economy” paradigm, which implies that internal economic differences within the nation’s borders are minor. If this is true, then national economic planning should be sufficient to ensure national economic growth. No “sub-national” plan-
ning is necessary; the national tools of economic policy should be adequate to lead the nation into prosperity.

The first implication of the “nation as an economy” paradigm leads to the opposite conclusion. The first implication infers that political jurisdictions encompass “economies” at the national, state, and local level. If this is true, then state and local economic planning are essential for the development of these sub-national economies. Thus, the prevailing view that polities coexist with economies cannot stand on its own. The nation cannot be comprised of a uniform national economy and a diverse set of local economies at the same time.

**Second,** the fundamental notion that regional economic variations within the nation are minor is subject to question. Experience has demonstrated clearly that neither prosperity nor recession is experienced uniformly throughout a nation. The following points illustrate the unevenness of economic development throughout the continental United States:

- During the economic recession of the late 1980’s and early 1990’s, the New York City Metropolitan Area experienced a disproportionate loss of employment, with 770,000 people losing their jobs. Additionally, its recovery during the mid-1990s has been much slower than the recovery experienced by other parts of the country.\(^{30}\)

- The New England states were also hit hard by the recession of the late 80’s, with the rate of job losses being over twice the national average. While the decline in employment was precipitous during the recession, the rise in employment has been slow during the recovery. It took over five years to recover all the jobs that the region had lost during the recession.\(^{31}\)

- The Houston Metropolitan Area, because of its economic dependence on the oil industry, has historically run counter to national economic growth trends. For example, during the economic stagflation period in the late 1970’s and early 1980’s, Houston averaged an annual employment growth rate of over 7 percent. This was

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fueled primarily by the growth in domestic oil consumption, which in turn was a response to the rising price of oil from the Middle East. However, during the late 1980’s, while the rest of the country prospered, the Houston area sunk into recession. Although the drop in the price of overseas oil assisted the “national” recovery, the Houston region suffered from a corresponding drop in demand for domestic oil.

- Many rural parts of the country continue to experience unemployment and poverty rates well above the national average. In Appalachia, for example, the Appalachian Regional Commission has identified 97 “distressed counties” with extremely high unemployment and low average income. These counties even lack basic services such as clean water and proper sewage treatment. While the “national economy” is expanding and “national unemployment” falling, the economies in many of these counties are often shrinking, and unemployment is rising.

- Some rural counties in the state of Maine have also failed to share in “national prosperity.” While the more urbanized southern counties have unemployment rates near five percent, many of the rural northern counties have unemployment rates in excess of 10 percent. This disparity prompted the governor to submit a rural development initiative entitled “OneMaine”, whose stated purpose was to “reunite the state’s divided economy.”

- To the extent that population growth reflects economic growth, trends throughout the country have been far from uniform. A recently released Census Bureau report documenting population shifts from 1990 to 1997 noted that:
  - Six of the top ten counties experiencing the greatest percentage growth were in either Colorado or northern Georgia.
  - Seven of the top ten counties experiencing the greatest numerical growth were in either Texas or California.

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32 Rodriguez, 146.
33 See Appalachian Regional Commission Web Page (http://arc.gov/programs/distresd/distress.htm)
- None of the fastest growing counties were in the Northeast. In fact, four of the ten counties losing the most population over the same time frame were from the Northeast region (Philadelphia, Brooklyn, the Bronx, and Hartford).\(^\text{36}\)

- Summarizing the findings of this survey, the New York Times wrote, “Overall, states in the Northeast and Midwest continued to lose ground to the booming growth centers of the South and West...sustaining the steady trend that is inexorably shifting the nation’s political and economic might toward the Sun Belt and Rocky Mountains.”\(^\text{37}\)

As these anecdotes reveal, economic activity is not truly a “national” phenomenon. In other words, prosperity and recession are not uniformly experienced throughout the space that is enclosed by a nation’s borders. Some places prosper, others fight to maintain the status quo, and still others fall into economic decline. Thus, “national averages” tell very little about what is happening in various parts of the country. In order to understand economic activity, one must look at the regional level.

### 3.3. A look at “regions”

Many authors have noted the importance of looking at economic activity through a regional, rather than a national, lens. They have asserted that the term “national economy” is an oxymoron, an inappropriate blending of politics and economics. The have argued that the “national economy” is in fact a “constellation” of regional economies, each of which possesses its own characteristics and its own level of prosperity. They have contended that policies that are implemented uniformly across a nation in response to “national economic conditions” are not responsive to varying regional economic conditions. In short, they have argued for the need to shift from a national to a regional economic paradigm.

This paradigm shift has significant implications for transportation planning. As mentioned earlier, transportation and economic activity are closely interrelated. If economic

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\(^{36}\) See Census Bureau Web Page (http://www.census.gov/Press-Release/cb98-41.html)

activity is a regional activity, then transportation is also a regional activity. And if one is going to orient a transportation system toward supporting economic development, then one should conduct transportation planning at the regional level. This runs contrary to current practice, in which most planning (and funding) is performed at the state and national level.

However, understanding the reality of economic regions is much easier than defining them precisely and establishing their geographic limits. The authors who expound on the need for a regional paradigm often stop short of explaining how one would draw real, definable borders around an economic region. This, too, has implications for transportation planning. It is one thing to say that transportation systems should be planned regionally; it is another thing to explain how that translates into real space.

The advent of Intelligent Transportation Systems (ITS) provides yet another impetus for defining “region”. One of the goals of ITS is to link together various traffic management functions that were previously deployed on an independent basis. For example, ITS technologies can give a bus (operated by a transit agency) the ability to preempt a traffic signal (operated by a local traffic operations center) in order to provide better service for the transit passengers. ITS technologies can also help integrate the operations of various local traffic operations centers within a metropolitan area, providing the ability, for example, to coordinate traffic signals and emergency responses on an area-wide basis. Applications such as these, which seek to coordinate the efforts of multiple institutions, could potentially enable one to manage transportation at the regional level. However, in order to achieve this, it will be necessary to come to an understanding of what is meant by “regional”.

This section will address the issue of “defining a region”. Section 3.3.1 will review the works of some of the more prominent “regional” thinkers, summarizing each author’s definition of a “region”. Section 3.3.2 will summarize some of the various ways that the US Government has attempted to view the nation from a “regional” perspective. Section 3.3.3 will synthesize the various ideas in an effort to establish definition of “region”.
that is useful to the transportation planner. Chapter 5 will build on these ideas en route to developing a formal definition of a “regional architecture”.

3.3.1. A review of regional literature

Alvin Toffler

In his forward-looking book The Third Wave, Toffler notes that the advent of information technology has revolutionized the workplace and helped usher in a “Third Wave” of civilization. With more people handling information and fewer people on assembly lines, the need for highly concentrated groups of people in one factory, all of whom work identical hours, is greatly diminished. People are freer to set their own hours. Certain individuals can work from home. Managers who monitor increasingly automated production processes can do so remotely. In short, centralized control is giving way to flexible management. Society is moving relentlessly toward economic decentralization.

The shift away from centralized control manifests itself in several ways, according to Toffler. One way is the emergence of distinct regional economies. With the Federal government’s ability to control economic activity diminished, regions are freer to pursue their own interests. This has resulted in a breakdown of national economies into regional and sectoral parts. Toffler notes:

- Regions...instead of growing more alike as they did during the industrial era, are beginning to diverge from one another in terms of energy requirements, resources, occupational mix, educational levels, culture, and other key factors. Moreover, many of these subnational economies have now reached the scale of national economies only a generation ago.

Toffler also notes that these regional economies, because they are unique, do not respond identically to national economic policies. Different regions face different economic problems, and nationally mandated “solutions” that do not differentiate between regions might only aggravate these problems. In Toffler’s words, “Only disaggregated, increasingly decentralized economic management can work in the new economy, for it,

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38 Unless otherwise noted, the term “region” should be understood as meaning “economic region”.

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too, is becoming progressively decentralized at the very moment it seems most global and uniform."\textsuperscript{40}

Thus, for Toffler, the “economic region” is largely a by-product of the “Third Wave” trend toward decentralization. However, he provides little details on what these regions actually look like. Toffler does not speculate on the geographic scope of these regions, other than to say that they are “subnational.” He does not estimate the appropriate population of an economic region, other than to note that “If Singapore with its 2.3 million people is a nation, why not New York City with its 8 million?”\textsuperscript{41} Moreover, he does not articulate any of the infrastructure requirements for an economic region, such as a modern highway system or an international airport.

Toffler’s primary contribution to “regional thinking” is the acknowledgment that the “nation as economy” paradigm is failing. Since the nation cannot ultimately control economic activity, economic autonomy has devolved to the subnational level. This has led to the rise of regional economies, each with its own unique set of strengths and weaknesses. According to Toffler, the emergence of a diverse set of economically potent regions forebodes “the crack-up of the nation.”\textsuperscript{42}

\textbf{Jane Jacobs}

Jane Jacobs, in her classic work \textit{Cities and the Wealth of Nations}, concurs with Toffler that the nation is not the appropriate unit of analysis at which to study economic behavior. She opens the book by pointing out a fundamental flaw in macroeconomic theory—its inability to explain the phenomenon of stagflation. The reason for this flaw, Jacobs asserts, is its invalid assumption that the nation is an economic entity. If one is to acquire a true understanding for how economic life works, one must find another unit of analysis.\textsuperscript{43}

\textsuperscript{40} Toffler, 278.
\textsuperscript{41} Toffler, 96.
\textsuperscript{42} Toffler, 333.
According to Jacobs, the salient economic entity is the “city economy.” She claims that “Distinctions between city economies and the potpourris we call national economies are important not only for getting a grip on realities; they are of the essence where practical attempts to re-shape economic life are concerned.” In fact, contrary to Toffler, Jacobs contends that cities have always been at the heart of economic vitality. Nations are the products of 16th and 17th-century political and military pursuits, not of “Second Wave” industrialism. Modern times have simply highlighted the inability of national governments to control the economic activity that has always originated in metropolitan areas.

In Jacobs’ economic construct, an economic region is actually composed of two elements: cities and city regions.

- **Cities** comprise a metropolitan core and its immediate suburbs. This is where the heart of industrial productivity lies. The process of replacing imports with substitute goods produced locally powers this productivity. The import replacement cycle generally proceeds in the following manner:
  - First, the city generates diverse exports. In the process, the city earns money, with which it purchases a wide array of imports.
  - Second, export productions decreases, accompanied by an “explosion” of import replacement.
  - Third, the city’s economy generates a variety of potential new exports, in response to the broadening of the economic base created by the process of import replacement.
  - Fourth, the city goes through a period of vigorous export generating, in the process earning still more money through which to purchase an even wider array of imports. This, in effect, represents a return to the first phase in the cycle.

The import-replacement process is foundational to regional economic development, according to Jacobs. She asserts that “Economic life develops by grace of innovat-

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44 Jacobs, 29.
45 Jacobs, 33-34.
ing; it expands by grace of import-replacing. These two master economic processes are closely related, both being functions of city economies.”

- **City Regions** represent the area just outside the central city. Jacobs describes city regions in the following manner:

  In the hinterlands of some cities—beginning just beyond their suburbs—rural, industrial and commercial work places are all mixed up together. Such city regions are unique, being the richest, densest and most intricate of all types of economies except for the cities themselves.

  City regions are not defined by natural boundaries, because they are wholly the artifacts of the cities at their nuclei; the boundaries move outward—or halt—only as city economic energy dictates.

In other words, city regions are by-products of active urban economies. As cities engage in import replacement, they unleash five different forces of economic growth. These forces simultaneously create city regions and link city regions to their urban “parents.” Jacobs identifies these forces as follows:

- **Markets.** An import-replacing city generates an enlarged market for imports. Manufacturers in city regions depend on these markets for sustaining their production.

- **Jobs.** Citizens that live in city regions depend on jobs created in the cities.

- **Transplants.** As costs rise and competition heats up in the urban core, many businesses elect to relocate. The city region provides an ideal site for such relocation. The costs are lower, but yet the business remains close to its suppliers and its primary market.

- **Technology.** The process of import replacement inevitably leads to the development of new technologies. Often, this technology relates to rural production. Thus, urban innovations often enhance the productivity of rural areas within the city region.

- **Capital.** The wealth generated in vibrant city economies typically leads to major capital expenditures, including new production plants, infrastructure, education, utilities, and housing. Many of these new facilities (such as highways, irrigation

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46 Jacobs, 39.
47 Jacobs, 45.
channels, and new schools) extend beyond the urban core into the outlying city region.

Jacobs' definition of an "economic region" provides much more detail than Toffler's definition. She provides a rough geographic scope—it contains a city and its immediate surroundings. She provides a working definition—it is a metropolitan-based entity that is tied together through the five interwoven threads of markets, jobs, transplants, technology, and capital. And she provides a blueprint for competitiveness—regions must “produce amply and diversely for their own people and producers as well as for others” if they hope to thrive economically.\(^4^8\) In short, Jacobs’ work puts some flesh on the “regional economic bones” outlined by Toffler.

**Neal Peirce**

In his work entitled *Citistates: How Urban America Can Prosper in a Competitive World*, Peirce seeks to build on the “regional economic foundation” laid by Jane Jacobs. In fact, Peirce explicitly acknowledges the pivotal role that Jacobs has played in the development of regional thought. As he notes in his annotated bibliography, “Jacobs has written the seminal works showing the central role of cities and urban regions in economic invention and growth throughout world history.”\(^4^9\)

Peirce begins his book by asserting that the end of the Cold War has issued in a new historical era—an era in which global competition is shifting from military power to economics. This shift has placed renewed emphasis on the importance of the “citistate”, or economic region. For while the nation state was the logical competitor in the military realm, it is the citistate that is the logical competitor in the economic realm. Thus, if the United States is to remain economically competitive, it must do two things. First, it must acknowledge that the national economy is best viewed as a “constellation of regional

\(^4^8\) Jacobs, 57.

economies.” And second, it must tailor its policies to accommodate the diverse needs of the regional economies that lie within its borders.\textsuperscript{50}

Peirce then goes on to highlight three of the forces that are propelling citistates to the forefront. The first is the trend toward \textit{urbanization}. Peirce notes that 80 percent of the world's population occupies just two percent of the globe's land surface.\textsuperscript{51} Within the United States, over half of the population lives in the 39 metropolitan areas with populations of 1 million people or more. This shift in population density has led to increasing concentrations of economic activity, thus highlighting the importance of regional economies.

The second trend that Peirce discusses is \textit{political devolution}. He cites legislation passed by the Italian parliament in 1990 that gave all its major metropolises “a kind of citistate status.” In this landmark legislation, the parliament ceded authority over land use, transportation, energy, and water systems planning to the citistate. It also handed over responsibility for supervising environmental and cultural resources to each metropolis. In short, the national government, recognizing that certain functions related to economic activity occur at a regional scale, ceded much of its planning authority to regional governments.\textsuperscript{52}

Peirce also notes a similar trend in the United States. The Clean Air Act, as well as the Intermodal Surface Transportation Efficiency Act (ISTEA), both called for increased regional coordination and cooperation in support of air quality attainment and transportation planning. Once again, these pieces of legislation were drafted in recognition of the fact that regional problems (such as pollution and congestion) require regional solutions. The ability to craft such regional solutions is strengthened through devolution of authority.

\textsuperscript{50} Peirce, 1-2.
\textsuperscript{51} Peirce, 4.
\textsuperscript{52} Ibid, 5-6.
The third trend that Peirce discusses is globalization. Information technology and expanded transportation networks have created a global network of communication and commerce, providing direct ties between regional economies throughout the world. With this transportation and information infrastructure in place, a citistate need not rely on the beneficence of its national government to engage in global trade. It can pursue such economic activity on its own initiative. Thus, the free flow of information and commerce, coupled with falling trade barriers, highlights the decreasing economic relevance of the nation state.

Following his discussion of the forces leading to the rise of citistates, Peirce briefly describes some of the characteristics of a citistate. Some of these characteristics are listed below:

- **Population.** In Peirce’s mind, the citistate is metropolitan-based. Although he doesn’t identify how big the city should be in order to qualify as a “citistate”, he does propose some broad guidelines. For example, a citistate should be large enough to address cross-jurisdictional challenges such as work force preparedness, education, physical infrastructure, environmental quality, and economic positioning. However, it should be small enough to foster personal interaction between citizens and institutions. In Peirce’s words, it should be “sufficiently contained geographically so that there’s a chance for people to coalesce within it.”

  A large state, such as California, Texas, or Illinois, would be too large to be considered a citistate.

- **Relationship between business and government.** Peirce envisions that successful citistates will be characterized by cooperative relationships between business and government. Both share a common interest in regional prosperity, and both possess certain resources that can contribute to that prosperity. In demonstrating the potential of public/private partnerships, Peirce makes reference to the construction of Denver International Airport. The $3 billion in bonds that financed the project were sold by the joint effort of the region’s business and political leaders.

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This characteristic of a citistate is very important in the context of this thesis. One of the fundamental ideas underlying this research is that transportation planning may be done more effectively if it is conducted as a joint public/private venture. Peirce's example illustrates how interaction between the public and private sectors can be an effective means of addressing regional transportation needs.

- **Geographic scope.** In Peirce's mind, the citistate is metropolitan-based. Peirce presents five different ways of viewing the geographic scope of a citistate. These possibilities include: (1) a core city and its immediate surrounding area; (2) a census-defined metropolitan statistical area; (3) the viewing area of a city's television states; (4) the radius of the longest commute (also known as the "commute shed"); and (5) all of the exurban, rural territory surrounding a city "up to the orbit of another citistate". However, Peirce stops short of recommending a particular geographic definition. Instead, he states,

> Indeed, given the infinite variety of geographic configurations, the very ambiguity of the definition of citistate may tell us a lot. The citistate is the most dynamic form of human settlement today. We are just beginning to sense its full, latent power. But it may be years before we grasp its limits, geographic or political.54

**Kenichi Ohmae**

In his book entitled *The End of the Nation State*, Kenichi Ohmae further develops some of the key characteristics of an economic region. Ohmae asks the same fundamental question as the other three authors: "Are nation states—notwithstanding the obvious and important role they play in world affairs—really the primary actors in today's global economy?"55 Ohmae's answer is a resounding "No".

Ohmae goes on to explain that the declining role of the nation in economic affairs can be better understood by examining the flows of the "4 I's", which are described below:56

- **Investment.** Now more than ever, private money traverses the globe, flowing to wherever an attractive investment is available. In most cases, national governments are not involved at either end of the financial transaction.

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54 Ibid
• **Industry.** Industrial relocations are commonplace, as multinational corporations endeavor to "serve attractive markets wherever they exist and to tap attractive pools of resources wherever they sit." According to Ohmae, government inducements to attract business are becoming increasingly irrelevant. Rather, it is the presence of markets and resources that is providing the impetus for industrial moves.

• **Information Technology.** Information technologies have enabled businesses to operate globally, alleviating the need to develop an entire business system in each country in which they operate. For example, engineers at a workstation in San Francisco could control plant operations in China. This development erodes still further the ability of governments to control industrial activities within their borders.

• **Individual Consumers.** As Ohmae puts it, "Consumers increasingly want the best and cheapest products, no matter where they come from." People are looking globally for quality products. Not only do they feel less compelled to "buy nationally", but they also—through the capabilities of modern communication and transportation technologies—have a greater ability to purchase products from throughout the world.

After discussing the ways in which the nation state is losing its control over economic activity, Ohmae moves into a discussion of international regions. This is one of the key contributions that Ohmae makes to "regional thought". Although the other three authors that were reviewed in this section all acknowledged that economic activity transcends political boundaries, none actually discussed how this phenomenon manifests itself in the international arena. Ohmae, on the other hand, devotes a considerable portion of his book to the discussion of "cross-border region states."

Ohmae introduces the notion of international regions in his brief commentary on Porter's work, *The Competitive Advantage of Nations*. Ohmae agrees with Porter in saying that the elements of economic competitiveness (such as skilled workers and extensive networks of supplier industries) perform better when they are clustered in close geographi-
cal proximity. However, Ohmae disagrees with Porter's assertion that these clusters should be located within the confines of a single nation state. Ohmae contends that "...these necessary groupings work equally well—and perhaps even better—when they lie across political borders and so are free of the burden of national interest." Ohmae then proceeds to document a number of international regions, including the following:

- San Diego (US) / Tijuana (Mexico)
- Pusan (South Korea) / Fukuoka and Kitakyushu (Japan)
- The "Growth Triangle" of Singapore / Johore (Malaysia) / Riau Islands (Indonesia)
- The Rhone-Alps region of France, centered on Lyon yet with close business and cultural ties to Italy
- The "Greater Growth Triangle" of Mendan (Indonesia) / Penang (Malaysia) / Batan (Indonesia)

One of the reasons that international regions flourish, in Ohmae's view, is that they avoid the trap of the "civil minimum". In theory, the "civil minimum" is a guarantee on the part of the national government to provide common levels of public services to all people everywhere in the country. These services include infrastructure construction, mail delivery, and education provision, to name a few. The idea is that, regardless of the cost of providing these services, everyone in the nation should have equal access to them. That is to say, the cost to the user should be the same, whether the mail is delivered in downtown Boston or Northern Minnesota.

However, according to Ohmae, the "civil minimum" is actually a tool wielded by the national government to maintain its grip on economic control. It does this by extracting money from prosperous city regions and subsidizing services in the less economically resilient rural portions of the country. These subsidies in the name of the "national interest" have two results. First, these subsidies provide a drain on the regions that fuel the nation's economic engine. Second, they shift the tone of political debate, moving it from a discussion of the greater public good to a discussion of the "pork" spending that will be necessary to garner the votes of rural constituents. In short, the implementation

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60 Ohmae, 64.
of the “civil minimum” sacrifices economic growth in the name of “national equity”. It is an attempt to retain economic authority in the hands of the central government, despite the fact that such control is becoming increasingly difficult to exercise.

Ohmae’s contention is that international regions are not as susceptible to being “drained” in order to support the civil minimum. Because these regions “belong” to multiple nations, they are not as susceptible to broad-based taxes to be used in support of “national interest”. Therefore, they represent some of the strongest opportunities in the world for future economic growth.

**Summary of the literature**
The four authors reviewed here form but a small contingent of the proponents of “regional thinking”. Many other authors could be cited, including Rosabeth Kanter *(World Class)* and William Barnes and Larry Ledebur *(The New Regional Economies)*. Nevertheless, a review of the works of Toffler, Jacobs, Peirce, and Ohmae is sufficient to identify some common regional themes.

*The term “region” implies the crossing of jurisdictional boundaries.*
The term “region” is used to fill a void in political and economic vocabulary. Traditionally, political and economic discussions have revolved around jurisdictional boundaries. One talks about “national elections”, about “national economic policy”, and about “statewide implementation plans”. However, many phenomena—education, transportation, and air quality, to name a few—are multi-jurisdictional in nature. In the absence of a more precise term, “regional” is used to describe the geographic scale at which such phenomena occur.

*The terminology for “regional economies” varies widely in name and in scope*
Authors who describe regional economic activity do not adhere to a common vocabulary. Toffler talks of “subnational economies”, Jacobs talks of “cities and city regions”, Peirce talks of “citistates”, Ohmae talks of “region states”, and Barnes and Ledebur talk
of “local economic regions”. Some view the region as a purely economic entity that must coexist with the existing political framework; others feel that regions should assume greater political authority. In short, “regional economies” are called different things by different people, and they mean different things to different people. The lack of consistency in terminology and meaning may contribute to the difficulty of “mainstreaming” regional thinking.

Regional borders are extremely difficult to define
Since a “region” (i.e. economic region) is an economic entity, its borders are defined economically. This makes it extremely difficult to draw these borders on a map. How does one determine the geographic location at which a city’s economic influence effectively ceases? Clearly, there is great difficulty in defining economic activity in terms of geographic space. It may be more appropriate to define a region in terms of its “sphere of influence” rather than in terms of geographic borders.

Regions are geographically contiguous
This is one way in which regions and political jurisdictions are alike. A global company that possesses offices and conducts business at various locations throughout the globe is not a “region”. Rather, regions comprise a collection of public officials and private enterprises that coexist in certain geographic locations. These public and private entities share a common interest—the economic prosperity of the region. Although they may interact with other regions (i.e. through trade or joint policymaking), the prosperity that each of these public and private entities pursues is shared primarily within the geographic scope of their “home” region.

Economic regions are interdependent
When one looks at a political map of the United States, one sees a series of independent states that together comprise the nation. Although most states share a common border with at least one other state, these borders do not overlap. Each state is represented separately.
However, if one were to look at an “economic” map of the United States, the notion of independence would be quickly dispelled. Although regions are characterized by a shared prosperity, that prosperity is dependent upon vibrant and dynamic relationships with other regions. Manufacturers in a particular region depend upon markets in other regions to purchase their goods. Retailers in a particular region often depend on mail orders from other regions. (L.L. Bean, for example, generates 90% of its revenue through catalog sales.) Telemarketing firms often employ people from one region yet sell their products throughout the world. In short, in contrast to the fixed nature of jurisdictional borders, an economic region’s borders are permeable.

**Economic regions are characterized by internal diversity.**

As mentioned before, regions are defined by economic activity. Within the confines of a region, however, this economic activity is not evenly distributed. Activity tends to be greatest in the urban core, decreasing in intensity as one moves closer to the ill-defined borders. This stands in contrast to political jurisdictions, which portray an image of uniformity within their borders. Figure 3-2 provides a picture of how one might view this characteristic of a region.

![Political Jurisdiction and Economic Region](image)

**Figure 3-2: Contrasting Political and Economic Regions**

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Regional borders are dynamic

Economic activity is not static. As section 3.2.2 noted, some regions within the United States are expanding, while others are holding steady or contracting. As the New York Times article quoted earlier pointed out, the current demographic trend is “inexorably shifting the nation’s political and economic might toward the Sun Belt and Rocky Mountains.” This means that economic regions in the South and West are expanding, while those in the Northeast are slowly shrinking. Thus, regional borders are flexible, shifting in response to broader economic trends. This stands in sharp contrast to the fixed borders defined by political jurisdictions.

Political jurisdictions tend to do a better job of incorporating rural areas than regions do.

Political jurisdictions have the convenient property of covering the entire geographic area of the United States. Virtually all citizens and businesses can identify the municipality and state in which they live and operate. Economic regions do not necessarily have this property. Many rural areas, which occupy broad swaths of land but do not contribute comparable amounts of economic activity, may be neglected within the regional framework.

This poses a fundamental problem: Should one define “region” in such a way that a nation’s set of regional economies encompasses its entire geography? On the one hand, it would be beneficial for a particular rural section of the country to know its appropriate region. Governments and businesses in rural parts of northern New England, for example, might benefit from knowing their “economic epicenter” as they seek strategies to develop economically. On the other hand, becoming overly concerned with matters of geography could detract from the basic economic motivation of the “competitive region.”

Table 3-1 summarizes some of the relevant differences between political jurisdictions and economic regions:
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Economic Regions</th>
<th>Political Jurisdictions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geographic Orientation</strong></td>
<td>Contiguous</td>
<td>Contiguous</td>
</tr>
<tr>
<td><strong>Borders</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Definition</td>
<td>Economically based</td>
<td>Geographically based</td>
</tr>
<tr>
<td>- Clarity</td>
<td>Fuzzy, inherently unclear</td>
<td>Clearly outlined</td>
</tr>
<tr>
<td>- Variation over time</td>
<td>Change as regional economic activity expands and contracts</td>
<td>Fixed</td>
</tr>
<tr>
<td>- Relationship with other borders</td>
<td>Permeable; overlap with other regions possible</td>
<td>Distinct; no overlap with other jurisdictions</td>
</tr>
<tr>
<td><strong>Internal Diversity</strong></td>
<td>Internally diverse, as economic activity varies in intensity within the region</td>
<td>No comparable internal distinction; assumption is that jurisdiction = uniform entity</td>
</tr>
<tr>
<td><strong>Relationship with other similar entities</strong></td>
<td>Interdependent</td>
<td>Independent</td>
</tr>
<tr>
<td><strong>Integration of rural areas</strong></td>
<td>Unclear, because geographic extent of borders is unclear</td>
<td>Clear, because they cover the entire geography of the nation</td>
</tr>
</tbody>
</table>

Table 3-1: Comparing Regions and Jurisdictions

Figure 3-3 illustrates how one might visualize a “nation of economic regions”. The bold lines represent the borders of the nation, and the lighter lines represent the borders of the states that lie within the nation. The shaded circles represent the economic regions.
Figure 3-3: Economic Regions overlaid on Political Jurisdictions

Figure 3-3 illustrates graphically many of the points mentioned above.

- Regional borders are not well defined.
- Regions, because they are defined economically, are not uniform in nature. They are characterized by centers of intense activity. These centers are surrounded by a periphery in which activity becomes less intense with distance.
- Economic regions do not conveniently adhere to state or national borders. The economic influence of these regions routinely spills over these borders.
- The "spheres of influence" of these regions overlap. Thus, some geographic areas might be considered part of two different economic regions.
- Some rural parts of the country may be ignored by the regional paradigm, not being closely related to any metropolitan areas.
3.3.2. US Government “regional” designations

The US Government has recognized the need for a more urban-centered view of the United States. To this end, many Federal agencies have developed various constructs that purport to take a “regional” view of the nation. Three of these constructs are listed below:

3.3.2.1 US Office of Management and Budget (OMB) – Metropolitan Areas

The OMB has taken data available from the Census Bureau and defined 328 “metropolitan areas”, or “MA’s”, within the United States. A metropolitan area has two basic components: a core area containing a large population nucleus, and a series of adjacent areas that have a high degree of social and economic interaction with the core area. These MA’s include three different population-based entities: metropolitan statistical areas (MSAs), consolidated metropolitan statistical areas (CMSAs), and primary metropolitan statistical areas (PMSAs). Each of these entities is defined below:

- The **MSA** is the fundamental building block of an OMB-defined “metropolitan area”. It refers to a county or group of adjoining counties that contain at least one urbanized area of 50,000 or more inhabitants. (In New England, MSAs are defined by groups of adjoining cities and towns, rather than counties.)

- An MSA that also has a population of one million or more may be designated as a **CSMA** if two conditions are met. First, the MSA must consist of multiple components, each of which has an urbanized area of 50,000 or more inhabitants. Second, local opinion must prefer that the components be viewed individually, rather than as one single metropolitan area.

- The component areas of a CSMA are then designated as **PMSAs**.

Currently, the OMB has designated 255 MSAs and 18 CMSAs in the United States. The CMSAs can be further subdivided into 73 PMSAs. In addition, there are 3 MSAs, 1 CMSA, and 3 PMSAs in Puerto Rico.62

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The “metropolitan area” view of the United States has at least three regional characteristics. First of all, MA’s are not confined by state borders. Second, MA’s are centered on an urban core. And third, MA’s have an economic-based motivation; that is, they seek to incorporate less developed areas into the metropolitan area as long as a strong economic relationship exists between the outlying counties and the urban core.

However, there are two potential shortcomings with the OMB’s view of a metropolitan area. First of all, MA’s do not spill over national borders. This runs contrary to the notion that the metropolitan region is an economic entity, since economic activity does not stop at the nation’s borders. Second, MA’s do not account for all the geographical area of the United States. Many rural parts of the country are not assigned to any metropolitan-based regions as defined by the OMB.

3.3.2.2 Bureau of Economic Analysis (BEA) – Economic Areas
Like the OMB, the BEA has endeavored to disaggregate the nation on an economic basis. To this end, the BEA has broken the United States down into 172 “economic areas”. The BEA defined these economic areas in the following way:
- First, it identified all of the metropolitan statistical areas and labeled them as “economic nodes”.
- Next, it assigned each non-metropolitan county to the economic node to which it was most closely related. The BEA based this assignment primarily on county-to-county commuting flows. The end result of this process was a preliminary set of 348 “component economic areas”, or CEAs.
- Finally, the BEA combined the CEAs to form a set of 172 economic areas. The BEA employed to criteria in its process of aggregated CEAs to economic areas. The first criterion was that the labor force of each economic area should work and reside in the area, thus minimizing cross-border commuting. The second criterion was that each economic area should be economically large enough to be part of BEA’s local area economic projections program.
The economic area concept adheres very closely to the regional principles outlined by authors such as Jacobs and Peirce. First of all, as the name suggests, the BEA economic areas are defined in terms of economic activity rather than political jurisdictions. Second, the economic areas are metropolitan-centered. Third, they incorporate surrounding hinterlands that are economically polarized toward the dominant urban core. Fourth, they transcend state borders. Moreover, unlike the OMB's metropolitan areas, the BEA’s economic areas cover the entire geography of the United States; no rural areas are excluded.

However, the OMB’s metropolitan areas and the BEA’s economic areas share this characteristic in common: They are confined by national boundaries. Although the BEA explicitly recognizes that state boundaries are irrelevant to economic activity, it does not seem to recognize that national boundaries are also irrelevant. This merely serves to reinforce how powerful the “nation as economy” paradigm has become.

3.3.2.3 US Department of Transportation – National Transportation Analysis Regions (NTARs)

The USDOT developed a set of 89 NTARs in an effort to better understand the interregional movement of people and goods. The motivation to develop these regions stemmed from recognizing that “The geography of transportation demand and activity are molded by economic, social, and physical forces that generally ignore political boundaries... As a consequence, much transportation data need to be organized by functional geography rather than by State or other large political units.”

Although both of the previous constructs (the OMB’s metropolitan areas and the BEA’s economic areas) attempted to reflect “functional” rather than political geography, neither was adequate for designation at an NTAR. Metropolitan areas were not sufficient because they did not cover the entire country. Economic areas were not sufficient because their geographic areas were too small. The USDOT wanted each region to en-

64 See National Transportation Analysis Regions web page (http://www.bts.gov/programs/cfs/ntar/ntar_defined.html)
compass the hinterland of the region’s terminals for long-distance transportation.\textsuperscript{65} However, some economic areas, such as Baltimore and Washington, were so small that the hinterlands of the regions' freight and passenger terminals overlapped.

Another shortcoming of the previous regional schemes (from the perspective of the NTAR developers) was that the number of designated regions was too large. As mentioned above, the purpose for designating NTARs was to study interregional transportation. Such a study requires an enormous amount of analysis, since it requires a record for each pair of regions. In order to reduce the scope of the study, the USDOT limited itself to analyzing a maximum of 90 regions (which would create 8010 regional pairs).

The USDOT chose to build on the BEA-designated economic areas in order to define the National Transportation Analysis Regions. The USDOT developed these regions in the following way:\textsuperscript{66}

- First, it identified the largest 80 economic areas (in terms of population and jobs). These were labeled as “NTAR cores”.
- Second, it added six ports to the list of NTAR cores, in order to distinguish them from neighboring ports.
- Third, it combined all NTAR cores that lay within 50 miles of each other. Distance was based on the shortest major highway route between each area’s major city. This reduced the number of cores from 86 to 84, as Providence merged into Boston and Washington merged into Baltimore.
- Fourth, it took five of the unselected BEA-designated economic areas that were furthest from the existing NTAR Cores and designated them as additional NTAR cores. This raised the total number of cores to 89, as Alaska, Great Falls (MT), Minot (ND), Rapid City (SD), and Boise (ID) were added to the list.
- Finally, it took the remainder of the unselected BEA economic areas and assigned them to the nearest NTAR core. These assignments were based on the distance of the shortest major highway route between metropolitan centers.

\textsuperscript{65} The USDOT defined “long distance movements” as “travel by individuals that is typically not made on a daily or weekly basis.” This typically ranged from 50 to 100 miles, depending on population density.
The strengths of the NTAR approach are essentially the same as the strengths of the previous two approaches. That is, it takes a metropolitan-based, economically motivated approach to regional designations. It also covers the entire geography of the United States, just as the BEA scheme does. Additionally, the NTAR approach explicitly recognizes two important facts: (1) regions are interdependent; and (2) the interactions between these regions are complex and difficult to analyze.

However, there appear to be at least two weaknesses to the NTAR scheme. First, it confines itself to national borders, just as each of the previous schemes did. Although the designers made an explicit decision to consider “functional geography” rather than political geography, they implicitly viewed the national border as an “economic boundary” of sorts. Second, the NTARs do not comprise a truly “urban-centered” region. The decision to aggregate economic areas means that each region has multiple metropolitan centers. Thus, an NTAR might be better described as a “cluster” of economic regions, rather than an economic region in its own right.

**Summary – US Government Regional Approaches**

The three approaches discussed in this section are but a few of the various attempts to view the United States from a regional perspective. Other Federal agencies, such as the Bureau of Labor Statistics, have also devised schemes for regional delineation. Although the motivations for developing these regional constructs may vary, one can identify a number of common themes.

*Each scheme recognizes that cities are at the center of economic activity*

Each scheme began its process of designating regional boundaries by identifying major cities. The major difference between each scheme lay in the way it answered the following question: How far beyond the urban core should one go before drawing the regional boundary?

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66 The procedure recorded here is somewhat simplified. For a more complete description, see the NTAR web page.
There appears to be common agreement that OMB-designated metropolitan areas provide a “window” into the nation’s “economic geography.” Viewing the nation in “economic space” is much more difficult than viewing the nation in geographical space. Given that economic activity is difficult to measure quantitatively, each scheme took the approach that population density was a good proxy for economic activity. Thus, each scheme used the Census-defined metropolitan areas as building blocks for developing their regional frameworks.

The regional borders in each scheme are distinct and without overlap
The authors reviewed in section 3.3.1 each contended that regional borders were very fuzzy. This reflected the notion that neither economic activity nor economic influence can be measured precisely. In fact, given that regions are economically interdependent, the concept of “borders” may not even be appropriate.

However, the three regional designations reviewed in section 3.3.2 are characterized by distinct borders. From a graphical point of view, the regional divisions appear to be no different than political divisions. Each region is separate; there is no overlap. This may not be an accurate reflection of reality, given that some rural areas may well be economically tied to two or more metropolitan areas.

National borders are a “stumbling block” to regional thinking
Every regional viewpoint devised by the Federal government restricts itself to national borders. True regional economies, such as San Diego-Tijuana or Seattle-Vancouver, are artificially divided by these regional schemes.

There are probably two reasons for the national border restriction. The first is the prevailing view that the nation truly does comprise an economy. Although this is inconsistent with the notion that economic activity happens on a regional scale, it is nevertheless firmly ingrained in the planning psyche. The second reason is the recognition of

noted earlier.
political realities. Even if the Census Bureau were to expand its definitions to include “international regions”, it would not have the authority to collect data from other countries.

*Transportation is a reflection of regional interdependence*

The authors of section 3.3.1 noted that economic regions, unlike political jurisdictions, are interdependent. In other words, the scope of a region’s economic activity does not truly end at its borders; rather, it extends both to neighboring and distant economic regions.

Interregional trade is a reflection of the interdependence of economic regions. Manufacturers receive raw materials from other regions, and they “export” their products to other regions. Thus, examining long-distance transportation trends (as the NTARs endeavor to do) provides one way of visualizing regional economic interaction.

Of course, freight transportation is not the only indicator of economic interdependence. For example, service industries in a particular region can also “export” their services over phone lines and other telecommunications links. Nevertheless, freight transport is perhaps the most visible and measurable economic indicator.

**3.3.3. Recommendations for a more comprehensive regional perspective**

It is beyond the scope of this thesis to prescribe an entirely new definition of an economic region. However, based on a review of regional literature and of various regional constructs, one can define some ways in which “regional thinking” can be refined. The following list of recommendations is designed to provide an appropriate perspective for conducting strategic transportation planning.

**Recommendation 1: Transportation planning should be done at the “metropolitan area” level**

Transportation professionals argue that transportation planning should occur at the same level as economic activity. Regional economists universally agree that economic
activity occurs at the regional level, and that the city is the fundamental building block of
the “economic region”. However, one question remains unanswered: How big must a
city be in order to be considered an “economic region”?

It seems that the OMB’s “metropolitan areas” provide a fair representation of economic
activity. This is evidenced by the fact that both the BEA’s “economic areas” and the
USDOT’s “National Transportation Analysis Regions” use them as the starting point for
their regional delineation efforts. This is also evidenced by the fact that the Federal law
requires all urban areas with a population over 50,000 to have a Metropolitan Planning
Organization (MPO) that is responsible for carrying out a “continuing, cooperative, and
comprehensive” transportation planning process.67

Although economic areas and NTARs are useful windows into the nation’s economic
structure, they are too big to be considered as “city-based regions”. First of all, they
generally encompass multiple cities, whereas an economic region is more accurately
depicted as a single city (or geographically proximate city pair) and its surrounding hin-
terland. Secondly, the designation of economic areas and NTARs is based on an effort
to “contain” commuting flows (and certain freight flows) within the delineated region.
However, as section 3.3.1 pointed out, there is no a priori reason why economic regions
should be “confined”. Even if a region’s commuters don’t cross these borders, the
goods produced by the region and the vacationers traveling to and from the region do
cross these borders on a regular basis.

Thus, the metropolitan area should serve as the geographic foundation of the transpor-
tation planning process. It not only treats each city as a fundamental economic entity,
but it is also commensurate with current planning processes. Because they are redef-
ined every ten years, metropolitan areas (as defined by the OMB) also conform to the
notion that economic regions have dynamic borders.

67 “Metropolitan Planning Organization: More Than Just Roads”. See Web page:
http://mall.cftnet.com/planning/mpo/mpo.htm
However, one might consider making two alterations to the current definition of a “metropolitan area”. These alterations are discussed in the next two recommendations.

**Recommendation 2: Expand the scope of the OMB’s “metropolitan areas” to include international regions**

It is important to break through the “national barrier” to regional thinking. If economic activity transcends state borders, then it transcends national borders as well. Getting beyond the “nation as economy” perspective is important. Defining international metropolitan areas such as San Diego-Tijuana would be a first step toward achieving this.

Of course, acquiring the necessary data would require some degree of international coordination. However, this coordination could also be an important stepping stone toward breaking down political barriers to regional economic activity.

**Recommendation 3: Assign all rural counties to a metropolitan area**

One problem that the developers of the economic areas and NTARs had was the fact that the OMB’s metropolitan areas did not cover the entire geographical area of the United States. One way to remedy this problem would be to assign each county currently classified as “nonmetropolitan” and assign it to an already-designated metropolitan area. This could be done by (1) analyzing the flow of freight to and from each rural county; and (2) analyzing commuting patterns to identify flows from the rural county to neighboring metropolitan counties. The goal, of course, would be to identify the metropolitan area to which each rural county is most closely linked economically. This is important in that it recognizes that all economic activity within a nation is ultimately linked to the metropolitan economic engines.

The Bureau of Economic Analysis’ “component economic areas” provide a good approximation of an economic region. As section 3.3.2.2 noted, component economic areas are derived by (a) designating all metropolitan statistical areas as “economic nodes”, and (b) assigning each metropolitan county to the economic node to which it is most closely related. Component economic areas thus incorporate the entire geogra-
phy of the United States while retaining a single city at the core of each region. Their only shortcoming is that they do not extend to encompass international regions, as discussed by Ohmae.

3.3.4. Conclusions – “A Look at Regions”

The introductory portion of Section 3.2 made the case that transportation is essentially a regional activity. That is, transportation activity—like economic activity—transcends jurisdictional borders. Therefore, it was concluded that transportation and economic activity should be managed at the same geographic scale. In other words, the regional scale is the “right” scale for managing transportation operations.

Until recently, the notion of “regional transportation management” was only a vision. However, the advent of Intelligent Transportation Systems (ITS) technologies—introduced in Chapter 2—has provided transportation planners with the ability to translate this vision into reality. ITS technologies provide the ability to sense vehicles throughout the transportation network, to distribute information quickly and cheaply, to process information in real time, and to distribute this information to transportation users. These technological advances enable one to advance beyond managing roads at an intersection level to managing the transportation system at a regional level.

This chapter has described what the phrase “a regional scale” means in geographical terms. Clearly, defining “region” is a complex task. Since regions are defined economically, their borders cannot be readily drawn in geographic space. In fact, the whole concept of “borders” may be irrelevant in defining a region, since global transport and telecommunication systems link each individual region to other regions throughout the global economy.

Nevertheless, transportation facilities exist in real space, and so transportation planning must occur in real space. Therefore, if transportation planning is to be conducted at the regional level, the “region” must defined geographically. We suggest that the best way to do this is to define the region as a “metropolitan area”, as currently defined by the
OMB. This definition (a) supports the existing transportation process, which requires an MPO for all metropolitan areas; (b) acknowledges that cities are at the heart of economic activity; and (c) provides the flexibility that is needed to accommodate changing demographics. However, the current definition of metropolitan areas should be modified in two ways. First, it should be expanded to include regions which cross national borders. And second, it should be expanded to include all rural counties. These two changes recognize that all economic activity is ultimately linked to metropolitan centers, and that these metropolitan centers of economic activity are blind to both state and national borders.

As an aside, it should be noted that the three recommendations presented in Section 3.3.3 are based largely on a United States perspective. This perspective is evident in two ways.

- First, the choice of a regional designation is based on definitions that are unique to the United States. Although the OMB-defined “metropolitan areas” are an accurate reflection of the “economic regions” described in Section 3.2, this exact designation will not necessarily be found in other countries.
- Second, the choice of a regional designation is reinforced by United States transportation policy. Since the 1960’s, the US Federal Government has required each OMB-defined “metropolitan area” to have a designated Metropolitan Planning Organization that is responsible for transportation planning. This reinforces the selection of the metropolitan area as the appropriate scale at which to plan and manage transportation. In countries where such policies do not exist, it may be appropriate to define the “region” somewhat differently.

A parallel research effort at MIT demonstrates how an “alternate” approach to designating regions may be appropriate in a foreign country. This research, conducted by Yasuo Tatsumi, suggests improvements to the strategic transportation planning process in the Osaka/Kobe/Kyoto metropolitan area in Japan. If one were to strictly follow the

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68 For more information on this research, see Yasuo Tatsumi’s thesis entitled Regional Strategic Transportation Planning System in the Osaka/Kobe/Kyoto Metropolitan Area in Japan, MST Thesis, Massachusetts Institute of Technology, May 1998.
guidance provided in this chapter, then one might divide this metropolitan area into three different regions, with each region being centered on one of the three cities. After all, each city has a population of over 1 million, and the combined population of the three cities is nearly 17 million.

However, Tatsumi considers that the three cities together comprise a single region. There are essentially two reasons for this. First of all, the region is tightly integrated economically. The cities have experienced similar rates of growth historically, and high volumes of people and goods travel between each city pair. Secondly, unlike the United States, Japan has not designated a metropolitan authority comparable to the MPO to perform strategic planning at the metropolitan level. Thus, there is no a priori reason to select individual cities (as opposed to the three-city area) to be the foundational units of transportation planning.

Therefore, from a transportation perspective, it is appropriate (at least in the Japanese context) to consider these cities as a “region”. With any regional designation, the bottom line is that they should (a) have a metropolitan base; (b) extend to the surrounding hinterlands that are closely linked economically with the metropolitan core; and (c) transcend political boundaries. Although these criteria may be interpreted differently in different national contexts, it is clear that the Osaka/Kobe/Kyoto designation meets all of these criteria.

In summary, Chapters 2 and 3 have provided a detailed examination of two terms—“regional” and “architecture”. The next two chapters will begin the process of synthesizing these terms. First, Chapter 4 will review the National ITS Architecture’s treatment of regional architectures. Chapter 5 will follow up by simultaneously building on the foundation laid in Chapters 2 and 3 and extending the ideas presented in Chapter 4 en route to constructing a comprehensive definition of a “regional architecture”. 
Chapter 4
“Regional Architectures” and the National Architecture

As the introduction to Chapter 2 pointed out, the term “regional architecture” means different things to different people. The purpose of this chapter is to examine, in detail, the National ITS System Architecture’s concept of what a regional architecture is. This chapter will complete the background portion of the thesis. Chapter 5 will build on the foundation laid by this chapter, as well as the previous two chapters, en route to proposing a broader, more comprehensive definition of “regional architecture”.

4.1. Introduction

In its document entitled “ITS Architecture Executive Summary”, the Joint Architecture Team of Lockheed Martin and Rockwell International wrote the following:

The National ITS Architecture provides a general framework that must be adapted and elaborated for use in supporting an interoperable regional transportation system design. It is recommended that regional architectures be developed as a major output of this process, which adapts the National ITS Architecture to reflect major service, technology, and interface choices which are most appropriate for the implementing region.69

As this statement reveals, the Joint Architecture Team felt that the success of the National Architecture could be measured, in part, by its ability to support the development of regional architectures. The writers designed the National Architecture to provide a broad set of choices regarding services, technologies, and interfaces. Regional transportation planners would need to select from among these choices in order to apply the general national framework to a specific geographical context.

However, though regional architectures were regarded as a “major output” of the National Architecture, only one of the 16 National Architecture documents—the Implementation Strategy—makes mention of them. And within the Implementation Strategy,

only one chapter—Chapter 4—explicitly discusses the process of regional architecture development.

The rest of the chapter will summarize the information on regional architectures provided in Chapter 4 of the Implementation Strategy. Section 4.2 will provide a brief overview of how regional architectures fit into the ITS Planning Process. Section 4.3 will review how the Implementation Strategy defines “regional architecture”. Section 4.4 will take a look at two examples of regional architectures provided by the Implementation Strategy. Finally, section 4.5 will critique the National Architecture’s treatment of regional architectures.

### 4.2. Regional Architectures and the ITS Planning Process

Chapter 4 of the Implementation Strategy opens by providing an overview of the ITS Planning Process. A schematic of the process is depicted in Figure 4-1 on the following page.
Represents significant milestones which call for policy maker input.

**Figure 4-1: The ITS Planning Process**

70 Extracted from *National ITS Architecture, Implementation Strategy*, pg. 4-4.
The ITS Planning Process depicted in Figure 4-1 is described in more detail in the *Interim Handbook on ITS Planning* (FHWA, 1996). In devising this framework, the FHWA envisioned that the ITS Planning Process would be integrated with the broader State and Metropolitan Transportation Planning processes. The first three tasks—Establish Core Stakeholder Coalition, Develop Vision, and Define Problems and Document Goals—would be common to both ITS and "conventional" planning. They would lay the groundwork for the next phase of the planning process—the identification of non-ITS and ITS solutions that would (a) address the existing transportation problems, and (b) support the region's transportation vision. The fourth task listed in Figure 4-1—Screen Market Packages—represents the identification of ITS solutions. All steps from this point on are oriented toward the deployment of ITS user services.

The task of defining a regional architecture falls in the middle of the prescribed process, following immediately after the selection of a series of "market packages". These market packages constitute a list of services that the region desires to implement. The regional architecture provides the framework by which the region will deploy these services. Finally, the strategic deployment plan takes the market packages and, using the architecture as a deployment framework, translates them into a series of projects. These projects, in turn, are integrated into the region's transportation improvement program. In short, the regional architecture is a stepping stone that links the identification of services with the deployment of services.

71 Most of the National Architecture documentation focuses on architecture elements as they relate to user services. A list of user services supported by the National Architecture was provided in section 2.3.4.1. However, the Implementation Strategy focuses most of its attention on market packages, which are defined as a set of deployment-oriented service options that provide a fine-grained look at user services. For example, the user service "route guidance" could be implemented using one of four market packages: autonomous route guidance, dynamic route guidance, ISP-based route guidance, and integrated transportation management/route guidance. In all, the Implementation Strategy identifies 56 different market packages, contrasted with only 30 different user services. For a more detailed treatment of market packages, please see Appendix A.
4.3. Defining “Regional Architectures”

After outlining how regional architectures fit into the ITS planning process, the chapter proceeds to define “regional architecture”. It does this in three basic ways. First, it describes what a regional architecture is, thus providing an initial working definition. Second, it describes what a regional architecture does, adding some specificity to the general definition. Third, it describes in general terms how one might construct a regional architecture.

4.3.1. What a regional architecture is

The Implementation Strategy does not provide a single, comprehensive definition of a regional architecture. However, the document does provide some glimpses into how one might define the term. Five of these glimpses are recorded below:

- A regional architecture is a “key product” of the process that applies the general National Architecture framework to a specific geographic area.
- A regional architecture is a “natural framework for integrating local systems”.
- A regional architecture is “a concise, formal statement of the architecture choices made by the region.”
- A regional architecture is “a product that is new to the regional planning function.”
- A regional architecture “represents a middle ground between regional planning and project implementation”.
- A regional architecture includes existing systems, as well as potential extensions to these systems, in order to support new transportation services that the region wishes to deploy.72

This list of brief definitions from the National Architecture seems to suggest two major characteristics of a regional architecture. First, a regional architecture could be characterized as a small-scale version of the National Architecture. Rather than applying to

72 National ITS Architecture, Implementation Strategy, pp. 4-21, 4-24, and 4-27.
an entire nation, a regional architecture would apply to a smaller geographic area, such as a state or a metropolitan area. Rather than supporting all user services, a regional architecture would support only the services that a particular region wants to deploy. And rather than providing a broad array of technological and interface choices, a regional architecture would present a specific set of selections from among these choices.

The second major characteristic suggested by these definitions is that a regional architecture is a new product in the transportation planning process. It is not a list of desired services, nor is it a list of desired projects. Rather, it is framework through which a set of desired services can be deployed in an efficient and mutually supporting way. In short, it is a framework that helps translate ITS services into ITS deployments, both in the present and in the future.

4.3.2. What a regional architecture does

The Implementation Strategy devotes more effort to describing what a regional architecture does than it does to defining what a regional architecture is. The following list summarizes the functions of a regional architecture as specified in the Implementation Strategy:

- It should “facilitate interoperability and inter-agency integration of transportation management”.
- It should add a level of specificity to the National Architecture by “balancing local conditions and existing infrastructure with newly planned functions and infrastructure.”
- It should identify the institutions and transportation management functions to be included in regional ITS deployments.
- It should specify a degree of coordination among these institutions.
- It should “map the transportation systems, operating agencies, and communications infrastructure for the region into the subsystems and communications interfaces identified by the National Architecture…”
• It should support the adoption of cost-effective compatibility standards.\textsuperscript{73}

This list helps to put some flesh on the bare-bones definition of a regional architecture provided in section 4.3.1. This list of brief descriptions suggests three important characteristics of a regional architecture.

**First,** it is evident that a regional architecture should be centered on *institutions.* As section 2.3.4.3 noted, the National Architecture provides a series of functionally defined subsystems. However, the regional architecture must identify which specific regional institutions will fulfill the roles defined by the "generic" national architecture. The regional architecture should also identify how these institutions will relate to one another. This would involve resolving such questions as how information will be distributed and how control will be exercised.

**Second,** it appears that a regional architecture is not simply "derived" from the National Architecture. Rather, a regional architecture results from the merger of the National Architecture with regional institutional characteristics. Figure 4-2 illustrates the manner in which one develops a regional architecture from the National Architecture, as described in the *Implementation Strategy.*

\textsuperscript{73} National ITS Architecture, *Implementation Strategy,* pp. 4-7, 4-8, 4-24, & 4-31.
Third, it appears that regional architectures and standards are closely related. Regional architectures link systems together from multiple agencies. As section 2.4.2 of this thesis pointed out, compatibility can be a major issue in these circumstances, since each system must be able to read and interpret data delivered from multiple other systems. By identifying the different institutional interfaces that will be necessary in order to deploy ITS, the regional architecture can proactively address key areas in which compatibility may be a problem and, therefore, where the adoption of standards will be necessary.

The Implementation Strategy highlights three general types of compatibility that a regional architecture should support.

- **National interoperability.** This level of interoperability would apply to interfaces with mobile systems (such as commercial vehicles). For example, a single truck equipped with an ITS subsystem (such as an electronic toll collection transponder) should be able to travel throughout the nation and interact with the local ITS infrastructure. It should not require the use of multiple transponders to accommodate differing local systems.
National interoperability can apply to the non-technical as well as the technical realm. Take, for example, a variable message sign that displays traffic information to passing motorists. The way in which messages are displayed on these signs should be consistent throughout the country. The use of different phraseology by different regions to convey similar messages could prove to be confusing to inter-regional travelers (such as commercial vehicle operators).

- **Regional interoperability.** This level of compatibility applies to ITS deployments in which the underlying coordination issues are regional, rather than national, in scope. For example, consider a situation in which all the municipalities in the Greater Boston Metropolitan Area wanted to coordinate their traffic systems. Because such coordination would require the connection of subsystems operated by different agencies, it would require all agencies to standardize their systems. However, it would not require the agencies to adopt the same standard that, say, the New York Metropolitan Area adopted. Interoperability would only be an issue at the regional scale.

- **No interoperability requirement.** In cases where a broad range of application-specific interfaces makes national standardization exceedingly difficult, the National Architecture does not suggest any standard. For example, the Architecture does not recommend a standard for the interface between the Fleet Management and Commercial Vehicle subsystems, because the nature of the interface depends heavily on the vehicle type. Generally speaking, the National Architecture does not recommend standards for interfaces between privately owned and operated systems.74

These various levels of interoperability suggest that a regional architecture should include two important steps. First, it should identify which interfaces (that is, connections between subsystems) will require national interoperability, which will require regional interoperability, and which will not require any interoperability. And second, it should require all regional ITS deployments to support the appropriate level of interoperability.

74 National ITS Architecture, Implementation Strategy, pp. 4-31 to 4-32.
Performance of these two steps will help ensure that the regional architecture is "consistent" with the National Architecture.

The primary barrier to performing the "interoperability steps" is the absence of certain critical standards. For example, assume that a particular region wanted to deploy an electronic toll collection (ETC) system. Since ETC requires interaction with mobile systems, all regionally deployed ETC systems should support national interoperability. However, this is currently impossible, because no national ETC standard has emerged. States such as Florida, Texas, and California have adopted systems using a "backscatter tag", while the northeast states have generally adopted systems using an "active tag". Thus, in the absence of a standard that supports national interoperability, it would be exceedingly difficult for regional architectures involving ETC systems to be "consistent" with the National Architecture. For this reason, the Implementation Strategy notes that consistency (at least with respect to standards) will not be an issue until well-defined standards are available.

4.3.3. National Architecture guidance on constructing a regional architecture

Besides describing what a regional architecture is and what it does, the National Architecture also provides some limited guidance on how one might construct a regional architecture. According to the Implementation Strategy, the process of constructing a regional architecture involves three steps:

- First, the regional transportation planners must map the existing system inventory and local institutional framework to the physical architecture framework.
- Second, the planners must identify standards requirements for each interface (i.e. national, regional, or no interoperability). They must also identify what standards are already available to meet these requirements.
- Third, the planners must assess the costs and benefits of achieving compatibility. That is, planners must compare the costs of retrofitting existing systems to be compatible with planned ITS deployments to the benefits of having a fully compatible re-

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76 National ITS Architecture, Implementation Strategy, pg. 4-32.
regional system. In some cases, it may be wiser to replace the existing systems with fully compatible systems after their life cycle is complete.77

It is important to reiterate that this 3-step regional architecture development process is extracted from the Implementation Strategy; it is not proposed by this thesis. It is not clear whether the level of detail advocated by this process is appropriate for the transportation planner. For example, it is unlikely that a transportation planner would need to be able to identify standards requirements for each interface in a regional architecture. This appears to be a system design issue that is best handled at the technical level, as opposed to being addressed at the more general and descriptive architecture level.

4.4. A brief glimpse into what a regional architecture looks like

After defining “regional architecture”, the Implementation Strategy provided two views of how a regional architecture might appear in a real-world context. The views are brief and provide little detail, but they provide a small window into what a regional architecture would actually look like.

4.4.1. Southern California Showcase Program

The first example is from the Southern California Showcase Program. This program, which was initiated by ISTEA as an opportunity to “showcase” the capabilities of ITS, attempts to integrate all freeway, arterial, bus, rail, emergency, sea/air, port and commercial vehicle operations within the I-5 Corridor in Southern California.78 Because of the broad range of services involved, as well as the broad geographic area encompassed by the corridor, the Showcase Program required an aggressive institutional integration effort. Figure 4-3 represents an attempt to achieve this integration by mapping regional institutions to the National Architecture framework. It is, in effect, a first cut at a “regional architecture”.

77 National ITS Architecture, Implementation Strategy, pg. 4-5.
78 http://www.the-partnership.org/travel/projects.shtml
Figure 4-3: Southern California Showcase Regional Architecture Mapping

Five points are worth noting about this regional architecture.

- First of all, some institutions are listed multiple times. For example, “Kernel” (which represents a yet-to-be-implemented provider of regional transportation information) shows up four different times in the architecture.

- Second, some institutions encompass multiple National Architecture-defined subsystems. For example, Caltrans District 12 in Orange County serves as both an Emergency Management subsystem and a Traffic Management subsystem.

- Third, the regional architecture made no mention of user services. Although the architecture was developed in order to support a set of user services, one could not determine which user services were chosen based on the architecture diagram alone.

- Fourth, the Showcase architecture does not include any reference to standards. For the architecture to be consistent with the National Architecture, it should identify the interoperability requirements (national, regional, etc.) for the various interfaces.

- Fifth, almost all of the subsystems recorded in the regional architecture are “Center” subsystems. As section 2.3.4.3 pointed out, the National Architecture designates 19 different subsystems, each of which belongs to one of four different systems—Traveler, Center, Roadside, and Vehicle. The “Center” system is composed of functions that would ordinarily be associated with institutions, such as “Emergency Management” or “Traffic Management”. The other three systems are generally defined by the hardware that these institutions use in performing their services, such as “roadway” infrastructure and “commercial vehicle” systems.

Since the Showcase architecture focuses mainly on institutions and devotes little attention to services, it logically follows that the architecture is comprised almost entirely of Center subsystems. (The architecture does not label them as “Centers”; rather, it categorizes the various Center subsystems by jurisdiction, such as “Orange
County” and “Los Angeles”.) In fact, of the 25 subsystems included in the architecture, only two belong to a non-Center system. 80

4.4.2. Dallas Area Architecture

The second regional architecture recorded in the Implementation Strategy is from the Dallas Metropolitan Area. This architecture is depicted in Figure 4-4.

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80 The one non-Center system included in the Showcase architecture is “Remote Access”, which is an alternate name for the “Traveler” system identified in Figure 2-7.

81 National ITS Architecture, Implementation Strategy, pg. 4-33.
The regional architecture for the Dallas Area appears to address some of the shortcomings noted in the Showcase architecture. First of all, it is broader in its scope, identifying Vehicle and Roadside subsystems as well as Center subsystems. By doing this, the architecture provides some details concerning how these subsystems should be connected. For example, it adds a communication link between the Information Service Provider subsystem and the Vehicle subsystem—a link that was missing in the Showcase architecture. It also identifies some important communication links between management centers and roadside infrastructure.

Second, the Dallas architecture identifies how some of the key interfaces should translate into interoperability requirements. For example, the architecture notes that the interface between the toll collection facilities and the region's vehicles should be interoperable on a national level. This is consistent with the guidance mentioned in section 4.3.2, given that the vehicle is a mobile element that should be able to interact with local ITS infrastructure throughout the country. National interoperability would permit a vehicle from New York, equipped with New York's EZ-Pass, to interact with the Turnpike Authority's toll booths in Texas.

The architecture also identifies which links are supported by existing standards and which links are not. For example, the tollbooth-vehicle link mentioned above does not yet have a communication standard. A standard is available, however, for the Freeway Management-Freeway link. In this case, the governing standard is the National Transportation Communications for ITS Protocol (NTCIP). This is a national protocol that, generally speaking, governs the communication between traffic management centers and roadside infrastructure.82

Nevertheless, the Dallas area architecture still leaves some questions unanswered.

- First of all, the architecture does not identify any user services. Although one could infer that the architecture was designed to support services such as traffic informa-

82 For more on the NTCIP protocol, consult the Web: http://www.ntcip.org.
tion, electronic toll collection, and traffic control, the architecture does not make this explicit.

- Secondly, the architecture does not identify the types of information that should be exchanged between the various institutions. It is unclear, for example, how a traffic accident on the Interstate would get reported to an “Emergency Management” agency. Would the Texas DOT be responsible for monitoring the roads and reporting incidents? Or would that responsibility fall on another agency, such as the State Police?

- Thirdly, the Dallas architecture would appear to violate the subsystem hierarchy established by the National Architecture. For example, according to the architecture diagram, the Information Service Provider subsystem is a part of the Traffic Management subsystem. However, according to the National Architecture, the Transportation Management and Information Service Provider subsystems are distinct entities belonging to the Center system (see Figure 2-7, section 2.3.4.3).

- Fourth, the overall structure of the Dallas architecture is unclear. For example, the Texas Department of Transportation and “Surface Streets” are depicted as parallel elements within the Traffic Management subsystem. This is confusing, since one element is an institution and the other is infrastructure. Similarly, “Freeway Management” (a National Architecture-defined subsystem) and “Cities without TMCs” (a municipal entity) are also depicted as parallel entities.

4.5. Critiquing the National Architecture’s treatment of Regional Architectures

The National Architecture, in its Implementation Strategy, provides some good initial guidance concerning regional architectures. It does this in at least five ways. First, it acknowledges that the National Architecture framework is very general, and that it will need to be tailored in order to be applicable to local conditions. Second, it highlights the need to consider a regional architecture as a “new product” of the regional strategic planning process, providing a critical link between service needs and project deploy-
ments. Third, it identifies the areas in which the development of standards will be criti-
cal. Fourth, it acknowledges that institutional coordination will be a key element of any
regional architecture. And fifth, it provides an initial glimpse at what a regional archi-
tecture might actually look like.

Nevertheless, the National Architecture’s treatment of regional architectures has many
shortcomings. Some of these shortcomings, as well as some solutions for these short-
comings, are listed below.

4.5.1. Institutions and subsystems should not be combined on the same dia-
gram.

Both the Showcase architecture and the Dallas architecture combined the region’s sub-
systems and institutions in a single diagram. However, this procedure made it some-
what difficult to interpret the diagram. For example, the Showcase architecture provided
an example in which one institution (Caltrans) performed functions of multiple subsys-
tems (Emergency Management and Traffic Management). However, the Dallas archi-
tecture provided a striking counterexample, in which one subsystem (Traffic Manage-
ment) required the combined efforts of multiple institutions (the Texas DOT and individ-
ual municipalities). The lack of hierarchy between institutions and subsystems can
cause confusion when trying to understand the architecture diagrams.

The reason for this confusion is that subsystems are defined functionally, whereas in-
stitutions are defined organizationally. It is possible for one institution to perform mul-
iple functions; however, it also possible for one function to require the cooperative efforts
of more than one organization. Thus, no clear hierarchy exists between subsystems
and institutions.

To avoid the confusion, regional architectures should simply be defined in terms of in-
stitutions. As long as the institutions involved have the capability of performing the
functions defined by the subsystems, it is not necessary to include both.
4.5.2. A regional architecture should include each institution only once.

This problem was noted in the Showcase architecture, in which “Kernel” (an Information Service Provider) was listed multiple times. This needlessly clutters the diagram; it is unnecessary to show how a particular institution is connected to itself. One could avoid this problem by following the advice listed above—that is, to define the regional architecture solely in terms of institutions, rather than in terms of some combination of institutions and subsystems.

4.5.3. Regional architectures should specify which user services (and/or market packages) they are designed to support.

Neither of the example regional architectures depicted in the Implementation Strategy made any mention of user services. However, one of the main functions of a regional architecture is to help translate user service needs into ITS deployments. For this reason, a regional architecture should specify the user services that it is designed to support. Additionally, the regional architecture should specify the institutions that are responsible (either individual or jointly) for the deployment of each user service.

4.5.4. Regional architectures should clearly designate which institutions are responsible for implementing each user service

In addition to specifying which user services the region is planning to deploy, a regional architecture should also specify which institutions are responsible for deploying these services. For example, consider a three-city region that is planning to deploy a service relating to incident management. The regional architecture should clearly indicate whether (a) each city is going to deploy the service independently; (b) the three cities are going to provide the service jointly (i.e. the cities will offer each other assistance
upon request), or (c) the three cities are going to combine their operations into a single "regional incident management center". Figure 4-5 illustrates these three deployment options graphically.
The need to designate responsibility for user services is important, because it forces the region to wrestle with issues of institutional change. As a region tries to determine who will be responsible for a particular service, it will need to confront questions such as:

- What are the costs and benefits of deploying a service on a city-by-city basis, as opposed to deploying the service on a regional basis?
- Can the region provide a better service to the public if the municipalities can agree to cooperate and share control?
- How might multiple municipalities implement a system of shared control? Would one city be assigned control and be responsible for directing the effort, or would cooperation be purely voluntary?
- Might it be worthwhile for the region to create a new entity to handle the additional tasks implied by deploying an ITS service?

By forcing a region to confront these questions, a regional architecture help identify ways in which institutional change can promote the interests of the region’s travelers. This is one way in which a regional architecture can be used proactively to facilitate institutional change.

### 4.5.5. Regional architectures should include information flows

Both of the example architectures depicted in Section 4.4 showed how each institution was physically connected to the other institutions. However, neither architecture specified what types of information needed to flow over those communication links. For example, while the Dallas architecture connected the Texas DOT to the Turnpike Authority, it did not explain what sorts of information needed to flow between the two organizations. This is a critical shortcoming, because the ability of each institution to perform its designated services depends, in part, on the prompt and accurate receipt of information from other institutions.

Therefore, a regional architecture should describe the basic types of information that must be distributed among the institutions in order to facilitate the implementation of user services. In the process of describing these flows, the architecture should address three important issues: the method by which information will be distributed between institutions, and the relationship among the user services, and the cost of implementing the architecture.
• *Method of information distribution.*

The regional architecture should identify the manner in which information will be distributed through the region. There are three basic ways in which this can be done: centralized, decentralized, or some combination of the two.

Consider, for example, a regional architecture that supports the provision of traffic information through two local radio stations (Station “A” and Station “B”). Suppose that the stations draw information from four different sources: Town C, Town D, vehicle probes, and a traffic-monitoring helicopter. There are basically three ways in which traffic information could be communicated to the radio stations. In a “centralized” architecture, all information would go to a centralized database, and each station would draw information from that database. In a “decentralized” architecture, each information source would communicate directly with each radio station. In a “hybrid” architecture, some sources would communicate directly with the radio stations, while others would relate the information to a central database. Figure 4-6 illustrates these different methods of information distribution.
NOTE: All arrows represent traffic information flows

Decentralized Information Distribution

Centralized Information Distribution

“Hybrid” Information Distribution

Figure 4-6: Alternate Methods of Information Distribution
• **Relationship among user services.**

In order to determine how information will be distributed, the various institutions must decide how the user services will be related to one another. Will each service be implemented independently? Will the services be implemented cooperatively? Or will there be some “middle ground” on institutional coordination?

Consider a situation in which a region seeks to deploy three different services—Variable Message Signs (VMS), Electronic Toll Collection (ETC), and Real-Time Traffic Reports. Two institutions will be involved in the deployment. The Turnpike Authority will be responsible for deploying the ETC scheme as well as the VMS’s, while a local radio station will be responsible for providing traffic reports. One could envision at least three ways in which these services could be deployed.

a) **Each institution could deploy the services independently.** The Turnpike Authority could deploy its ETC system, identify traffic and incident information on the turnpike based on data from the transponders, and display the information to other turnpike drivers on the VMS’s. The local radio station would gather information with its own resources and broadcast it to the general public.

b) **The institutions could integrate their services on a “one-way” basis.** The Turnpike Authority will generate a significant volume of information from its transponders. This information would be of benefit to the radio station, which could broadcast this information to the public. This would represent modest integration of the user services, with information flowing from the Turnpike Authority to the radio station.

c) **The institutions could completely integrate the services.** The radio station is likely to have access to information on the roads to which the turnpike connects. The radio station could provide this information to the turnpike authority, which could display this information on its VMS’s. With the two institutions providing one another with supporting information, the user services could be considered “fully integrated”.

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Figure 4-7 graphically depicts these three options, illustrating varying relationships among user services.

**Figure 4-7: Information Distribution and the Relationship among User Service Deployments**

- **Cost of implementing the architecture.**

  Considering the way that information will flow among institutions should also lead to careful consideration of the cost of implementing the architecture. Constructing a system of information distribution can prove to be very costly. It can require the re-
placement of existing communication media, the addition of new communication links, the purchase of a centralized database, and the training of personnel—each of which presents a considerable financial expenditure. Moreover, the coordination required by the architecture can be politically costly, calling for cooperation among independently-minded jurisdictions. Thus, the region should consider both the financial and political costs of the architecture as it diagrams the information flows.

4.5.6. The process of constructing a regional architecture outlined in the Implementation Strategy needs elaboration.

The Implementation Strategy presents a simple, three-step process to defining a regional architecture. As section 4.3.3 pointed out, these three steps are: one, map existing systems and institutions into the National Architecture framework; two, identify standards requirements; and three, assess the costs and benefits of achieving compatibility. However, the process of constructing a regional architecture is, in reality, much more involved than this, as the following points demonstrate.

- One cannot simply map the existing institutional framework into the National Architecture framework. As section 4.5.1 noted, relationship between regionally defined institutions and National Architecture-defined subsystems can be very complex. The “mapping” exercise mentioned by the Implementation Strategy really consists of three steps. First, one must identify which subsystems are needed in order to deploy the selected set of user services. Second, one must identify which regional institutions are needed in order to fulfill the functions defined by these subsystems. And third, one must identify the communication links that are necessary in order to connect these institutions.

- When two (or more) institutions are needed in order to fulfill a single function, the regional architecture should identify how these institutions will relate to one another.
Section 4.5.4 discussed this issue at length, and it mentioned some of the questions that must be addressed in the process of assigning responsibility for user services.

The three-step method of architecture development specified in the Implementation Strategy does not address these thorny questions of centralized versus decentralized control. It simply calls for the region to map institutions into subsystems. It addresses how subsystems should relate to one another, but it tends to overlook the more important questions of how institutions should relate to one another.

- Another aspect of regional architecture development that the “three-step” process neglects is the extent of institutional change required by the architecture. It is possible that some user services will require functions that no existing institutions in the region can readily provide. In such cases, one must address an important question: Should the new responsibilities be assigned to existing institutions, or should they be assigned to a new entity?

The way in which this decision is answered can significantly affect what the regional architecture might look like. For example, consider a situation in which a region seeks to implement the “ride sharing and matching” user service. Figure 4-8 depicts a simplified architecture possibility, in which the service is allocated to two existing entities—the City A DOT and WXYZ Newsradio.
In this example, both entities store ridesharing information. Suppose that an individual contacts the City A DOT and requests some rideshare information, as depicted in Figure 4-7. The DOT will do two things with this request: it will process the request "in-house", and it will forward the request to WXYZ Newsradio. WXYZ will then process the request and provide a response to the DOT. Once the DOT has consulted its own database and received WXYZ's response, it will prepare a consolidated response to send to the individual.

An alternate approach to the deployment of this user service would be to create an entirely new entity—one that would be solely devoted to processing ride sharing and reservation information. In this case, all information would be stored at one central location. This would greatly simplify the architecture, as depicted in Figure 4-9.
Of course, creating a new entity can be very difficult. It may require the influx of new expertise from outside the region, and it may require substantial public investment. Nevertheless, it may also present a more efficient solution to the deployment of regional user services, especially if it is not restricted to jurisdictional boundaries. Thus, the regional architecture development process should explicitly consider the tradeoffs involved in adding responsibilities to existing institutions versus creating a new institution. The need to do so is not addressed by the National Architecture.

4.5.7. The National Architecture never explicitly discusses what it means by “regional”.

Although the Implementation Strategy discusses “regional architectures” at length, it never defines what it means by “regional”. From the Dallas example, one would assume that the regional architecture is constructed at the metropolitan level. However, the Showcase architecture encompassed multiple metropolitan areas, including Los Angeles and San Diego. In fact, there is nothing in the Implementation Strategy that would preclude one from constructing a regional architecture at any subnational level.

This issue is very important from the perspective of integrating regional architecture development into the strategic planning process. If “regional” refers to a metropolitan area, then the regional architecture would most likely be developed by the appropriate Metropolitan Planning Organization (MPO). If “regional” refers to the state level as well, then state Departments of Transportation might also get involved in developing “state-wide” regional architectures. However, if “regional” refers to both a metropolitan area and its economically related hinterland—that is, if “regional” refers to the economic region discussed in Chapter 3—then some new entity might need to be designated to develop the regional architecture.
4.6. Summary

The primary goal of this chapter has been to highlight some of the key features of a regional architecture. The chapter has taken a three-step approach toward pursuing this goal. First, it has summarized some of the key regional architecture features identified by the National Architecture. Second, it discussed some of the shortcomings in the National Architecture’s treatment of regional architectures. And third, it suggested some features of a regional architecture that would be responsive to these shortcomings.

Contribution of the National Architecture

The National Architecture made several contributions toward the goal of developing a regional architecture. These contributions include the following:

- It points out that the regional architecture should be a new product of the transportation planning process.
- It notes that regional transportation institutions should be a key component of a regional architecture.
- It recognizes that the regional architecture exists in order to support the implementation of a series of user services.
- It provides a comprehensive list of user services, as well as a series of data flow diagrams that support these user services.
- It highlights the importance of institutional coordination in the provision of transportation services.
- It identifies the importance of identifying specific levels of interoperability for the various interfaces highlighted in the architecture.

One can conclude, based on the National Architecture, that a regional architecture should be a unique document that consists of the following elements:

- A list of the user services that the region wishes to deploy
- The regional transportation institutions that provide the selected user services
- The communication links between these institutions
• The appropriate level of interoperability which should apply to these communication links
• The data flows which travel over these communication links

Shortcomings of the National Architecture
The National Architecture essentially took a "first cut" at developing a regional architecture. One can identify a few shortcomings from this first effort, including the following:
• The National Architecture recommends combining institutions and subsystems on the same diagram. However, this can create a very confusing diagram. In some cases, one institution may perform functions identified in multiple subsystems. In other cases, a single subsystem may require the combined efforts of multiple institutions.
• In situations in which a single subsystem requires the combined effort of multiple institutions, the National Architecture does not identify how these institutions should relate to one another. That is, the National Architecture does not discuss decision-making structures or command-and-control functions.
• Of the two examples of a regional architecture provided by the Implementation Strategy, neither identifies the user services to be supported or the data flows to be communicated.
• The National Architecture does not discuss various options for information distribution—such as centralized, decentralized, or hybrid forms of communication.
• The National Architecture does not point out the potential for using the regional architecture proactively to facilitate institutional change. The architecture development process is likely to highlight ways in which changes to the existing institutional structure can enhance the quality of transportation services. The opportunity to use the architecture to reorient institutional relationships is not explicitly noted by the National Architecture.
• The National Architecture does not specify what it means by "regional".
Recommended characteristics of a regional architecture

Based on the aforementioned shortcomings of the National Architecture, one can recommend some additional features that a regional architecture should incorporate. These include the following:

- It should include lines of responsibility that identify which institution (or group of institutions) will be responsible for deploying each user service.
- Its basic elements should be institutions alone, not a combination of institutions and subsystems.
- It should describe the data flows between the various institutions.
- It should outline a decision-making structure in cases where multiple institutions perform the same service.

In the process of constructing the architecture and identifying these features, one should consider the following issues of importance:

- The manner in which information is to be distributed among the institutions (i.e. centralized, decentralized, or hybrid)
- The relationship among the user services (i.e. independent vs. interdependent)
- The relationship among multiple entities performing similar functions (i.e. will each institution be autonomous, or will some institutions exercise a degree of centralized control?)
- The possibility of creating a new institution to either handle or coordinate the additional responsibilities created by the ITS deployments
- The geographic scope of the architecture

At its very core, a regional architecture is a framework for regional institutional collaboration whose goal is the implementation of a set of transportation services. The next chapter will elaborate on this definition and further develop the points mentioned above.
Chapter 5
Defining “Regional Architecture”

The purpose of this chapter is to define the term “regional architecture”. The chapter will take the following approach in seeking to achieve this objective.

- First, it will summarize the salient contributions that the previous three chapters have made toward a definition of “regional architecture”.
- Second, it will examine how the notion of “regional architecture” might be expanded to include non-ITS as well as ITS services.
- Third, it will propose a definition for a “regional ITS architecture” which (1) addresses the shortcomings noted here in the National Architecture’s definition of the term; and (2) includes the possibility of applying a regional architecture to “conventional” services.
- Fourth, it will present an illustrative scenario, in which a regional architecture will be constructed to support the deployment of services in a fictional three-city region.

The following chapter (Chapter 6) will elaborate upon and critique the new concepts discussed in this chapter. Chapter 7 will then take a step back and propose a framework for integrating regional architectures into the strategic transportation planning process.

5.1. What a “Regional Architecture” Should Include

The previous three chapters have (a) provided information on what the term “architecture” actually means, in a computer systems as well as an ITS context; (b) described what the term “region” means, particularly in a transportation planning context; and (c) reviewed what the term “regional architecture” means as defined by the National Architecture. This section will review the most important contributions that these background chapters have made toward defining the term “regional architecture”. The goal of this
section will be to outline some of the basic principles that a broader definition of “re-
gional architecture” should include.

5.1.1. Review of Chapter 2: Defining ‘Architecture’
Chapter 2 contributed three key ideas to the definition of the term “regional architec-
ture”. First, it provided a general definition of the term “architecture”. Second, it high-
lighted the two key tasks that an ITS architecture must achieve. And third, it discussed
the important role that institutions play in defining an ITS architecture. The next three
subsections will review these ideas in detail. The fourth subsection will summarize how
these ideas translate into requirements for a definition of a regional architecture.

5.1.1.1 A general definition of “architecture”
Chapter 2 quoted from the Mission Definition document of the National Architecture,
which provides a good working definition for the term architecture. This definition (origi-
nally quoted in section 2.3.4) may be summarized as follows: “a framework of intercon-
nected subsystems that together provide user services through allocated functionality
and defined interfaces.” This definition is good in that it mentions five important char-
acteristics of a system architecture.

(a) Its purpose is to support a particular service or set of services.
(b) It is a framework—a description of how a system should operate. It does not specify
    the technologies that will implement the system.
(c) It is composed of subsystems, which serve as the fundamental elements whose in-
    teractions provide the selected set of user services.
(d) It assigns functionality to each of the subsystems. That is, it describes the particular
    role that each subsystem will play in the process of providing the user services.
(e) It identifies the communication links that tie the various subsystems together.

Although this definition was provided by the National Architecture, it is general enough
to apply to a wide range of applications, including individual computer architectures,
computer system architectures, and ITS architectures.
5.1.1.1 The two tasks of an ITS architecture

Chapter 2 described how the architecture concept transferred naturally from the computer systems realm to the ITS realm. Both computer system architectures and ITS architectures have a common task—to link multiple subsystems together in order to provide a single service. For example, the “client/server” computer system architecture links multiple computers together in order to provide a service like an ATM withdrawal. Likewise, an ITS architecture links multiple subsystems together to provide a transportation service, such as electronic toll collection.

However, an ITS architecture has a second task that distinguishes itself from a traditional computer system architecture. That task is to link multiple services together so that they function as a coherent “transportation system”. In other words, an ITS architecture must identify ways in which information from one service can be distributed to other services that could benefit from the information. For example, it should link a “traffic information” service (which would have knowledge of traffic accidents) to an “emergency management” service (which has the responsibility of responding to such accidents with medical assistance).

5.1.1.2 ITS Architectures and the Institutional Element

The third key idea brought out by Chapter 2 is that institutions play a critical role in the crafting of ITS architectures. This stems from the second major task of an ITS architecture—to link services together. Transportation services are provided by institutions; therefore, the coordination of services will require a joint effort on the part of the institutions involved. The introduction of the “institutional element” into ITS architectures brings three key architectural issues to the forefront—cooperation, compatibility, and control.

- Cooperation. The requirement for institutional cooperation is one way in which ITS architectures are different from computer system architectures. The subsystems of a computer architecture (such as a client/server architecture) are generally owned
and operated by a single entity. By contrast, the subsystems involved an ITS architecture are often operated by different entities. Thus, interaction among subsystems at a technical level requires interaction among people at an institutional level.

- **Compatibility.** Because the subsystems in an ITS architecture are often purchased and operated by different agencies, compatibility can become a very important issue. The sharing of information between technical systems can be stifled in the absence of communications standards that apply to all institutions, both public and private.

- **Control.** Some of the ITS user services require the implementation of various control measures. For example, both the “demand management” and the “traffic control” services require one to make decisions concerning how the transportation system should be operated. These decisions raise some basic questions about how the control should be exercised. Should each town control its own traffic flows? Should each town manage its own incidents? If the municipalities in a metropolitan area would like to coordinate their traffic flows, how should they structure their operations? Should they appoint a central “transportation authority” to monitor the network and make decisions, or should the towns each maintain their autonomy and exchange information rather than control? Such questions of institutional control are another way in which ITS architectures distinguish themselves from computer system architectures.

5.1.1.3 **Summary: Chapter 2 contributions to “regional architecture” definition.** Based on the three key ideas mentioned above, one can identify a series of characteristics that a new definition of “regional architecture” should possess. These characteristics are summarized in Table 5-1.
A regional architecture should exist in order to support the provision of a set of transportation services.

A regional architecture should seek to integrate these services so that the transportation network functions as a coordinated system.

A regional architecture should be a descriptive framework, not a prescriptive design.

A regional architecture should do at least four things:
- It should list the services that the architecture is designed to support;
- It should list the basic subsystems whose interactions will provide the services;
- It should assign functionality to each subsystem, defining its role in the provision of the transportation services; and
- It should identify the communication links between the subsystem.

A regional architecture should focus and clarify institutional interactions.
- It should define how these institutions cooperate in the provision of transportation services.
- It should identify areas in which compatibility of technical systems will be an issue.
- It should identify how the institutions will resolve issues of control in the provision of certain user services.

<table>
<thead>
<tr>
<th>Characteristics of a Regional Architecture as suggested by Chapter 2</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>• A regional architecture should seek to integrate these services so that the transportation network functions as a coordinated system.</td>
</tr>
<tr>
<td>• A regional architecture should be a descriptive framework, not a prescriptive design.</td>
</tr>
<tr>
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</tr>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>- It should identify how the institutions will resolve issues of control in the provision of certain user services.</td>
</tr>
</tbody>
</table>

Table 5-1: Regional Architecture Characteristics Suggested by Chapter 2

5.1.2. **Review of Chapter 3: Defining “Region”**

Chapter 3 was oriented toward shedding some light on the term “region”. The following line of argumentation formed the basic motivation for the Chapter:

| Premise 1 | Transportation activity and economic activity are intrinsically linked |
| Predise 2 | Economic activity occurs at the regional level |
| Intermediate | Transportation should therefore be planned, operated, and managed at the regional level |
| Conclusion | A regional architecture is a transportation planning, operations, and management tool |
| Premise 3 | A regional architecture is a transportation planning, operations, and management tool |
| Conclusion | The term “region” in “regional architecture” should refer, geographically speaking, to the area encompassed by an economic region. |
This raises a fundamental question: What is a “region”? The chapter responds to this question in two ways. First, it contrasts the contemporary notion of economic regions (hereafter simply referred to as “regions”) with the traditional notion of political jurisdictions. And second, it proposes a specific definition for a “region”. The two subsections will provide more detail on these two responses.

5.1.2.1 Comparing “regions” and “jurisdictions”

One way in which to better understand the concept of “regions” is to compare and contrast them with a more familiar concept—political jurisdictions (i.e. towns, counties, states, and nations). Drawing on the writings of authors such as Jacobs and Ohmae, Chapter 3 noted several important characteristics of a “region”. Table 5-2 documents these characteristics, as well as comparable characteristics of jurisdictions.

<table>
<thead>
<tr>
<th><strong>Regional Characteristics</strong></th>
<th><strong>Jurisdictional Characteristics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically-based</td>
<td>Geographically-based</td>
</tr>
<tr>
<td>Defined primarily by what exists at the core—a metropolitan area</td>
<td>Defined primarily by what exists at the periphery—a border</td>
</tr>
<tr>
<td>Borders are unclear, not easily defined</td>
<td>Borders are clear and well-defined</td>
</tr>
<tr>
<td>Borders are permeable, as economic activity flows (in the form of goods and services) from one region to another</td>
<td>Borders are rigid, as each jurisdiction is clearly distinguished from another</td>
</tr>
<tr>
<td>Characterized by competition—regions competing with other regions to provide their citizens with a high quality of life</td>
<td>Characterized by autonomy—jurisdictions jealously guarding their right of self-government</td>
</tr>
<tr>
<td>Dynamic in form—borders shift according to the ebb and flow and economic activity</td>
<td>Static in form—borders change very little over time</td>
</tr>
</tbody>
</table>

**Table 5-2: Comparing Regions and Jurisdictions**

At its core, the distinction between regions and jurisdictions is this: One is defined in terms of economic activity, while the other is defined in terms of historically designated borders. In other words, regions exist primarily in “economic space”, while jurisdictions exist primarily in geographic space. However, in order for the “regional” concept to be
useful from a transportation planning perspective, one must define “region” in terms of geographic space. Any such definition should satisfy three criteria. First, it should conform as closely as possible to the regional characteristics listed in Table 5-2. Second, it should cover the entire geographic area of the nation, since all geographic areas have transportation needs. And third, it should conform, if possible, to some of the current regional designations already established by the Federal government.

### 5.1.2.2 US Government Regional Designations

Chapter 3 also reviewed the schemes that three Federal agencies have devised in order to divide the nation on a regional basis. Table 5-3 summarizes these various regional subdivisions.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Designation</th>
<th>Description</th>
<th>Total # in US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office of Management and Budget (OMB)</td>
<td>Metropolitan Statistical Area (MSA)</td>
<td>County or group of adjoining counties containing at least one urbanized area of at least 50,000 population</td>
<td>255</td>
</tr>
<tr>
<td>OMB</td>
<td>Consolidated Metropolitan Statistical Area (CMSA)</td>
<td>An MSA with at least 1,000,000 population AND multiple component areas with 50,000 or more inhabitants</td>
<td>18</td>
</tr>
<tr>
<td>OMB</td>
<td>Primary Metropolitan Statistical Area (PMSA)</td>
<td>A component area of a CMSA</td>
<td>73</td>
</tr>
<tr>
<td>Bureau of Economic Analysis (BEA)</td>
<td>Component Economic Area (CEA)</td>
<td>An MSA combined with the non-metropolitan counties to which it is most closely related</td>
<td>348</td>
</tr>
<tr>
<td>BEA</td>
<td>Economic Area</td>
<td>An aggregation of CEAs, oriented in order to minimize cross-border commuting</td>
<td>172</td>
</tr>
<tr>
<td>US Department of Transportation (USDOT)</td>
<td>National Transportation Analysis Region (NTAR)</td>
<td>An aggregation of BEA’s, oriented so that the borders encompass the hinterland for the region’s long-distance terminals</td>
<td>89</td>
</tr>
</tbody>
</table>

**Table 5-3: Summary of US Government Regional Designations**
Based on the three criteria established in the previous subsection, the most appropriate regional designation for purposes of constructing a regional architecture is the Component Economic Area (CEA). Table 5-4 summarizes the ways in which CEAs satisfy some of the most important “regional criteria”.

<table>
<thead>
<tr>
<th>Regional Criteria</th>
<th>CEA Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically-motivated, metropolitan-based</td>
<td>Possesses a single Metropolitan Statistical Area at its core</td>
</tr>
<tr>
<td>Dynamic in form, shifting with ebb and flow of economic activity</td>
<td>Is flexible in form, being reevaluated at the conclusion of each Census</td>
</tr>
<tr>
<td>Not confined by political jurisdictions</td>
<td>Transcends city limits and state borders, although confined to national borders</td>
</tr>
<tr>
<td>Should cover entire geographical area of the nation</td>
<td>Covers the entire geographical area of the US, attaching all non-metropolitan counties to the MSAs with whom they have the closest economic ties</td>
</tr>
<tr>
<td>Should conform to existing regional designations</td>
<td>Is designated by the Bureau of Economic Analysis</td>
</tr>
</tbody>
</table>

Table 5-4: Comparing Regional Criteria to Component Economic Areas

In short, CEAs provide a mechanism for capturing the economic impact of a metropolitan area in well-defined geographical space. In doing so, they provide a good geographical foundation upon which a regional transportation plan can be built. Nevertheless, CEAs do have one major shortcoming—they do not transcend national borders. Thus, the Bureau of Economic Analysis, in conjunction with the Census Bureau, should expand the scope of both MSAs and CEAs to encompass international regions. This would constitute an important first step toward breaking through the “nation as economy” mindset and recognizing the importance of regional economic activity.

5.1.2.3 Summary: Chapter 3 contributions to “regional architecture” definition

Based on the previous review of regional characteristics and designations, one can identify a series of characteristics that a new definition of “regional architecture” should possess. These characteristics are summarized in Table 5-5.
A regional architecture should be oriented toward planning, operating, and managing the transportation system at the regional level.

The term "region" in "regional architecture" should refer, geographically speaking, to the area encompassed by an economic region.

The Component Economic Area (CEA) is the regional designation that conforms most closely to the regional characteristics noted by many "regional" authors.

Each CEA is centered on a Metropolitan Statistical Area, and each MSA has a designated Metropolitan Planning Organization (MPO). Therefore, MPO's should play a primary role in the development of a regional architecture.

Table 5-5: Regional Characteristics Suggested by Chapter 3

<table>
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</tbody>
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5.1.3. Review of Chapter 4: "Regional Architectures" and the National Architecture

In order to arrive at a definition of "regional architecture", it is important to understand the genesis of the term. With that goal in mind, Chapter 4 examined the National Architecture's treatment of "regional architectures". It sought to examine the context from which it emerged and the concept that it originally embodied.

In essence, Chapter 4 helped to put a "face" on some of the more theoretical concepts noted in the previous two chapters. The Implementation Strategy document, in some ways, represented a first attempt at constructing a regional architecture. It was an ambitious effort, endeavoring to merge the theoretical notions of architecture development with the realities of the transportation planning process. Chapter 4 critiqued this effort, noting both its successes and its shortcomings. In doing so, the chapter attempted to further identify what a regional architecture might actually look like.

Based on a review of the National Architecture, Chapter 4 proposed several important characteristics of a regional architecture. These proposals are summarized in Table 5-6.
A regional architecture should consist of the following 5 elements:
- User services
- Regional institutions
- Lines of responsibility
- Lines of communication
- Data flows

The regional architecture development process should include:
- Identifying the user services/market packages that the region wishes to deploy;
- Identifying which National Architecture-defined subsystems are needed in order to implement these services; and
- Identifying which regional institutions will perform the functions defined by these subsystems.

Subsystems should not be a part of the final regional architecture.

In developing a regional architecture, one must address the following questions:
- How will information be distributed? Centralized? Decentralized? Hybrid?
- In what way will costs place a constraint on the architecture?
- How will multiple entities performing similar functions relate to one another? With centralized control? Decentralized control?
- In what way will the region accommodate the additional responsibilities created by ITS deployments? By assigning them to existing entities? Or creating a new entity?
- What will be the geographic scope of the architecture?
- What sorts of compatibility requirements does the architecture present? Which interfaces require national interoperability? Regional interoperability? No interoperability?

Table 5-6: Regional Architecture Characteristics Proposed by Chapter 4

5.2. Broadening the Perspective

Thus far, the thesis has proceeded under the implicit assumption that regional architectures should support only ITS services. This follows from the vision set forth by the National Architecture, which simply viewed them as a tool for supporting regional ITS deployments.

83 In his Masters thesis, Rodriguez referred to questions like these as “Architecture Aspects”. The set of responses to these questions constituted the “Architecture Attributes”. 
However, it is worthwhile to consider how the architecture concept might be broadened in order to apply to all services in which the exchange of information can assist the performance of the transportation system. These services need not fall under the rubric of Intelligent Transportation Systems. A wide variety of so-called "conventional services"—from plowing the roads to conducting intermodal transfers to maintaining grade crossing signals—require institutions to exchange information.

The following list summarizes some of the motivations for adopting a "broader" approach to regional architectures.

- Many of the non-ITS services\textsuperscript{84} that provided by a region require coordination among multiple agencies. For example, a region with multiple transit agencies could benefit if the agencies coordinated their schedules and routes. Furthermore, if the region was undergoing extensive road construction, those agencies could benefit from receiving road closure information from the Highway Department. A regional architecture could provide a framework for providing this coordination.

- Many transportation professionals have noted the importance of intermodalism. The provision of smooth and efficient transfers between modes can play a critical role in supporting more efficient use of the existing transportation infrastructure. A regional architecture can provide a framework for coordinating the efforts of the institutions that operate and maintain the various modes.

- The rural hinterlands outside the metropolitan core also face the need for coordinated transportation services. For example, rural intermodal shipments during snowy weather can be delayed if the roads to the rail siding are not cleared in time to make the daily train departure. Broadening regional architectures to include coor-

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\textsuperscript{84} The term “non-ITS services” can encompass a wide variety of transportation services. In fact, the border between ITS and non-ITS services can become very blurry. For example, a taxi cab service would not be considered an "ITS" service. However, the use of an autonomous in-vehicle navigation device by the cab driver would be considered an ITS service. Thus, one could say that, in this situation, an ITS service (route guidance) is supporting a "conventional" transportation service (taxi cab).

For the sake of simplicity, this thesis will simply break the world of transportation services into 2 categories—ITS and non-ITS. All services directly supported by the National Architecture will be considered ITS services. All other services will be considered "non-ITS," from maintaining a road to running transit buses. This thesis supports the view that all services that require cooperation of (and hence the exchange of information among) multiple institutions should be included in and supported by the regional architecture.
dination of non-ITS services can make the architecture concept relevant to the rural sections of the region as well as the metropolitan sections.

- Regions that do not have a current need for ITS may wish to deploy ITS systems in the future. Having a regional architecture already in place that governs the existing non-ITS services would facilitate these future deployments.

- Moreover, the exercise of coordinating transportation services can support a still broader objective—the adoption of a systems perspective to transportation. Prominent transportation professionals such as Larry Dahms have noted that the “Interstate model” remains dominant in the minds of many Congressmen.85 This model has two underlying characteristics. First, it contends that the answer to transportation problems is the provision of more infrastructure. And second, it views each mode in isolation, failing to consider how the various modes interact.

The development of a regional architecture that supports the integration of transportation services is one way of shifting away from the “Interstate model”. First, by focusing on transportation services, a regional architecture presents a forum in which a region can consider alternate solutions to transportation problems. This represents a shift away from the “build more infrastructure” perspective. And second, by explicitly considering how various transportation institutions interact, a regional architecture also considers how various modes interact. This represents a shift away from the “modes in isolation” perspective.

In short, there are at least three reasons for expanding the regional architecture concept to include both ITS and non-ITS transportation services. First, this approach acknowledges that provision of transportation services of all types is fragmented, with nominal coordination among the service providers. Thus, the need for institutional cooperation is not unique to ITS deployments. Second, this approach recognizes that most of the “action” in the transportation world is in the non-ITS realm. If the architecture concept is to be helpful, it should be applied there as well. And third, this approach recognizes that many regions may wish to delay the deployment of ITS services to some future date.
Constructing a regional architecture that is oriented toward existing non-ITS transportation services can proactively address the future expansion of ITS in these regions by providing a deployment framework in advance.

The next two sections will present the “broader” concept of a regional architecture in more detail. Section 5.3 will propose a definition for the term, while section 5.4 will propose a method for constructing a regional architecture.

5.3. Defining “Regional Architecture”

The various characteristics of a regional architecture noted in the previous two sections suggest the following definition:

A regional architecture is a framework that describes how various transportation institutions will interact in order to provide an integrated series of transportation services in a metropolitan-based region.

This definition incorporates several important characteristics that were emphasized in the previous two sections. The following points elaborate on these characteristics.

- The provision of coordinated transportation services is the primary motivation for a regional architecture.
- A regional architecture should support both “conventional” and advanced transportation services.
- The goal of a regional architecture should be to support a “regional transportation system”. A regional transportation system appears to the user as a coherent and unified network, not a fragmented array of independently provided services.
- A regional architecture should focus primarily on the movement of goods and people within the confines of an economic region. However, because the economic vitality of a region is also related to interactions with other regions, a regional architecture

85 “Transportation: Show Me the Money!” --Presentation by Larry Dahms, Director of the Metropolitan Transportation Council, at MIT, 27 March 1998.
should also recognize the importance of supporting interregional flows of goods and people.

- A regional architecture should contain the five key elements noted in section 5.1. That is, it should include institutions, user services, lines of responsibility, lines of communication, and information flows.

This definition provides a good description of what a regional architecture is, and it highlights its major characteristics. However, it leaves three important questions unanswered: What does a regional architecture actually do? What does a regional architecture actually look like? And how does one go about constructing a regional architecture? The next section will address these questions in detail through the use of an illustrative example.

5.4. Constructing a Regional Architecture: An Illustrative Example

In the absence of an example, the “regional architecture” concept can remain theoretical and vague. In order to clarify the concept, it will be helpful to provide a simple example of how a particular region might actually construct a regional architecture. This section will provide such an example.

Section 5.4.1 will start by describing a fictional 3-city region. It will describe the physical layout of the region, the existing institutional structure, and the existing transportation services. It will also provide a list of new transportation services that the region would like to deploy.

Section 5.4.2 will then propose and demonstrate a four-stage approach to constructing a regional architecture. It will build on the foundation laid by the National Architecture, and it will introduce some of the new architecture concepts mentioned earlier in this chapter. This subsection will conclude with a sample regional architecture for the illustrative region.
5.4.1. The “Greater Jefferson Metropolitan Area”

This section will use a fictional region known as the “Greater Jefferson Metropolitan Area” in order to describe, in detail, the process of developing a regional architecture. Figure 5-1 provides the physical layout of this simplified metropolitan region.
Overview of the region

As the diagram reveals, the Greater Jefferson Metropolitan Area consists of three distinct jurisdictions—one central city (known as Jefferson) and two smaller adjacent cities (known as Fillmore and Clinton). Each jurisdiction has a central business district (CBD) that serves as the city’s employment center. The region’s one airport, known as the Jefferson International Airport, is located in Clinton. One interstate runs through the region, traversing both Jefferson and Clinton. A number of four-lane arterials connect the CBD’s to the airport, to each other, and to neighboring regions.

Commuting flows

During peak travel hours, trips originate from various points throughout the region and terminate in one of the CBD’s. Jefferson is the economic epicenter of the region; most of the region’s industries reside in Jefferson’s CBD. Accordingly, Jefferson draws its labor force from throughout the region. Fillmore and Clinton have much more modest business districts. However, they also draw their labor force from throughout the region, creating a modest amount of city-to-suburb and suburb-to-suburb travel.

Existing transportation institutions and services

The State Turnpike Authority (STA)

The State Turnpike Authority operates the limited access highway that runs through the region. The turnpike provides four exits in the Greater Jefferson Metropolitan Area (known hereafter as the “Jefferson region”). Exit 1 provides access to arterial A1, which links the Fillmore CBD with the Jefferson CBD. Exit 2 provides access to arterial A2, which connects the Jefferson CBD to the airport. Exit 3 provides access to arterial A3, which connects the Clinton CBD to points north. Exit 4 provides access to arterial A4, which connects Fillmore and Clinton.

The STA has recently implemented an electronic toll collection system along the entire length of the highway within the state’s borders. About 50% of the region’s commuters have already purchased a transponder from the STA, which costs about
$25. The transponders produce a tremendous amount of traffic information for the STA, including (a) an estimate of the number of travelers on any particular turnpike link; and (b) the average speed on any link. The STA is also thinking about deploying a set of Variable Message Signs (VMS's) along the highway. These signs could use the data acquired from the transponders to provide travelers with information on turnpike travel conditions.

WJAM Newsradio

One radio station, WJAM Newsradio in Jefferson, provides traffic information to residents of the region. At the moment, the radio station gathers its own traffic information. This information comes from one of two sources:

- Cellular phone calls from travelers (the so-called “WJAM cell-phone force”)
- A privately-owned helicopter that traverses the region during rush hour

Traffic Operations Centers (TOCs)

Each city has a traffic operations center (TOC) that controls traffic signals within its jurisdiction. Each TOC is responsible for (a) monitoring traffic conditions within its jurisdictional boundaries, and (b) identifying and responding to local traffic incidents. The TOCs have two primary sources of information by which they keep abreast of local traffic:

- Each TOC monitors a set of loop detectors, placed at all major intersections within the jurisdiction. The feedback from the loop detectors can be used to identify significant traffic jams; however, the feedback is not specific enough to tell how long a queue is at a particular intersection.
- Additionally, each TOC monitors a “hotline”, by which travelers can make a toll-free cellular phone call and report serious incidents. When the TOC detects an incident, it notifies the police department and the fire department.

Transit Agencies

Each city also has a provider of public transportation. The three transit agencies in the region are the “Jefferson Metro”, the “Clinton Bus Service”, and “Fillmore Tran-
sit". Each transit operator provides two types of service: Express service that trans-
ports people from outlying areas to the CBD, and local service that transports people
within the CBD. Each transit agency operates solely within the borders of its corre-
sponding jurisdiction. For example, the Fillmore Metro buses do not operate within
either Jefferson's or Clinton's city limits.

Each transit agency monitors its services through an operations center. Each op-
erations center has radio communication with its buses. Communication is two way:
The bus drivers can report service disruptions to the operations center, and the op-
erations center can deliver instructions to the bus drivers. Additionally, each transit
agency has some extra buses, which can be used in emergencies or special events.

Jefferson Airport Council

A quasi-public entity known as the "Jefferson Airport Council" is in charge of the fa-
cilities at Jefferson International Airport (JIA). The Council also operates the access
road that connects arterial A2 to the airport. This road can become quite congested
in the morning hours, as commuter flights carry many of the region's business trav-
elers between 6:00 am and 7:30 am. A toll of two dollars is charged to all vehicles
that access the airport. The Council, which plans on converting to electronic toll
collection within the next twelve months, uses this toll facility to finance terminal and
runway maintenance.

Jefferson International Airport is home to several commuter airlines that operate
primarily in the morning and evening hours. At night, the airport serves both UPS
and FedEx freight shipments.

Jefferson Regional Planning Council

The Jefferson Regional Planning Council (JRPC) is the designated MPO for the re-
gion. It is comprised of representatives from each of the three jurisdictional govern-
ments, with the Jefferson delegation receiving proportionately higher representation
due to its larger population. Additionally, the TOCs, the transit agencies, the State
Turnpike Authority, and the Jefferson Airport Council each have one representative on the JRPC. The Jefferson Regional Planning Council is responsible for developing a Transportation Improvement Plan each year, as well as a 20-Year Strategic Transportation Plan every four years.

5.4.2. Constructing a regional architecture for the Jefferson region
The previous subsection identified the region’s infrastructure and examined the underlying institutional structure. This subsection will build on this foundation by proposing a four-stage procedure for constructing a regional architecture. The first few paragraphs will describe the procedure. Then, subsections 5.4.2.1 through 5.4.2.6 will apply the procedure to the Jefferson region.

Stage I: Identify the user services that the region would like to implement
Before one can construct a regional architecture, one must first determine which services the region would like to deploy. This is usually determined through public outreach on the part of the transportation planning community.

Stage II: Analyze the ITS Services
The second stage of the procedure requires the region to individually analyze each ITS service. At the end of Stage II, the region should have a collection of “service architectures”—one service architecture per ITS service.

At this point, it will be important to define the term “service architecture”. This term is not used anywhere in the National Architecture. It is unique to this thesis, and it is introduced as an intermediate step in the development of a regional architecture. The term is defined as follows:

A service architecture is a framework that describes how various institutions will interact in order to provide a single transportation service to the region. It contains the same components as a regional architecture; the only difference is that it only supports the implementation of one service.
In Stage II, a service architecture will be constructed for each ITS service. This involves a five-step process.

- In step 1, each ITS service will be broken down into subsystems and data flows, based on guidance provided in the National Architecture.
- In step 2, the subsystems and data flows will be mapped to the National Architecture’s “sausage diagram” (also known as the “physical architecture”). This diagram was originally presented in Figure 2-8 (section 2.3.4.4).
- In step 3, the institutions that provide these services will be identified. The types of data possessed by each institution will also be identified in this step.
- In step 4, decisions will be made concerning how these institutions will relate to one another concerning the provision of the service. These decisions will involve resolving issues of decision-making and control.
- In step 5, a “service architecture” will be constructed for each service. As mentioned above, each service architecture will contain the five elements of a regional architecture. This includes (a) the user service to be implemented; (b) the institutions that will implement these services; (c) lines of responsibility identifying the institutions that will implement the services; (d) communication links that will connect these institutions; and (e) information flows along these communication links.

**Stage III: Analyze the non-ITS Services**

After the service architectures are constructed for the ITS Services, the region must do the same for the non-ITS services. However, the procedure for constructing a service architecture in support of a non-ITS service differs in at least two ways. First, the National Architecture does not provide any guidance on the construction of a regional architecture that supports non-ITS services. Thus, steps 1 and 2 of Stage II are not relevant to Stage III. And second, a non-ITS service may include information that is not passed on in “real-time”. Thus, its corresponding service architecture must distinguish between “real time” and “non-real time” (or planning) information flows.

The process for constructing a service architecture for a non-ITS service consists of three steps:
- In *step 1*, each service will be broken down into the institutions that are needed in order to provide the service.
- In *step 2*, decisions will be made concerning institutional relationships. This step requires one to (a) consider the possibility of creating a new institution; (b) precisely define the service; (c) determine who will be responsible for providing the service; and (d) determine how information will be distributed among the various institutions.
- Lastly, in *step 3*, a “service architecture” will be constructed. It will identify the same five basic components used to characterize the ITS service, while making a clear distinction between planning and real-time information flows.

**Stage IV: Aggregate the Service Architectures to create the Regional Architecture**

Once all of the service architectures are constructed, they are combined in order to create the regional architecture. Expressed mathematically, one could say that the regional architecture equals the sum total of all service architectures. Some of the issues related to the aggregation of service architectures will be addressed in Chapter 6.

Subsections 5.4.2.1 through 5.4.3.6 will demonstrate how this procedure may be applied in the Jefferson region.

- Subsection 5.4.2.1 will illustrate Stage I of the procedure, resulting in a list of services that the region would like to deploy.
- Subsections 5.4.2.2 through 5.4.2.4 will illustrate Stage II, resulting in service architectures for each of the ITS services selected by the region.
- Subsection 5.4.2.5 will illustrate Stage III, resulting in a service architecture for the non-ITS service selected by the region.
- Subsection 5.4.2.6 will illustrate Stage IV, in which the service architectures are aggregated to form a regional architecture. This section will also address some different ways in which the regional architecture may be formatted.
5.4.2.1 Stage I: Identify the user services that the Jefferson Region would like to deploy

The JMPC recently completed a public outreach program, in which it solicited feedback on the performance of the regional transportation system. The outreach program consisted of four different public forums—two held in Jefferson, one in Clinton, and one in Fillmore. At the forums, residents mentioned several concerns about the current performance of the transportation system. The most commonly cited problems were as follows:

a) The transit system was not very supportive of people who lived in one city but worked in another. Workers who commuted via transit between cities needed to take an outbound bus on the first leg of the journey, and then transfer to an inbound bus operated by a different transit agency for the second leg of the journey. The interagency transfers were difficult for two reasons. First, the bus schedules for the different agencies were not coordinated. And second, the bus routes did not always overlap. That is, the last stop for one city’s outbound bus was, in some cases, nearly a half mile away from the first stop of the adjacent city’s inbound bus.

b) All four turnpike exits became very congested during the morning and evening rush hours. This was primarily due to the fact that the traffic signals located near the off-ramps did not change their signal pattern despite the heavy rush hour traffic volumes. The congestion tended to create unsafe conditions, creating traffic backups onto the turnpike at times.

c) The first commuter planes departing from JIA left at 6:00 am. However, the first bus did not arrive at JIA until 6:15 am. Thus, early commuters could not take the bus to the airport.

d) There was concern that the new electronic toll collection scheme planned for the airport access road would not be compatible with the turnpike’s existing ETC scheme.

e) Very little accurate traffic information was available in real time to the public. WJAM provided traffic reports every half-hour, but the infrequent service was often unreliable.
f) Traffic incidents often took an hour or more to clear. Although the road crews removed the incidents quickly once they arrived, the time from the incident to the arrival of the crews was often quite slow.

Desired regional transportation solutions
After receiving this feedback, the JRPC assembled in order to determine a plan of action. The Council identified four services that (a) could be readily implemented using existing technology; and (b) would address at least some of the aforementioned transportation problems. These services were:

- Surface street control
- Public broadcast of traveler information
- Incident management
- Coordination of transit agency schedules

The first three services can be considered as ITS user services, while the fourth has a more “conventional” orientation.

The identification of the user services that the region would like to deploy concludes Stage I of the regional architecture development process. Sections 5.4.2.2 through 5.4.2.4 will now address Stage II—the construction of a service architecture for each of the three ITS services.
5.4.2.2 ITS Service #1: Surface Street Control

The purpose of this service is to resolve rush-hour congestion problems caused by locally controlled traffic signals at the Turnpike exits. The following step-by-step procedure that follows will translate this service into a "service architecture" that will govern its deployment.

**Step 1: Identify subsystems and data flows**

"Surface Street Control" is identified by the National Architecture as one of 56 specially designated "market packages". The National Architecture designed these market packages in order to provide planners with a refined view of the more generally defined user services. In order to provide ITS implementers with some "visibility" into how these market packages might be deployed, the Implementation Strategy breaks each package down into three fundamental components: subsystems, equipment packages, and data flows. Figure 5-2 is an excerpt from the Implementation Strategy that describes the Surface Street Control market package.

![Figure 5-2: Surface Street Control Market Package](image)

In order to understand this diagram, a short explanation is appropriate.

- The large, shaded blocks are two of the nineteen ITS subsystems defined by the National Architecture. These subsystems can be mapped directly onto the physical architecture, or "sausage diagram", depicted in Figure 2-8.

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86 National ITS Architecture, Implementation Strategy, pg. A-1. For more information on subsystems and equipment packages, consult section 2.3.4.3 of this thesis, as well as Appendix A to this thesis.


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• The smaller, clear blocks represent three of the 111 equipment packages defined by the National Architecture. Each equipment package is a physical set of ITS resources that performs a particular function. In the words of the Implementation Strategy, “Equipment packages represent the lowest level of decomposition identified by the Physical Architecture.”

Equipment packages play a dual role in providing structure to the National Architecture. First, they serve as the fundamental building blocks of each subsystems. That is, each subsystem is assigned a unique set of equipment packages; no two subsystems possess the same equipment package. Secondly, they serve as the fundamental building blocks of market packages. That is, each market package consists of an array of selected equipment packages. Consequently, the subsystems that “own” these equipment packages also become part of the market package.

• The arrows represent the types of data that are exchanged between the subsystems. The Logical Architecture document defines each data flow in more detail. However, for purposes of constructing a regional architecture, the high-level view of data exchange represented here will suffice.

A more detailed explanation of the National Architecture terminology used in this chapter can be found in Appendix A to this thesis.

Step 2: Map subsystems to the physical architecture
Figure 2-8 in section 2.3.4.4 depicted the “physical architecture” as defined by the National Architecture. The physical architecture represents a merging of the 19 subsystems with the lines of communication that link them together. Figure 5-3 illustrates how the Surface Street Control market package maps into the physical architecture.

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The physical architecture diagram provides very little detail concerning how the system actually functions. It simply illustrates how the two subsystems should connect to each other as they provide the Surface Street Control service. In this instance, a wireline connection (such as a phone line) will allow the traffic management subsystem to communicate with its roadside infrastructure.

A comparison of the market package diagram with the physical architecture diagram leads to four interesting observations. First of all, the market package diagram describes data flows, while the physical architecture diagram does not. Second, the physical architecture diagram describes the communication medium connecting the two subsystems, while the market package does not. Third, the physical architecture diagram states nothing about the particular services being supported, whereas the market

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89 Diagram extracted from National ITS Architecture, Implementation Strategy, pg. 2-4.
package diagram explicitly supports a particular service. Fourth, neither diagram includes institutions; they are centered solely on functionally defined subsystems.

Based on this analysis, it is evident that neither diagram provides a complete picture of the Surface Street Control service. Rather, they provide complementary images of potential ITS deployments. However, before the picture can be complete, it is necessary to identify which institutions will actually provide the service.

**Step 3: Identify the institutions**

In this scenario, three institutions will be required to deploy Surface Street Control throughout the region.

- **The State Turnpike Authority.** The STA manages the turnpike that delivers automobiles to the congested intersections. As section 5.4.1 pointed out, the STA has just implemented electronic toll collection on the turnpike. This new service provides the STA with three important pieces of information.
  - First, by monitoring the tollbooths on the off-ramps, the STA knows in real time how many vehicles are approaching the congested intersections.
  - Second, by monitoring the tollbooths on the on-ramps as well, the STA can determine in real time the number of vehicles on any particular turnpike link.\(^{90}\)
  - Third, by monitoring the movement of individual transponders, the STA can determine average travel speeds on each turnpike link. If average speeds suddenly decrease, this may be a sign that a particular exit ramp has become particularly congested.

- **The Jefferson Traffic Operations Center.** The Jefferson TOC controls the traffic signals at the intersections by exits 1 and 2. The TOC can identify extended periods of congestion by monitoring the loop detectors at each intersection.\(^{91}\) However, they cannot determine the length of the queue, nor can they determine if traffic has been backed up onto the turnpike.

\(^{90}\) A link is defined as the stretch of road between any two exits on the turnpike.

\(^{91}\) See section 5.4.1 to review the technical capabilities of the Traffic Operations Centers.
• The Clinton Traffic Operations Center. The Clinton TOC controls the traffic signals at exit 3. This TOC possesses the same capabilities and faces the same constraints as the Jefferson TOC.

**Step 4: Make decisions concerning institutional relationships**

Step 3 revealed a very important fact: The functions defined for the “Traffic Management” subsystem will actually be performed by three different institutions. However, before the service can be deployed, it will be necessary to determine how these institutions will relate to one another.

The most obvious short-term solution to the congestion problem is to alter the traffic signal light cycles during rush hour. The market package diagram in Figure 5-2 seems to suggest this. It calls for the Traffic Management Center to send new “signal control data” (i.e. changes in the light cycle) to the traffic light in response to changes in the status of traffic at the intersection. However, this strategy leaves one key question unanswered: Who will decide how to operate the traffic lights? In other words, who will make the decisions concerning when and how to alter the light cycles in order to reduce congestion at the busy intersections? In this situation, there are three possibilities—the STA, the individual TOCs, or some central authority. Each possibility has some advantages and disadvantages.

• The STA. The primary advantage of this option is that the STA has the best knowledge of the traffic flow feeding into the various intersections. They would be able to anticipate heavy off-ramp volumes in advance and proactively adjust the signal timing to avoid congestion. However, there are two disadvantages to this option. First, the STA would make decisions based solely on turnpike traffic. Thus, they would be unable to account for problems created by traffic on the local roads feeding into the same intersections. Second, the STA does not currently have access to the signal controls. Therefore, new control devices would need to be constructed in order to hand over the signal controls to the STA.
- **The TOCs.** The primary advantage of this option is that it requires the least change, since the TOCs already control the signal timing. Another advantage is that the TOCs can adjust their signal control strategies to account for local traffic conditions. The biggest disadvantage is that the TOCs currently do not possess enough information to efficiently operate the signals. In order to time the light cycles appropriately, the TOCs would need to have information on the status of traffic at the turnpike's off-ramps. This, in turn, would require an influx of information from the STA.

- **A central authority.** The primary advantage of having a central authority operate the traffic signals is that they would presumably operate in the best interests of all regional travelers. In other words, they would endeavor to serve the interests of both the turnpike travelers (served by the STA) and the local travelers (served by the TOCs). However, implementation of this option faces one large hurdle—the institution does not exist yet. Creating a single authority to govern such services can be expensive, both from a financial standpoint (it would require employing a new staff and installing new equipment) and from a political standpoint (the TOCs might be reluctant to relinquish control to an authority that may not share their operational priorities).

In this scenario, it seems most appropriate to let the TOCs retain control over the traffic signals. First, it would be a logical extension of their current responsibilities. Second, it would minimize the amount of new infrastructure that would need to be constructed. And third, it would require the least institutional change. However, in order to enable the TOCs to make more informed traffic management decisions, the STA should provide the TOCs with information on traffic flows.

**Step 5: Constructing the “service architecture”**

Having identified the institutional relationships and the decision-making structures, it is now appropriate to construct the “service architecture”. This architecture will provide the institutional framework for deployment of the “Surface Street Control” market package. One possible service architecture, which reflects the information discussed and the decisions made in steps 1 through 4, is depicted in Figure 5-4.
This diagram contains all five of the “architecture components” noted in section 5.1.

- **User services.** The smaller, unshaded boxes represent the user services that the region wishes to deploy. Since this is a “service architecture”, only one service (by definition) is depicted.

- **Institutions.** The large, shaded boxes represent the institutions that are involved in the deployment of the user service.

- **Lines of responsibility.** The lines that connect institutions to the user services are referred to as “lines of responsibility.” They indicate that a particular institution has some measure of control over the provision of the service. In this example, the solid line connecting the Jefferson Traffic Operations Center with the “Surface Street Control” box indicates that the TOC has operational control over the service.

Each line of responsibility has a level of interoperability assigned to it. In this example, both lines of responsibility have a box with an “R” next to them, indicating that the technology used to implement the services in each city should be interoperable.
at the regional level. This would allow the cities of Clinton and Jefferson to integrate their traffic control systems at a later date, if so desired.

- *Lines of communication.* The arrows that connect the State Turnpike Authority to the two Traffic Operation Centers represent lines of communication. In this case, information is distributed in a somewhat decentralized fashion. A centralized communication structure would have the STA submit its information to a centrally located database. Each TOC would be required to draw its information from the database, rather than receive it directly from the State Turnpike Authority.

- *Data flows.* The information located next to the arrows represents the data flows. In this scenario, the State Turnpike Authority is required to provide traffic information to each TOC. The data flows are described at a high level and with little detail, similar to the data flows noted in the market package diagram. The purpose of identifying data flows is simply to describe the *types* of information that need to be exchanged between the institutions.

It is also appropriate to highlight three key points concerning the “service architecture” diagram.

*First,* the “Center” subsystems are not a part of this diagram. In this example, though the “Surface Street Control” market package included one such subsystem (Traffic Management), this subsystem does not appear on the service architecture. This is because subsystems simply describe the functions that the architecture must perform. Once the institutions that provide these functions are identified, there is no longer a need to label the subsystems.

*Second,* the equipment packages that were identified in the market package diagram are not included in the service architecture. The equipment packages constitute a lower level of detail that a regional architecture need not include.
**Third,** all other subsystems—that is, the Roadside, Traveler, and Vehicular Subsystems—are excluded from this diagram. Each of these subsystems represents “transportation hardware” of some sort, such as a transponder, a tollbooth, or a kiosk. For purposes of developing a regional architecture, these subsystems are better considered as part of the regional infrastructure. The goal of the regional architecture is simply to structure institutional relationships so that they support the operation of the infrastructure in the region.

It is this point that distinguishes the regional architecture from the technical framework of the National Architecture. The regional architecture is not a technical document. It lets the technical functions of the ITS deployments rest on the details provided in the National Architecture. Rather, the regional architecture *supplements* the National Architecture. It recognizes that the ability to coordinate technical systems depends on parallel coordination of the institutions that operate these systems. In short, it provides an institutional framework that supports the technical framework provided by the National Architecture.

In summary, it is helpful to review the five steps that were used to develop a “service architecture”, noting the key functions and contributions of each step.

- **Step 1** involved identifying the subsystems and data flows that accompanied the service being analyzed. In this example, the region selected a service—Surface Street Control—which corresponded with one of the National Architecture-defined market packages. In such instances, one can extract the appropriate subsystems and data flows directly from the *Implementation Strategy*. This step served three purposes. First, it identified the types of institutions that will be required to deploy the service (in this case, “Traffic Management”). Second, it indicated the types of data flows that need to be exchanged among these institutions. And third, it provided guidance on the appropriate level of detail for these data flows.
• **Step 2** involved mapping the subsystems identified in step 1 to the physical architecture. In this example, two subsystems (Traffic Management and Roadway) were mapped into the architecture and connected by a wireline communications link. This step served two purposes. First, it provided an overview of the technical framework that the regional architecture will support. And second, it provided a broader context for the ITS deployment under consideration, showing how individual market packages fit into the overall National Architecture framework.

• **Step 3** involved identifying the institutions that would be responsible for deploying the ITS service under consideration. In this case, three different institutions—the State Turnpike Authority, the Jefferson TOC, and the Clinton TOC—were identified as having a role in implementing the “Surface Street Control” market package. This step also involved identifying the types of information possessed by each institution. Step 3 served two main purposes. First, it translated the functionally defined subsystems into actual institutions. And second, it identified the assets that each institution could contribute toward deploying the service.

• **Step 4** involved making decisions concerning institutional relationships. In this case, decisions were made concerning how the STA, the Jefferson TOC, and the Clinton TOC would relate to one another as they provided the “Surface Street Control” service. This step served three purposes. First, it addressed the issue of information distribution (i.e. centralized vs. decentralized). Second, it addressed the issue of institutional change (i.e. assign responsibilities to existing entities vs. creating a new entity). And third, it provided a framework for decision-making (i.e. centralized vs. decentralized control).

• **Step 5** involved the construction of the “service architecture”, as shown in Figure 5-4. It translated the information provided and the decisions made in the first four steps into a visible deployment framework.
At this point, service architectures for each of the other services can be constructed. Once these have been completed, the sketches can be “aggregated” in order to create the regional architecture.
ITS Service #2: Public broadcast of traveler information

The purpose for deploying this service is to inform travelers about areas of traffic congestion in the Jefferson region. In particular, this service is aimed at providing information on traffic flows in the Central Business Districts and on the turnpike. Once again, the five step procedure will be used to construct a "service architecture", which will specify how the region’s institutions must interact in order to implement the service.

Step 1: Identify subsystems and data flows

This service conforms very closely to the “Broadcast Traveler Information” market package identified by the National Architecture. Figure 5-5, excerpted from the Implementation Strategy document, describes the subsystems and data flows involved in providing this service.
Figure 5-5: Broadcast Traveler Information Market Package

This diagram is considerably more complex than the "Surface Street Control" diagram. To explain:

- This diagram includes two subsystems (Traffic Management and Transit Management) that are not shaded. These represent subsystems that participate in the deployment of the market package through data sharing. In other words, the unshaded subsystems support the deployment of the service, but they will not be responsible for the deployment itself. The equipment packages that support the data sharing (i.e. through collecting traffic and transit information) are specified as parts of separate market package.

93 The equipment packages that support the data sharing operations of the Traffic Management subsystem are found in four different market packages: Incident Management, Traffic Network Performance Evaluation, Virtual TMC and
This diagram involves three different Center subsystems. The Information Service Provider (ISP) subsystem represents the entity (which could be a single institution or group of institutions) that will broadcast travel information to the public. The Transportation Management and Transit Management subsystems are the entities that will provide information on the state of the network to the ISP. In other words, the ISP will receive information from the Transportation and Transit Management subsystems, package it in a meaningful and useful way, and distribute it to the public.

The other three subsystems depicted in the diagram represent three different ways that the ISP can broadcast information to the public. The first way is to broadcast information to individual vehicles. One example of this would be to distribute travel information over AM radio. The second way is to broadcast information to “Remote Traveler Support” locations. An example of this would be the distribution of travel information to remotely located kiosks, located in prominent places and accessible to the public. The third way is to broadcast information to “Personal Information Access” locations. An example of this would be to publicize traveler information on the Internet, which individuals would be able to access from their home computers.

It is important to distinguish between what the market package supports and what the market package requires. The market package supports the broadcast of traveler information over multiple modes of communication. However, it does not require the ISP to use all of these modes. An ISP could select a single distribution channel (such as AM radio broadcasts) and be consistent with the guidance provided in this diagram.

Because this market package supports multiple traveler information applications, the region must select the specific applications that it would like to deploy. For purposes of this scenario, it is assumed that the region would simply like to have traveler information broadcast over the radio. At this time, the region is not interested in distributing information in other ways.

Smart Probe Data, and Railroad Operations Coordination. The equipment packages that support the data sharing operations of the Transit Management subsystem are found in 3 different market package diagrams—Transit Vehicle Tracking, Transit Fixed Route Operations, and Demand Response Transit Operations. Please see Appendix A of the Implementation Strategy for more information.

The functions defined for Center subsystems closely correspond to functions defined for institutions. Therefore, the names of the Center subsystems suggest regional institutions that will need to be involved in service deployment. See Section 2.3.4.3 and Appendix A to review the four different categories of subsystems.
mation over the Internet, nor is it interested in constructing kiosks to display traveler information. However, the region is open to the idea of pursuing a more sophisticated method of traveler information services in the future. (Chapter 6 will explore this option.)

Step 2: Map subsystems to the physical architecture

The choice to restrict the “Broadcast Traveler Information” market package to radio information is important in that it eliminates two of the subsystems identified in Figure 5-5. The “Remote Traveler Support” and “Personal Information Access” subsystems are no longer needed in order to deploy the service. Figure 5-6 illustrates how the “revised” Broadcast Traveler Information market package maps into the physical architecture.

![Diagram of Broadcast Traveler Information Mapped to Physical Architecture](image)

Figure 5-6: Broadcast Traveler Information Mapped to Physical Architecture

As this diagram illustrates, the interactions among the subsystems are more complex in this market package than in the previous one. There are not only more subsystems involved, but there are also more different modes of communication. Consider how this

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95 Diagram extracted from National ITS Architecture, Implementation Strategy, pg. 2-4.
First, the traffic management subsystem sends traffic information via wireline to the Information Service Provider. The ISP receives this information, packages it, and sends it out to its transmission tower via wireline. The tower then converts this transmission and sends it over the airwaves, which are considered to be a "wide area wireless" communication medium. These airwaves are subsequently received over the radio by the vehicle subsystem.

It is important to note that Figure 5-6 does not depict the way in which traffic information is collected. This is because the "Broadcast Traveler Information" service is simply concerned with the distribution of traveler information. It assumes that the information has already been gathered by various agencies; the only task that remains is to consolidate the information and disseminate it to travelers. The task of collecting the information is assigned to a different market package.

Once again, it is important to note that the market package diagram and the physical architecture mapping supplement each other. The market package diagram provides information on the data that is being exchanged and the service that is being provided. The physical architecture illustrates how these subsystems will communicate, and it places the market package into the broader National Architecture context.

Another key point worth highlighting is that all "Center" subsystems communicate with one another via wireline. This is demonstrated by the wireline communications "sausage", which links together all of the Center subsystems on the physical architecture diagram. One can infer, therefore, that the institutions that operate these subsystems will also communicate via wireline. In other words, when a Traffic Operations Center (which performs the functions defined by the Traffic Management subsystem) sends information to a radio station (which performs the functions defined for the ISP subsystem), it should do so via wireline.
For this reason, a regional architecture need not specify a communication medium. The only data flows that a regional architecture defines are those that travel between institutions. One can assume that if these institutions are performing functions defined for Center subsystems, then they communicate with one another via wireline.

It is important to note, however, that “wireline” doesn’t necessarily indicate a physical communication medium. According to the National Architecture, “wireline” refers to any communication medium that connects two fixed points. Normally, this would involve twisted wire pairs, coaxial cable, or fiber optics. However, it could also involve terrestrial microwave links or an area radio network.96 A more accurate name for “wireline” communication would be “fixed-to-fixed” communication.

**Step 3: Identify the institutions**

Nine different institutions in the Jefferson region can contribute to the provision of the “Broadcast Traveler Information” service. These institutions, and the information that they possess, are listed below.

- **State Turnpike Authority.** The STA possesses three important pieces of traffic information: (1) the number of vehicles on each link of the turnpike; (2) the number of vehicles passing through each exit on the turnpike; and (3) the average speed on each link of the turnpike.97
- **The three Traffic Operations Centers.** Each TOC monitors a set of loop detectors placed at busy intersections throughout the city (see section 5.4.1). Therefore, each possesses some information on traffic conditions within city limits.
- **The three transit agencies.** Each transit agency (the Jefferson Metro, the Clinton Bus Service, and Fillmore Transit) has an operations center that monitors the provision of transit services. These operations centers possess two key pieces of information. First, because they have radio communication with the buses, they know—to a rough approximation—if their buses are running on schedule. This would be of use to prospective transit users. Second, because of this communication link with

96 *National ITS Architecture, Executive Summary*, pg. 6.
97 Consult “ITS Service #1, Step #3” for an explanation of how the STA can determine this information.
the bus drivers, the transit agencies can receive reports of observed traffic incidents. This would be of use to travelers of all types.

Additionally, each transit agency possesses a key transportation asset—additional buses. These buses can be used to help relieve periods of increasing road congestion, such as might occur during the road construction season or before major sporting events.

- **The Jefferson Airport Council.** The JAC maintains the access road to Jefferson International Airport. The Council can provide congestion information on this toll road, which would be useful to travelers who need to catch morning commuter flights.

- **WJAM Newsradio.** The radio station currently broadcasts regional traffic information every 30 minutes. As section 5.4.1 noted, the station has two sources of data: (1) a helicopter that observes traffic conditions during rush hour; and (2) a toll-free information hotline that receives cellular phone calls from motorists who observe traffic problems.

It is helpful at this point to note how these institutions correspond to the “Center” subsystems identified in steps 1 and 2:

- The *Information Service Provider* is responsible for distributing traffic information to the public. In this case, WJAM Newsradio serves as the ISP.

- The *Traffic Management* subsystem, according to Figure 5-5, is responsible for providing traffic information to the ISP. Figure 5-5 also implies that the Traffic Management subsystem is responsible for collecting traffic information, even though this task is addressed by a different market package. In this scenario, six different institutions collect and distribute this information: the STA, the Jefferson Airport Council, the three Traffic Operations Center, and WJAM Newsradio. It is interesting to note that the radio station is both an ISP (in that it broadcasts traffic information) and a Traffic Manager (in that it collects traffic information with its own resources).

- The *Transit Management* subsystem, according to Figure 5-5, is responsible for providing information on transit schedules and fares. The three transit agencies together comprise this subsystem. However, in this application, the transit agencies...
will not be required to deliver information on fare schedules. Rather, they will simply provide information on (a) whether or not the buses are running on schedule; and (b) whether or not supplemental service is being offered.

**Step 4: Make decisions concerning institutional relationships**
The next step is to determine how these institutions will relate to one another in the provision of this service. This involves three basic questions. First, will the service be provided by existing institutions, or will it require the creation of a new institution? Second, who will control the provision of this service? Will one institution be in charge of broadcasting the traffic information, or will it be the joint responsibility of multiple organizations? Third, how will information be distributed among the various institutions? The following paragraphs will address these questions in order.

**Will the service be provided by existing institutions?** In this scenario, it appears that the region will be able to efficiently provide the service using the existing institutions. The problem is not the absence of information—nine different agencies already possess some information on traffic conditions. Nor is the problem the absence of a service provider—WJAM Newsradio already possesses the capacity to broadcast traffic information to every traveler in the region. Rather, the problems are that (a) the institutions are not communicating their information to the service provider; and (b) the service provider does not broadcast its information with enough frequency. These problems can be solved at lower cost by improving the performance of the existing institutions, rather than creating a new entity.

**Who will control the provision of the service?** It seems clear that the radio station should be in charge of providing this service. It already possesses the communications infrastructure required to broadcast the information throughout the region. Moreover, with its traffic “hotline”, the radio has also demonstrated its willingness and its ability to receive information and provide it to the public.
However, asking the radio to perform this service could pose financial difficulties. WJAM would need to (a) receive and process more information than it does currently, and (b) provide more frequent broadcasts. These are both costly operations. If the radio station does not feel that the market will support these increased costs, they may request assistance in the form of subsidy. Nevertheless, a government-provided subsidy, in this instance, would likely be less expensive than creating a new information provider with a new communication tower.

*How will information be distributed among the various institutions?* Since only one service provider exists in the region, all traffic information must ultimately filter to the same point. Thus, there are two options for information distribution:

- The first option is that all agencies send their information directly to the radio station. The disadvantage of this option is that it requires the radio station to juggle transmissions in real time with multiple agencies. The advantage of this option is that it is relatively inexpensive to implement, requiring only that a few new communication lines be installed and that a few more people be hired to monitor them.

- The second option is that all agencies send their information to a centralized database. The radio station would then draw information from this database as needed. The main disadvantage of this approach is that it requires the creation of a new entity—the database manager. However, this may also be considered an advantage, since it permits the radio station to deal with only one entity.

This example will assume that costs are a real constraint, and will therefore select the first communications option.

*Step 5: Construct the "service architecture"*

Having identified the institutions, the relationships among the institutions, the decision-making structures, and the method of information distribution, it is now appropriate to construct the service architecture. One possible architecture that follows from the information presented and decisions made in Steps 1 through 4 is depicted in Figure 5-7.
Several notes should be made about this architecture:

**First**, the architecture places significant demands upon the radio station. Now, not only must they process their own traffic information (from the helicopter and from the motorist phone calls), but they must also process input from eight other independent agencies. As mentioned earlier, this will require additional communication lines to receive the information, as well as additional staff and computers to process the information.
One way to reduce the number of different lines of communication would be to consolidate the Traffic Operations Centers. Say, for example, that each city agreed to combine its individual TOCs into a single regional TOC. This entity could then consolidate the region’s traffic information (with regard to traffic on the arterials and in the CBD’s) and send a single message to the radio station. The same tactic could also be applied to the transit agencies. If all three of these agencies agreed to consolidate and create a single regional entity (The “Greater Jefferson Transit Authority”), then the three different transit data flows could be combined into a single line of communication.

The problem with such changes is that they can be costly, both financially and politically. Creating a regional transit authority would likely require construction of a new facility, or significant expansion of an existing facility. It would also require renovating the buses, so that they provided a uniform, “regional” appearance. Moreover, it would require each agency to surrender a degree of control over the services provided to their jurisdiction. These kinds of changes can be very difficult to make. It is likely that the costs of implementing such changes would far outweigh the benefits gained by consolidating information flows, at least in the context of this one service.

Second, the architecture lists the radio station only one time. This is because this thesis views institutions as the fundamental element of a service architecture. Each institution is listed once, with its responsibilities and information flows diagrammed as appropriate.

This is noteworthy because it differs from the “regional architecture” concept prescribed by the National Architecture. According to the Implementation Strategy, the first step in constructing a regional architecture is to map the existing system inventory and local institutional framework to the physical architecture framework. If this approach were taken, then the radio station would need to be listed twice, because WJAM performs functions assigned to both the Traffic Management subsystem (in that it monitors traffic

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96 See Section 4.3.3
conditions with its own assets) and the Information Service Provider subsystem (in that it broadcasts traffic conditions).

Therefore, the “institutional approach” adopted by this thesis can help simplify the architecture diagram in two ways. First, it avoids the possibility of listing institutions twice. And second, it eliminates the need to include “subsystem” boxes in the service architecture.

**Third**, the service architecture diagram notes that the technology that the radio station employs as it implements its service should be interoperable at the national level. This is indicated by the “N” located just above the line of responsibility connecting WJAM to the “Broadcast Traveler Information” service. The need for national interoperability stems from the fact that WJAM provides this service to mobile users. In other words, any driver should be able, with the same device, to receive traffic information from regions across the country.

Of course, in this instance interoperability is not really a problem. The information will be broadcast over the radio in a format that all vehicles will be able to receive. However, if the radio station ever decided to expand its service (i.e. by providing route guidance information to in-vehicle digital receivers), it would need to keep this national interoperability requirement in mind.

**Fourth**, this architecture provides for decentralized coordination between transit agencies and the TOCs. To illustrate this, suppose that the Jefferson TOC reported to WJAM that a major accident on arterial A6 (see Figure 5-1) was causing significant delays in the Jefferson CBD. If the Jefferson Metro operations center was tuned in to the radio station, it could respond by providing additional transit service. It could then notify WJAM of its decision, so that the radio station could publicize the transit alternative to other listeners.
This is certainly not the most efficient way of distributing information. If the Jefferson TOC were to notify the Jefferson Metro directly, then the additional transit service might be delivered sooner. However, the quicker response time might not justify the additional coordination effort required. It may be easier (and cheaper) for the transit and traffic agencies to use WJAM as an information "clearinghouse" from whom they can draw information as needed.

**Fifth**, the architecture does not describe operations that institutions perform internally. For example, the architecture does not depict that the radio station actually provides information to itself (i.e. through the roaming helicopter).

**Sixth**, the architecture does not depict the recipients of a particular service. For example, although travelers of all types (i.e. transit users, truck drivers, commuters, and vacationers) can receive this information, they are not included on the diagram. The architecture simply describes how institutions interact in order to provide the service. All other entities are "outside" the architecture.
5.4.2.4 ITS Service #3: Incident Management

Although they occur relatively infrequently, traffic accidents occasionally bring traffic in some parts of the Jefferson region to a standstill. This is because (a) few alternate routes are available for many commuters, and (b) the emergency crews are often slow to respond to the incident. Thus, the purpose for deploying this service is to improve the speed with which traffic accidents are cleared from the roadway. In particular, the service is aimed at clearing incidents from the turnpike and the six arterials during the morning and evening rush hours.

Step 1: Identify subsystems and data flows

Like the previous two services, this service conforms to one of the market packages identified by the National Architecture. Figure 5-8, excerpted from the Implementation Strategy, describes the subsystems and data flows involved in providing the "Incident Management" market package.

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This diagram requires four points of explanation:

First, this diagram contains three unshaded subsystems (Information Service Provider, Roadway, and Emergency Vehicle). Section 5.4.2.3 made two important notes about these subsystems: (a) they support the market package through data sharing; and (b) the equipment packages that support the data sharing are defined as part of a separate market package.

It is interesting to compare Figure 5-8 with Figure 5-5. In Figure 5-5, a “traffic information” arrow flows from an unshaded “Traffic Management” subsystem to a shaded “Information Service Provider” subsystem. On the other hand, in Figure 5-8, a “traffic information” arrow flows from a shaded “Traffic Management” subsystem to an unshaded “Information Service Provider” subsystem. Based on this comparison, it is evident that the two diagrams are complementary. In other words, Figure 5-8 describes one way in which the Traffic Management subsystem acquires data, while Figure 5-5 describes the way in which it shares that data.

Second, this diagram involves 3 different institution-oriented subsystems. The Traffic Management subsystem represents the entity (which could be a single institution or group of institutions) that detects the traffic incident. Once it detects the incident, the Traffic Management alerts two different entities: the Emergency Management subsystem, and the Information Service Provider. The Emergency Management subsystem represents the entity that responds to the alert from Traffic Management and clears the traffic incident. The Information Service Provider represents the entity that receives the alert from Traffic Management and disseminates information about the incident to the region’s motorists.

Second, three other subsystems are also represented in this diagram.
- The **Emergency Vehicle** subsystem is used to distinguish the mobile emergency management team (such as an ambulance crew or a tow truck) from the emergency management “headquarters” (such as a hospital or a truck dispatch center).
- The **Other TM** subsystem represents another Transportation Management entity in a neighboring city or region that could provide assistance as needed.
- The **Roadway** subsystem represents roadside infrastructure owned by the Transportation Management subsystem. This infrastructure can serve at least two different purposes. First, if it includes equipment such as loop detectors or roadside cameras, it could detect incidents and alert the Transportation Management subsystem. Second, if it includes a Variable Message Sign (VMS), it could respond to messages from the Transportation Management subsystem and display traffic incident information to travelers.

**Fourth**, it should be noted that, once again, the information flows on the diagram are depicted at a very high level. For example, the diagram tells virtually nothing about the extent of coordination that should occur between Transportation Management subsystems. This lack of specificity provides the region with considerable flexibility when deciding the level of coordination that should exist among the various institutions.

It is assumed in this scenario that the Jefferson region expects its incident management service to perform two functions. First, it should support the prompt distribution of information to incident clearing teams; and second, it should support the provision of information to the local radio station. Because the region does not possess any Variable Message Signs, the region will not distribute information to roadside infrastructure, even though this is supported by the market package.

**Step 2: Map subsystems to the physical architecture**

Figure 5-9 illustrates how the “Incident Management” market package maps into the physical architecture. Even though there are no VMS’s in the region, the “roadway” subsystem is still included in the physical architecture. This is because the region does
possess roadside infrastructure that is capable of detecting incidents and reporting data to the management centers.

![Diagram of incident management mapped to physical architecture](image)

**Figure 5-9: “Incident Management” Mapped to Physical Architecture**

Based on this diagram, one can trace the physical flow of information through the transportation network. First, the roadway subsystem detects the incident and passes the information, via wireline, to the Traffic Management subsystem. The Traffic Management subsystem then alerts the Emergency Management subsystem and the Information Service Provider, via wireline, about the incident. The Emergency Management subsystem alerts the mobile Emergency Vehicle subsystem via wide area wireless (i.e. 2-way radio), providing it with the information it needs to respond to the incident. Likewise, the ISP alerts individual vehicles via wide area wireless (i.e. AM radio), providing them with information about the incident.
Step 3: Identify the institutions

At least 14 different institutions in the region can contribute to the provision of the “Incident Management” service. These contributions can come in four different forms—incident detection, response coordination, incident clearing, and information dissemination. The institutions, the information they possess, and the contributions they make are chronicled below:

- **The three Traffic Operations Centers.** The TOCs will, generally speaking, serve two functions. First, they will detect incidents within their jurisdiction. As mentioned before, each TOC possesses some equipment (such as loop detectors and the “traffic hotline”) that can be used to monitor traffic and detect accidents. Second, the TOCs will be responsible for coordinating the incident management response within each jurisdiction.

- **The three transit agencies.** Each transit agency has numerous buses operating on the region’s arterials. These buses provide constant surveillance of the transportation system, and they can be used to detect traffic incidents. As long as all buses maintain radio communication with their respective operations centers, each transit operations center will be able to stay abreast of traffic conditions within city limits.

- **The three police departments.** Each city in this region possesses its own police department. The police departments have three responsibilities—they assess the damage at the scene of the accident; they alert an appropriately sized incident clearance team to remove the damaged vehicles; and they direct traffic around the incident. Also, because the police routinely patrol the streets, they can also provide some incident detection information.

- **The three fire departments.** Each city also has its own fire department. The fire departments also have three responsibilities—they put out fires at the scene of the accident, they remove people that may be trapped in the damaged vehicles, and they alert the hospital of the need to send an ambulance.

- **The State Turnpike Authority.** As mentioned previously, the data gathered from electronic toll collection facilities can assist the STA in detecting incidents on the

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100 Diagram extracted from the National ITS Architecture, Implementation Strategy, pg. 2-4.
turnpike. The people who man the tollbooths also can detect incidents, either through direct observation or through information passed to them by motorists.\footnote{As section 5.4.1 noted, even though the STA has inaugurated electronic toll collection, many motorists have not purchased the transponder. Therefore, the STA must still provide some toll collectors.}

- \textit{WJAM Newsradio.} The radio station provides two important assets that can assist in the deployment of this user service. First, it has the ability, through the use of its cellular phone hotline and its traffic helicopter, to detect traffic incidents throughout the region. And second, it has the ability to publicize traffic information over the radio.

It is helpful to note how these institutions correspond to the “Center” subsystems identified in steps 1 and 2:

- The \textbf{Emergency Management} subsystem bears responsibility for physically clearing the incident. The \textit{police departments} and the \textit{fire departments} would both be considered part of this subsystem.

- The \textbf{Transportation Management} subsystem bears responsibility for detecting the incidents, coordinating the appropriate responses, and dispatching emergency vehicles to clear the scene of the accident. The \textit{Traffic Operations Centers}, the \textit{transit agencies}, the \textit{police departments}, the \textit{STA}, and \textit{WJAM Newsradio} all contribute to these functions.

- The \textbf{Information Service Provider} bears responsibility for broadcasting traffic incident information to the general public. \textit{WJAM Newsradio} performs this function for the Jefferson region.

\textbf{Step 4: Make decisions concerning institutional relationships}

The goal of this step is to determine how the region’s institutions will relate to one another as they provide the “incident management” service. In this step, this service will be broken down into three components—a \textit{response coordination} component, an \textit{incident clearance} component, and an \textit{information broadcast} component. For each service component, three questions must be addressed. First, will the component be performed by existing institutions, or should a new institution be introduced? Second, who will
control the implementation of each service component? And third, how will information be distributed during the execution of each component? The following paragraphs will address these questions in order.

**Will the service components be performed by existing institutions?** The institutional infrastructure in the Jefferson regional appears adequate to perform all three service components. The region does not lack for traffic information—eleven different institutions (the three police departments, the three transit agencies, the three TOCs, the STA, and WJAM Newsradio) all possess some traffic information. The region has also designated some agencies to coordinate the response, some agencies to clear the incidents, and an agency to provide traffic information. In short, the region has already addressed the functions required by the “incident management” service. What is needed is not a new institution, but a new level of coordination among the existing institutions.

**Who will control the implementation of each service component?** The response coordination component should be handled by each of the three TOCs. The police and fire departments should jointly perform the incident clearance component for each jurisdiction. And WJAM Newsradio should handle the information broadcast component.

These decisions lead to two further questions. The first is, to what extent should the TOCs coordinate with each other as they orchestrate their incident responses? The easiest solution to implement would be for each TOC to be responsible for coordinating responses within its own jurisdiction. If a particular incident is too serious to be handled with jurisdictional resources, then the TOC should have the option of requesting support from neighboring TOCs. With this possibility in mind, the three TOCs should craft an agreement that pledges their support to one another whenever needed. In this way, each TOC can “act regionally” while maintaining its autonomy. This kind of agreement would also preclude the need to create a “regional TOC” to handle such incidents.
The second question that needs to be addressed is this—who will be in charge of the incident clearance function? Should the police department be responsible, or should the fire department be responsible? In practice, it is possible for the two independent entities to jointly provide the service. This scenario will assume that the two departments can act cooperatively, even in the absence of delegated authority.

**How will information be distributed among the various institutions?** There are basically two types of information flows involved in providing the “incident management” service. The first type are *incident information* flows, which alert an institution to the presence of an accident. The second type are *response coordination* flows, which alert an institution of the need to respond to an accident. These two types of information flows will be discusses below.

- **Incident information flows.** These information flows must eventually filter to two agencies—the TOCs (which coordinate the response) and WJAM Newsradio (which broadcasts the traffic information to the public). They can be handled in one of two ways. The first way is to have all agencies report incident information to WJAM Newsradio. The radio station can then distribute this information to the appropriate TOC. For example, if the Clinton Bus Service Operations Center discovered an incident, it would notify the radio station, which would in turn notify the Clinton Traffic Operations Center. The second way is to have all agencies notify the TOCs directly. The TOCs would then coordinate the incident response and pass the information on to the radio station.

The advantage of having everyone report to the radio station is that it simplifies the TOCs “information pipeline”. Each TOC would only need to interact with the radio station, which would act as an information clearinghouse of sorts. However, this method has two large drawbacks. First of all, it could delay the distribution of information to the TOCs; this, in turn, could in turn delay the response time of the incident clearing crews. Second, it potentially places too many demands on the radio station. WJAM Newsradio is a private entity, and it may not want to serve as a
clearinghouse of traffic incident information—a service which, despite its societal value, will not add to their bottom line.

For these reasons, this architecture will require all information to flow direction to the Traffic Operations Centers. This will increase the communications demands on the TOCs, but it will also provide them with quicker access to potentially urgent information. The only information that will flow from the radio station to the TOCs are traffic incidents which are discovered by the radio station’s own traffic monitoring assets.

- **Response coordination flows.** These flows all originate with the Traffic Operations Centers. Because both the police department and the fire department are responsible for clearing the incident, both must receive direct notification from the appropriate TOC. Furthermore, because both departments must cooperate in order to clear the incident, additional communication link should be provided that will allow them to talk directly to each other.

**Step 5: Construct the “service architecture”**

The first four steps identified the institutions, assigned responsibilities, and defined how the institutions will relate to one another. It is now appropriate to construct the service architecture. One possible architecture, which follows naturally from the information presented and decisions made in steps 1 through 4, is depicted in Figure 5-10.
Figure 5-10: Service Architecture for Incident Management User Service
Several points need to be made about this service architecture.

1. The Traffic Operations Centers are the focal point of this service. They serve four very important functions: (1) they receive traffic incident information, (2) they coordinate the city’s response to the incident, (3) they pass on information to the radio station, and (4) they coordinate with other TOCs in cases of serious incidents.

2. Internal operations are not reflected in the service architecture. For example, the fact that each TOC gathers some traffic information on its own is not displayed on this architecture. The architecture focuses on interactions between institutions, to the exclusion of activities within each institution.

3. One option for implementing this service would be to create a regional TOC. This entity would either consolidate the existing TOCs, or it would exist separately with command authority over the city TOCs. However, this architecture adopts the view that the difficulties involved in creating such an institution would not be justified by the limited benefits that it would bring. Traffic accidents occur locally, and they should be handled locally.

4. The State Turnpike Authority and WJAM Newsradio could be considered “regional” entities, since they interact regularly with each jurisdiction. Regional entities play an important role in providing a broader perspective to transportation problems. For example, the radio station could tell the Jefferson TOC how an accident near the Jefferson turnpike exits is impacting traffic flow in Clinton.

5. According to the architecture, there is no communication link between police departments of different jurisdictions. This reflects a fundamental architecture choice; that is, the region has delegated all inter-city traffic coordination to the Traffic Operations Centers.
6. Neither mobile systems (i.e. ambulances) nor roadside infrastructure (i.e. loop detectors) are represented on the service architecture. Again, the architecture focuses on institutional relationships, not technical interaction.

7. Decentralized control is a key characteristic of this architecture. That is, the responsibility for implementing the incident management service is distributed among multiple institutions. This is primarily due to the absence of a regional “incident management authority” (such as a regional TOC). The net effect of this decentralized approach to incident management is that accidents are generally handled on a city-by-city basis.

8. Decentralized information distribution is also an important characteristic of this architecture. Information flows are directed to individual TOCs, rather than to a centralized information clearinghouse. This is largely a consequence of the decentralized control structure.¹⁰²

9. The “Broadcast Traffic Information” component must be nationally interoperable, because it supplies a service to mobile users. This won’t be a problem as long as information is distributed by radio, but could become an issue as more advanced means of dissemination become available. The “coordinate response” function requires regional interoperability, since different TOCs, fire departments, and police departments from throughout the region must be able to communicate with one another. The “clear incident” function has no interoperability requirement, since it only requires that the police and fire departments be able to communicate.

10. Finally, it is worthwhile to ask this question: What is the difference between what the architecture proposes and the status quo? This approach presents three advantages over the current situation, in which incidents are detected and handled purely at the municipal level. First, it opens up channels of communication between the

¹⁰² One could also conceive of a situation characterized by centralized information distribution and decentralized control. For example, the region could require all institutions (i.e. the STA and the transit agencies) to relay any incident
TOCs, so that regional coordination can take place as necessary. Second, it takes advantage of information acquired by “regional entities” such as the State Turnpike Authority and WJAM Newsradio. And third, it distributes information on local traffic problems to the entire region, enabling commuters to adjust their travel patterns accordingly.

The last three subsections have led to the construction of three service architectures—one for Surface Street Control, one for Broadcast Traveler Information, and one for Incident Management. All of these are ITS services that are supported by the National Architecture.

The next subsection will describe the construction of a service architecture for a non-ITS service—Coordinated Transit Routes and Schedules. This section will comprise Stage III of the regional architecture development process.
5.4.2.5 Non-ITS Service #1: Coordinated Transit Schedules and Routes

As the introduction to this section pointed out, each jurisdiction currently operates its own transit service. This means that transit commuters who do not live and work in the same city must transfer between bus lines on their way to and from work. These inter-agency transfers can be difficult. The schedules of the three transit agencies are not coordinated, so some commuters have lengthy waits at the transfer points. Moreover, some of the routes do not match, causing some commuters to walk up to half a mile to transfer to the appropriate bus.

The purpose of this service, therefore, is to address the problems associated with these transfers by coordinating the schedules and the routes of the express buses. The goal is to provide the region’s labor force with a smoother transit commute.

The method for developing a “service architecture” for non-ITS services will differ somewhat from the method for the ITS services. Step 1 for the ITS service procedure does not apply, because there are no market package diagrams corresponding to non-ITS services. Step 2 does not apply either; one cannot map non-ITS services to an ITS-oriented physical architecture. Therefore, only the last three steps of the ITS service procedure will apply to non-ITS services.

**Step 1: Identify the institutions**

This step is very straightforward. The only institutions of concern are the three transit agencies—the Jefferson Metro, the Clinton Bus Service, and Fillmore Transit. Each agency contains two important pieces of information: the schedules of each bus, and the routes of each bus.

It is important to remember that each transit agency operates two different types of bus service—*express* and *local*. Express service transports commuters from the outlying areas to the Central Business District, while local service transports commuters within
the CBD. Therefore, the only buses that will require coordination are the express buses operated by each agency.

**Step 2: Make decisions concerning institutional relationships**

The next step is to determine how the three agencies will relate to one another as they attempt to coordinate their services. This step will involve addressing four key questions, which are addressed in the paragraphs that follow:

**Will the service be provided by existing institutions?** The provision of coordinated transit schedules and routes can be accomplished in one of two ways. The first way would be to consolidate the three transit agencies into a single regional transit agency. This consolidated entity would have the authority to designate routes and coordinate schedules on a regional basis. The second way would be to have the existing agencies join to coordinate their express bus routes and schedules.

Each method has its advantages and disadvantages. The creation of a regional bus service would likely provide the best service from the perspective of the commuter. First of all, it would eliminate inter-agency transfers, as the agency's jurisdiction would transcend city borders. And second, it would have the authority to change, modify, or add to existing routes in support of regional commuters. Moreover, the creation of a regional entity would reduce the need for institutional coordination, since the agency could make certain scheduling and route decisions unilaterally.

Thus, the primary advantage of the “consolidation method” is that it can potentially operate very efficiently once it is created. The problem is that such an entity can be very difficult to create. Each existing transit agency has a firmly established history and constituency. These agencies might be strongly opposed to surrendering control to a regional entity that may not share their goals or continue their services. Moreover, as the discussion of ITS Service #2 (section 5.4.2.3) pointed out, the creation of a regional transit agency can be costly from a financial perspective, likely requiring both facility expansion (to house the new headquarters) and bus renovation.
For these reasons, the best approach to improving transit services in the Jefferson region is to rely on the cooperative efforts of the existing transit agencies. This approach can improve the performance of the regional transportation system while minimizing the political and financial costs of doing so. In short, although the kind of institutional coordination required by this approach can be difficult, it is probably easier than institutional creation.

*How will the service be defined?* Once the decision is made to maintain the existing institutional structure, it is important to define the service. There are several different ways in which the “provision of coordinated transit schedules and routes” could be implemented.

- **Method 1: Information distribution.** This method would simply require each agency to publicize its routes and schedules, ensuring that this information is disseminated to the other two cities. With this information, residents of each city could better plan their commutes, taking into account the operational policies and schedules of each transit agency.

  This method has two advantages. First, it is cheap. It would simply require each agency to print out paper brochures and distribute them to the other two agencies. Each agency could also publish their routes on the Internet, where the information would be available to all. Second, this method is easy to implement, since it requires very little institutional coordination. However, this method also has two major drawbacks. First, it doesn’t really change anything for the existing commuters. It is very likely that the regular commuters already know how the system works and have already determined the most efficient way to work. Second, this method places a great deal of responsibility on the commuters themselves, requiring them to gather information and coordinate their own trip.

- **Method 2: Change existing schedules and routes.** This method would require all the institutions to gather together and coordinate their express routes. In generally,
these routes run from the city boundaries to the CBD. This method would have two goals: first, to minimize the distance that passengers must walk when transferring between bus lines; and second, to minimize the waiting time involved during the transfers. Figure 5-11 depicts the geographical areas in which these inter-agency transfers take place.

![Figure 5-11: Key Points of Coordination for Regional Bus Service](image)

In order to implement this policy, it is necessary to establish some “coordination criteria”. In this example, two criteria would be appropriate. The first criterion would
be to require that the arrival time of one agency’s outbound bus be scheduled within five minutes of the departure time of the other agency’s inbound bus. For example, referring to Figure 5-11, this would require the outbound Jefferson Metro bus to arrive at point A within 5 minutes of the scheduled departure of the Fillmore Transit bus from the same point. The second criterion would be that the outer terminus points should be located within 150 yards of each other. Again referring to Figure 5-11, this would require all terminus points in the vicinity of point B to be within 150 yards of one another.

This method has two distinct advantages over the “information distribution” method. First, by proactively addressing the problems associated with inter-agency transfers, this method provides a much better service for the regional commuter. Second, by encouraging interaction among the three transit agencies, this method takes a step forward in the development of a “regional transportation system” that appears to the user as an integrated series of services. In short, this method is supportive of a “regional” approach to transportation.

- **Method 3: Change existing routes and include real-time coordination.** This method would essentially be an extension of the previous method. It would involve not only modifying routes and schedules, but also providing communications links among the transit agencies. This would permit the agencies to adjust their schedules in response to delays. Say, for example, that an outbound Jefferson Metro bus headed for point B (in Figure 5-11) was delayed due to traffic congestion. The bus could inform the Metro Control Center of the delay; they, in turn, could notify the Clinton and Fillmore Control Centers of the delay. The other two control centers would then have the option of telling their inbound buses at point B to delay their departure in order to accommodate the transferring passengers. In this way, the transit agencies could make adjustments in real time in order to provide a better service for the region’s commuters. Figure 5-12 illustrates how this communication might occur.
Figure 5-12: Example of Real-Time Coordination among Transit Agencies

Once again, the primary advantage of this method is its ability to provide a better service to the regional commuter. It also takes another step toward developing a "regional transportation system" by supporting real-time communication as well as planning-oriented communication. However, this plan also has two potential drawbacks. First, it may place too much of a burden on the transit agencies. The Control Centers may already have their hands full coordinating their own operations, without having to consider the needs of the other agencies as well. Second, this approach may hinder service to the existing customer base. To follow on the example of Figure 5-12, suppose that the inbound Clinton and Fillmore buses delayed their departures by 7 minutes to accommodate the late Jefferson Metro bus. Although the delayed departure would help the transferring passenger from Jefferson, it would hurt the Clinton and Fillmore commuters on the delayed route who would otherwise have gotten to work on time.

This example will use method 3 as the approach for implementing the user service. First of all, it provides the best overall level of service to the region's commuters. Sec-
ond, its cost of implementation is relatively low. All that it requires is (a) some staff time to coordinate routes and schedules, and (b) an extra radio link between the transit agencies to support the real-time coordination. And third, it represents the most aggressive attempt to integrate the three transit agencies without creating a new entity. In short, this approach retains institutional autonomy while providing the best opportunity, enabled by information technology, to provide a quality transit service.

The region could conceivably improve the quality of this service by using the electronic toll collection service in order to locate buses in real time. At the moment, however, the region will not pursue this strategy. This strategy would only work for buses operating on the turnpike, and at this time virtually all buses operate on surface streets. This is because the turnpike is essentially an inter-city route, whereas all buses are currently operated on an intra-city basis.

It is important to note that method 3 requires two types of information flows—planning flows and real-time flows. The planning flows would include the exchange of information on routes and schedules. They would be used to coordinate routes and transfer points on a regional basis, in an effort to make inter-agency transfers easier for inter-city commuters. The real-time flows would be used further improve the quality of inter-agency transfers on a day-to-day basis by responding to periodic service delays.

Who will control provision of the service? Once the service has been defined, it is important to determine how the transit agencies will relate to one another as they implement the service. There are basically two ways of doing this. The first option would be to delegate responsibility for overseeing institutional coordination to one agency, while the second option would be to have each agency initiate its coordinating efforts independently.

The advantage of the first option (referred to as the “lead agency” option) is that it holds someone accountable for implementing the service. Suppose, for example, that the Jefferson Metro was selected to oversee the tasks associated with institutional coordi-
nation. This would require the Jefferson Metro to (a) establish a forum in which the three agencies could discuss route and schedule changes; and (b) verify periodically that each agency is implementing the agreed-upon changes. In the absence of a lead agency, the cooperative efforts needed to implement the service might not readily take place.

However, there are two drawbacks to this option. First of all, in the absence of any hierarchical structure, the Jefferson Metro would not have any power to enforce its responsibilities. That is, it would have no statutory authority to compel the other two agencies to either develop or abide by “regional” policies. Secondly, this option impinges upon the autonomy of the Fillmore and Clinton transit agencies by subjecting them to the oversight of the Jefferson Metro.

The second option poses no threat to institutional autonomy. Each of the three city pairs (Jefferson-Clinton, Jefferson-Fillmore, and Clinton-Fillmore) could meet separately, working out the details of route adjustment, schedule modification, and real-time coordination in the absence of an overseeing authority. However, this option could result in varying levels of service. For example, if the Jefferson-Clinton relationship proved to be stronger than the Clinton-Fillmore relationship, then the commuters between Clinton and Fillmore might not receive as good a service as the Jefferson-to-Clinton commuters. In short, the quality of service would not be uniform throughout the region if each city pair pursued its coordination efforts independently.

Therefore, the “lead agency” option appears to be the best approach. In the absence of a regional agency with statutory authority over regional transit services, it is important to designate a lead agency to spearhead the coordination efforts. The lead agency can bring all parties to the table and foster inter-agency coordination, even though it does not possess any formal authority over the other agencies.

In this instance, it would seem reasonable to hold the Jefferson Metro responsible. They are not only the biggest transit agency, but they also serve the largest number of
regional commuters (that is, commuters that travel between cities within the region). Admittedly, acting as a lead agency will be a challenging task for the Jefferson Metro. However, in the absence of a regional transit authority, this approach represents the best option for moving toward a “regional” transit service.

**How will information be distributed among the various institutions?** This question has been implicitly addressed in the preceding paragraphs. In essence, this service—which shall officially be referred to “planning and real-time coordination of transit routes and schedules”—requires both centralized and decentralized communication. The planning coordination will involve “centralized” communication. That is, all agencies will convene in a regional forum in order to address route and scheduling conflicts on a regional (as opposed to city pair) basis. However, the real-time coordination will involve “decentralized” communication. That is, as a particular agency experiences delays in its service, it will inform the other affected agencies on an individual basis.

**Step 3: Construct the “service architecture”**

The first two steps have addressed five important issues. First, they identified the regional institutions that will be involved in deploying the service. Second, they addressed the question of whether the service would require the creation of a new regional entity. Third, they defined the service. Fourth, they assigned responsibility for implementing the service. And fifth, they identified how information will be distributed among the institutions.

At this point, it is appropriate to construct the service architecture. One possible architecture, which follows from the information presented and decisions made in steps 1 and 2, is depicted in Figure 5-13.
Several notes should be made about this architecture:

First, this architecture divides the user service into two different components. The first component is "Schedule and Route Planning Coordination". This is a planning function performed jointly by all transit agencies, and it occurs before the passengers actually experience the service. The second component is "Service Delay Coordination". This is a real-time function performed by pairs of agencies, and it occurs while the passengers are experiencing the service.

Second, this architecture distinguishes between "primary" and "secondary" lines of responsibility. This distinction is necessary when a "lead agency" is designated to spearhead the deployment of a particular service. The solid line connecting the Jefferson
Metro to the “Schedule and Route Planning Coordination” service represents the primary line of responsibility. It indicates that the Jefferson Metro is both involved with and responsible for the deployment of the service. The dashed lines connecting Fillmore Transit and the Clinton Bus Service to the same service represent secondary lines of responsibility. These lines indicate that the other two agencies—although directly involved in deploying the service—do not bear responsibility for the deployment.

The “Service Delay Coordination” services only involve primary lines of responsibility. This is because both agencies in a particular city pair are responsible for coordinating real-time transit service adjustments.

Third, the architecture depicts both real-time and planning information flows. The real-time flows are depicted with solid arrows, while the planning flows are represented by dashed arrows.

Fourth, this architecture includes many “2-way” arrows. This indicates that information can flow both ways between the two institutions. For example, the “Delay Information” arrow between the Jefferson Metro and the Clinton Bus Service points both ways. This means that either agency can send delay information to the other. Similarly, the “Response” arrow also points both ways, meaning that either agency can (and should) notify the other agency of its response. For real-time information flows (i.e. information flows designated with solid arrows), the arrows occur in pairs.

For a particular incident, the pairs of real-time two-way arrows will operate in opposite directions. For example, if the Jefferson Metro were experiencing delays, information would travel from the Jefferson Metro to the Clinton Bus Service along the “Delay Information” arrow. The response to these delays would travel from the Clinton Bus Service to the Jefferson Metro along the “Response” arrow.

Fifth, this architecture, though it supports a “conventional” service, still contains interoperability designators. In this example, the “R” next to the lines of responsibility
associated with “Service Delay Coordination” indicates that this service should be implemented using regionally interoperable technology. Of course, if the coordination takes place via two-way radio or telephone, interoperability will not be an issue. However, it is possible that, in the future, such coordination could be automated. Automatic Vehicle Locators on the buses could eventually replace radio transmissions from the buses to the control centers, and automated electronic messaging could eventually replace a phone call between control centers. When these changes take place, each agency should keep in mind that the technology must be interoperable throughout the region. Otherwise, the coordination efforts will fall flat due to incompatibility.

5.4.2.6 Stage IV: Aggregate the Service Architectures to create the Regional Architecture

This subsection concludes the four-stage regional architecture development process. At this point, an architecture has been drawn for each of the four services identified by the Jefferson Regional Planning Council. It is now time to aggregate the four “service architectures” and create the regional architecture. The proposed regional architecture for the Jefferson region is depicted in Figure 5-14. The legend for the architecture is described below. Table 5-7, which provides detailed information on the data flows, follows the architecture.

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Legend

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>FFD</td>
<td>Fillmore Fire Department</td>
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<tr>
<td>FPD</td>
<td>Fillmore Police Department</td>
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<tr>
<td>FTOC</td>
<td>Fillmore Traffic Operations Center</td>
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<td>FT</td>
<td>Fillmore Transit</td>
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<td>CFD</td>
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<td>WJAM</td>
<td>WJAM Newsradio</td>
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<td>STA</td>
<td>State Turnpike Authority</td>
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Figure 5-14: Regional Architecture for the Jefferson Region
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<td>WJAM</td>
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**Table 5-7: Information Flows for the Jefferson Regional Architecture**
The following points summarize some of the key aspects of the regional architecture depicted in Figure 5-14:

1. The regional architecture contains the same five components of a "service architecture"—user services, institutions, communication links, data flows, and lines of responsibility. It is more complex than a service architecture, because it supports multiple services.

2. The regional architecture depicts two different types of communication channels.
   - The first type is a “one-way” channel, represented on the diagram as a one-way arrow. These channels describe a situation in which the flow of information moves predominately in one direction. An example is the “incident information” data flow between the State Turnpike Authority and WJAM Newsradio. This channel, for the most part, carries data from the STA to WJAM. The only information sent in the opposite direction would be a “confirm” signal, with WJAM notifying the STA that they have successfully received the information.
   - The second type is a “two-way” channel, represented on the diagram as a two-way arrow. This type of channel carries data back and forth between entities. An example is the “delay information” data flow between the Jefferson Metro and Fillmore transit, which reflects the fact that both agencies send delay information to one another. In Table 5-7, all information flows that occur on “two-way channels” are represented by the phrase “information exchange”.
   - Since a single channel can carry multiple data flows, only one communication channel is depicted between any two entities. For example, the Fillmore Traffic Operations Center supplies three different types of information to WJAM, but—as far as the architecture is concerned—they are sent over a single communication channel.

3. The regional architecture makes it easy to determine which agencies are providing multiple services. For example, one can determine from glancing at the architecture that the Jefferson Traffic Operations Center is responsible for two services—“coordi-
nate incident response” and “surface street control”. This characteristic of the dia-
gram allows one to quickly determine the extent to which control is either centralized
or decentralized. If the user services are performed primarily by a single institution,
then it is evident that control is centralized. If, on the other hand, responsibility for
the services is distributed among multiple institutions, then it is evident that control is
decentralized.

4. The regional architecture also makes it easy to determine the services that are the
joint responsibility of multiple institutions. For example, one can readily discern that
the Clinton Bus Service, and Jefferson Metro, and Fillmore Transit jointly provide the
“Schedule and Route Planning Coordination” service. This characteristic of the dia-
gram makes it easy to assess the degree of regional cooperation that the architec-
ture requires. If many of the services supported by a particular architecture require
the joint effort of institutions from multiple jurisdictions, then one could conclude that
the architecture requires extensive “regional integration”.

5. The regional architecture compresses a great deal of information into a single dia-
gram. For this reason, the diagram can be confusing to someone who either (a) is
unfamiliar with the regional architecture concept, or (b) is seeing the diagram for the
first time.

One way to improve the way in which the regional architecture is presented is to
break the diagram down by institutions. For example, one could break the regional
architecture for the Jefferson region down into 14 “institutional architecture dia-
grams”—one diagram for each institution in the region. Each institutional architec-
ture diagram would include four components:
a) The institution itself;
b) The user services (if any) for which the institution is responsible;
c) All communication links to other institutions; and
d) The information flows along these communication links.
In short, an “institutional architecture diagram” depicts the regional architecture from the perspective of a single institution. The diagrams that follow represent the institutional architectures for each of the institutions in the Jefferson region. The diagrams will be prefaced by a legend, refreshing the reader on the meaning of each of the architecture symbols.

**Institutional Architecture Legend**

- **JEFFERSON TRAFFIC OPERATION CENTER**: The Institution for whom the institutional architecture diagram is being drawn
- **Jefferson Metro**: Other institutions with which the “featured” institution interacts
- **Surface Street Control**: User service
- **R**: Line of responsibility (designates responsibility for a user service)
- **Information flow arrow**: Appropriate level of interoperability

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103 There are 15 different institutions in the Jefferson region; however, only 10 different diagrams will be presented. This is because the diagrams that cover the police and fire departments are identical for all three towns (with the exception of the names).
Figure 5-15: Institutional Architecture Diagram for the Jefferson Traffic Operations Center
Figure 5-16: Institutional Architecture Diagram for the *Clinton Traffic Operations Center*
Figure 5-17: Institutional Architecture Diagram for the Fillmore Traffic Operations Center
Figure 5-18: Institutional Architecture Diagram *WJAM Newsradio*
Figure 5-19: Institutional Architecture Diagram WJAM Newsradio

Figure 5-20: Institutional Architecture Diagram for Jefferson Airport Council
Figure 5-21: Institutional Architecture Diagram for Jefferson Metro

Figure 5-22: Institutional Architecture Diagram for Clinton Bus Service
Figure 5-23: Institutional Architecture Diagram for Fillmore Transit

Figure 5-24: Institutional Architecture Diagram for Fillmore Fire Department and Fillmore Police Department

104 This diagram provides the institutional architecture information for two agencies—the Fillmore Fire Department and the Fillmore Police Department. The diagram will be identical for the other Fire and Police Departments.
To review, the preceding ten diagrams expand the diagram depicted in Figure 5-14. Taken together, they provide an alternate way of viewing a regional architecture. They provide a useful way of seeing the impact that the regional architecture will have on each individual institution.

5.5. Summary

This chapter has been devoted to answering one basic question—What is a regional architecture? The chapter has addressed this question in three ways. First, it drew upon the work of previous chapters in order to provide a comprehensive definition of the term. Next, it proposed and illustrated a procedure for constructing a regional architecture. Finally, it provided an example of what a regional architecture might actually look like.

This chapter has attempted to build on the foundation established by the National Architecture, so that the proposed definition is a logical extension of the ideas presented in its Implementation Strategy. At the same time, this chapter has attempted to address some of the shortcomings identified in the National Architecture’s treatment of regional architectures. Furthermore, this chapter has proposed to broaden the scope of regional architectures, so that they encompass non-ITS as well as ITS services. The idea is that an architecture can be a tool for coordinating the efforts of multiple institutions that must interact in order to provide a transportation service.

The next chapter will critique the regional architecture development process proposed in this chapter. It will attempt to answer three questions. First, how might the regional architecture be affected by services that are developed and deployed at a later date? Second, how might the process respond to situations in which one institution must distribute a great deal of information while getting nothing in return? And third, how might the architecture be more proactive in facilitating institutional change? In asking these questions, this chapter will critically examine the proposed regional architecture development process to see if it should be modified in any way.
Chapter 6

The 4-Stage Regional Architecture Development Process: A Critical Evaluation

Chapter 5 proposed a 4-stage development process by which a region could construct a regional architecture. Stage IV of that procedure called for the “aggregation” of all service architectures in order to create the single regional architecture diagram. This stage of the process assumed that the regional architecture is, in fact, the sum total of the individual service architectures. However, this raises an important question—might something get lost in the aggregation process? In other words, might the simple process of “superimposing” service architectures overlook some key elements that a regional architecture should consider?

This chapter will explore the answer to this question. It will consist of three sections, each of which will examine a different aspect of the aggregation issue.

- **Section 6.1** will look at the issue of inequities in the distribution of information. When one assembles a regional architecture “service by service”, one may fail to recognize a situation in which one institution is being required to contribute a disproportional share of information. Section 6.1 will look at the problems that could arise in this situation, and it will discuss how a region may address those problems.

- **Section 6.2** will examine the possibility that assembling a regional architecture in a piecemeal fashion may overlook the potential for proactive institutional reform. The regional architecture development process described in Chapter 5 developed a “service architecture” for each user service; any changes to the region’s institutional structure were evaluated on a service-by-service basis. However, it is not likely that the benefits accrued from a single service will be sufficient to justify significant institutional change. Section 6.2 will examine the need to take a retrospective view of the regional architecture. One may find that broader institutional change is justified when considered in the context of multiple services.
• **Section 6.3** will address a basic question: If a region decides to change or add a service at a later date, can one simply draw a new service architecture and superimpose it on the existing regional architecture? In other words, does the “aggregation principle” work when services are deployed over time? If not, how should a region go about modifying and updating the original regional architecture in order to reflect the addition of the new service? Section 6.3 will use an illustrative example to address these questions.

• Finally, **Section 6.4** will provide a brief summary of the chapter.

The primary purpose of this chapter is to critique the proposed procedure for developing a regional architecture. Its goal is to (a) identify any shortcomings in the procedure, and (b) modify the procedure (if necessary) to address these shortcomings.

### 6.1. Problems Associated with Inequities in Information Distribution

The advent of Intelligent Transportation Systems has transformed the transportation environment. Before ITS, transportation managers had access to very little information on the “state of the network”. Now, with the assistance of ITS technologies, the transportation environment is becoming rich with information. The regional architecture responds to this new environment by describing how institutions should share this data in order to improve the performance of the regional transportation system.

Thus, regional architectures call upon institutions to disseminate information. However, the requirement to distribute data to other agencies can impose a significant cost to an institution. For example, the Jefferson regional architecture requires the STA to distribute turnpike traffic and incident information to both the Clinton and the Jefferson Traffic Operations Centers. This may force the STA to (a) install additional communication equipment, and (b) hire additional personnel to monitor the equipment.

When a region assembles a regional architecture in a piecemeal fashion (as detailed in Chapter 5), it may fail to notice that some institutions are being required to distribute far more information than they receive. If an institution finds itself in this situation, it may
conclude that the costs of participating in the regional architecture far outweigh the benefits received. This could conceivably lead to one of two negative results in the long-term.

- **Outcome #1:** The institution (hereafter referred to as a “dispensing institution”) could “bail out” and discontinue its participation. The public would suffer the loss in this situation, as it would experience either the degradation or loss of a particular service.

- **Outcome #2:** The institution could end up acquiring some “political leverage”, as other regional institutions become dependent upon its information. With this leverage, the dispensing institution could threaten to cut off the flow of information to others if some sort of conflict were to arise in the future. In other words, the lack of balance in information flows may create an unhealthy “balance of power” among the region’s institutions.

A region can respond to the lack of “information balance” in one of three ways. The first response would be to simply financially reimburse the dispensing institutions. The second response would be to require the other agencies to *provide* a service that would benefit the dispensing institutions. In this way, the costs of distributing the information would be compensated by the provision of a service. Finally, the third response would be to *introduce* a service that would benefit the dispensing institution. In this way, some information could be directed back to the dispensing institution, thereby correcting the imbalance.

In the Jefferson regional architecture, the State Turnpike Authority is an example of an institution that is required to distribute a disproportionate amount of information. The regional architecture requires the STA to distribute turnpike traffic and incident information to four different agencies, but it provides no information in return. This situation is made obvious by examining the institutional architecture for the STA, which was originally presented in Chapter 5 and is reproduced in Figure 6-1.
Generally speaking, the Jefferson region can respond to this lack of "information balance" in one of three ways. The first response would be to have the government (at the local, state, or federal level) financially reimburse the STA for providing the information. On the surface, this option appears to be the simplest solution. The STA would provide the service (i.e. disseminating turnpike travel information), and the government would provide a subsidy to cover the costs. However, this option poses three potential problems.

- First, it would be very difficult to determine the appropriate amount of subsidy. The government would have to either (a) estimate the costs of providing the information, or (b) accept the STA’s cost estimates.
- Second, this policy could create the impression that all institutions with a net “out-flow” of information are entitled to a subsidy. It would lead to a thorny question: How much “imbalance” must an institution have before it qualifies for government aid?
• Third, this policy might run into opposition from the region’s citizens. From the public’s viewpoint, the STA already receives a substantial level of income from its tolls. Why then do they need still more income from the government in the form of subsidy? Thus, this policy might be difficult to justify politically.

The second option available to the Jefferson region would be to require the other agencies in the Jefferson region to provide a service that would benefit the STA. For example, the municipal Traffic Operations Centers could provide incident response services for any turnpike accidents that happen within their jurisdiction, as “payment” for the information received from the STA.

The third option available to the Jefferson region is to introduce a service that would benefit the STA. This option could be used to direct some information toward the STA, thereby correcting the imbalance. The rest of this section will describe how the Jefferson region might take advantage of this option.

Section 5.4.1 noted that the STA is considering the future deployment of Variable Message Signs (VMS’s) along the turnpike. Originally, the STA planned to simply display information on turnpike traffic conditions. However, given the abundance of information on local traffic conditions, it would be possible for the STA to acquire and display information on the roads to which the turnpike connects.

For example, the “Surface Street Control” service required the STA to distribute information to both the Jefferson Traffic Operations Center (JTOC) and the Clinton Traffic Operations Center (CTOC). These institutions, in turn, used the information to help them adjust the timing of their traffic signals. No information was sent back to the STA.

However, the STA could benefit tremendously if they were to receive feedback from the TOCs on local traffic conditions. The STA could position its VMS’s along the turnpike about a mile before the off-ramps leading to the congested intersections. Based on information from the TOCs, the VMS’s could inform drivers about (a) traffic conditions on
the arterials to which the turnpike connects, and (b) the possibility of local backups extending onto the turnpike.

There are basically two reasons that this possibility of information exchange was overlooked. First, the regional architecture development process calls for services to be developed one by one. Since the “Surface Street Control” service was developed in isolation from other services, the notion of information exchange was not considered. And second, the Jefferson Regional Planning Council, during its public outreach effort (discussed in section 5.4.2.1), never identified the need for VMS’s on the turnpike.

This section will not develop a service architecture supporting the VMS service. Rather, this section simply seeks to make this point—the process of developing a regional architecture should not be considered “complete” once the service architectures have been aggregated. Rather, the process should involve some iteration, in which the region (a) examines the institutional architectures, looking for institutions that are sending out a disproportionate share of information; and (b) looks for ways to address the situation before it becomes a long-term problem.

The best solution for addressing problems of information imbalance is to introduce a new service that would be beneficial to the “dispensing institution”. This solution simultaneously provides an additional service for the public and avoids the need for potentially controversial government subsidies.

6.2. Piecemeal Analysis and its Implications for Institutional Reform

The previous section noted one of the problems associated with piecemeal analysis—the possibility that some institutions will be assigned to distribute a disproportionate amount of information. However, this is not the only potential problem associated with this approach. Piecemeal analysis may also fail to reveal opportunities for significant institutional change.
The regional architecture development procedure outlined in Chapter 5 analyzed each service individually. Decisions about institutional relationships were made on a service-by-service basis. If the costs of a proposed institutional change outweighed the benefits for a particular service, than the changes were ignored.

However, this type of analysis may not take advantage of the opportunity to proactively address institutional change. This section will briefly revisit the three ITS services examined in Chapter 5, which included Surface Street Control, Broadcast Traveler Information, and Incident Management. For each service, this section will point out the potential benefits of introducing a new institution—in this case, a regional Traffic Operations Center. The section will conclude by discussing why a regional Traffic Operations Center was not proposed for the Jefferson region, and it will briefly mention how one might introduce a more proactive approach to regional architecture development.

6.2.1. **Surface Street Control and the Addition of a Regional TOC**

The purpose of the Surface Street Control service was to reduce congestion at four different interchanges in Clinton and Jefferson. The service architecture, originally presented in Figure 5-4, is reproduced in Figure 6-2. As the diagram reveals, each TOC must provide the service to the intersections that lie within its jurisdictional borders.
An alternate approach would be to create a regional Traffic Operations Center (TOC) that would handle all 4 intersections in both cities. A regional TOC would provide two benefits in the context of this service. First, it would provide for regionally coordinated traffic flows at busy intersections adjacent to the turnpike. This could serve as a stepping stone toward regionally coordinated traffic signalization. Second, it would reduce the number of different agencies to which the State Turnpike Authority would need to provide traffic information. An alternate service architecture that would involve a regional TOC is depicted in Figure 6-3.
6.2.2. Broadcast Traveler Information and the Addition of a Regional TOC

Under the proposed "broadcast traveler information" service architecture, each TOC provides WJAM Newsradio with information on traffic conditions within their respective city limits (see Figure 5-7). WJAM then consolidates the various reports and produces a single, regional traffic information broadcast. A regional TOC that consolidates the region's three municipal TOCs would simplify WJAM's tasks in two ways. First, it would consolidate the information on a regional basis before submitting the report to WJAM. And second, it would simplify WJAM's communication needs, requiring only one line into the station instead of three. A possible "broadcast traveler information" service architecture that would include a regional TOC is depicted in Figure 6-4. For purposes of comparison, see Figure 5-7 in section 5.4.2.3.
6.2.3. Incident Management and the Addition of a Regional TOC

Under the proposed incident management service, each Traffic Operations Center has three major responsibilities. First, it receives incident information from 3 different sources (its own loop detectors, the municipal transit agency, and the STA). Second, it coordinates the city’s incident response by communicating with the local police and fire departments. And third, it coordinates with other TOCs for backup support, if necessary. The service architecture that supports this proposed scenario is depicted in Figure 5-10.

A regional Traffic Operations Center could both simplify and improve the region’s incident response capabilities. First of all, it would provide a single point of contact for all traffic incidents in the region. This would mean that the STA would only need to distribute information to one agency, rather than three. Second, it would eliminate the need for inter-city communication during serious incidents. The regional TOC would be able to draw upon the region’s resources immediately, thus providing a quicker response to
major incidents. Third, it would simplify the flow of information to WJAM Newsradio, as one regional TOCs messages would replace three municipal TOCs messages.

A possible service architecture that supports the incident response user service using a regional TOC is depicted in Figure 6-5. For comparison purposes, see Figure 5-10. A comparison of the two diagrams reveals that communication flows are much less complex under the "regional TOC" scenario.

Figure 6-5: Alternate “Incident Management” Service Architecture with Regional Traffic Operations Center
6.2.4. Toward a More Proactive Approach to Institutional Reform

Sections 6.2.1 through 6.2.3 demonstrated that creating a regional TOC promises would provide many benefits. However, when each service is analyzed individually, these benefits are outweighed by the costs. Generally speaking, the creation of a new regional entity entails two kinds of costs:

- **Political Costs.** A regional TOC would likely require the municipal TOCs to surrender some measure of control. For example, if a major incident were to occur in Jefferson, a regional TOC—without acquiring any local approval—could conceivably require the Clinton Police and Fire Departments to assist. This possibility may not resonate well with the municipality of Clinton. After all, these police and fire departments were paid for by Clinton tax dollars; thus, local officials should control them.

- **Financial Considerations.** Even if a region agrees in principle to create a regional TOC, the issue of financing the change would remain. A new building would need to be constructed to house the new entity. The building would need to be equipped with state-of-the-art data communication and processing technology. New staff members would need to be hired to handle the additional duties of the regional TOC. And new emergency response vehicles would need to be purchased. In short, the creation of a new entity can be an expensive proposition, requiring the construction of new physical facilities and the hiring of additional personnel.

No single service (at least in this case study) can justify these significant expenditures. However, the benefits accrued from the three services combined may be sufficient to justify the costs of creating a new institution. For this reason, the possibility of creating a new regional entity should be considered in light of its impact on a group of services, not just in light of its impact upon a single service.

This discussion reiterates the need to approach the development of a regional architecture in an iterative way. Once the service architectures have been aggregated, regional planners should do the following.

- First, they should review the service architecture development process to identify which services could be assisted through creation of a new entity. For example, in
the Jefferson region, the service architecture development process recognized that the creation of a regional TOC would be of benefit to three different ITS services.

- Second, if a new entity is identified that can support more than one service, then regional planners should reconsider the total costs and benefits of creating the new entity. For example, in the Jefferson region, the planners should compare the costs of creating a regional TOC to the total benefits that it provides to the three ITS services. If the benefits outweigh the costs in this broader context (as opposed to the service-by-service context), then the region should seriously consider creating the new institution.

### 6.3. Regional Architectures and the Deployment of Services over Time

Chapter 5 proceeded on the assumption that all user services would be deployed simultaneously. That is, the regional architecture development process assumed that all changes in institutional responsibilities and institutional structure would occur at the same time.

This section will consider some of the implications of this assumption. It will address the following question: What would happen if the Jefferson region wanted to implement a more sophisticated form of traveler information? More specifically, how might the regional architecture be affected if the region chose to deploy a more advanced traveler information system at a later date?

This section will consist of two parts. Section 6.3.1 will construct a service architecture for a more advanced information service. Section 6.3.2 will discuss what would happen if this service architecture were overlaid onto the existing regional architecture.
6.3.1. Constructing a service architecture for the new “Broadcast Traveler Information” service

In order to construct a service architecture, this subsection will follow the first two stages of the four-stage “regional architecture construction process.” This process is described in more detail in Section 5.4.2.

Stage I: Identify the user services that the region would like to deploy

Chapter 5 noted the four services that the Jefferson region wanted to implement (see Section 5.4.2.1). One of these services was “public broadcast of traveler information”. Originally, the region chose to limit the service to simply include the provision of traffic information over the radio. However, let us assume that, five years later, the region wishes to upgrade the quality of the service. It would like to improve the existing traveler information service by adding the following features:

a) Route-specific information accessible by telephone. This would allow travelers to dial up the service and receive up-to-the-minute traffic information on specific routes.

b) Traveler information available via the Internet. This would provide travelers with access to a “traffic information web page”. The page would feature a map of the region, with information on traffic conditions displayed graphically for each of the region’s major routes.

Stage II: Construct the Service Architecture

Step I: Identify subsystems and data flows

This step is identical to step 1 in section 5.4.2.3, since the broadly defined “Broadcast Traveler Information” service is the same. The region does not want a new service; rather, it wants an improvement in the quality of the existing service. The market package diagram corresponding to this service, originally depicted in Figure 5-5, is reproduced in Figure 6-6. For explanatory notes on the diagram, please consult section 5.4.2.3.
Step 2: Map subsystems to physical architecture diagram

This step takes the subsystems identified in the market package diagram and maps them into the more general framework provided by the physical architecture diagram. However, before proceeding, it is important to note how the functionally-defined subsystems correspond to the physical elements that people will interact with.

- The "Remote Traveler Support" subsystem provides traveler information at public kiosks. Since the region does not want to install any kiosks, this subsystem will not be included as part of the physical architecture diagram.
- The "Personal Information Access" provides individuals with traveler information through personal computers and telecommunications equipment. The information can be accessed at home, at work, or while traveling. In this example, three differ-
ent items would comprise the Personal Information Access subsystem. They include (1) home telephones, (2) personal computers (via Internet access), and (3) cellular telephones.

- The “Vehicle” subsystem, in the words of the *Implementation Strategy*, “provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and convenient travel by personal automobile.”105 Three examples of components of a vehicle subsystem are (1) transponders for electronic toll collection, (2) in-vehicle route-guidance devices, and (3) radios for receiving traffic reports. However, a cellular phone is generally *not* considered part of the “vehicle” subsystem. When used to access traffic information, a cellular phone is considered by the National Architecture to be part of the “Personal Information Access” subsystem.

The market package diagram also includes three Center subsystems—Traffic Management, Transit Management, and Information Service Provider. As Chapter 5 pointed out, the names of these subsystems suggest the types of institutions that will be involved in deploying the service. All three Center subsystems will participate in the provision of the service.

Figure 6-7 illustrates how this market package (as adapted for the Jefferson region) maps into the physical architecture diagram. Once again, for more explanatory notes about the diagram, please refer back to section 5.4.2.3.

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Figure 6-7: New "Broadcast Traveler Information" Service Mapped to Physical Architecture

This diagram is very similar to Figure 5-6, which mapped the "radio-centered" traveler information service to the physical architecture. There are two primary differences between the two diagrams.

- Figure 6-7 adds the "Personal Information Access" subsystem. This reflects the expansion of service, in which traffic information is also provided over the phone and over the Internet.

- Figure 6-7 also adds 2 new communication links. The link connecting the Personal Information Access subsystem to "wireline" communication represents 2 types of data flows: (a) information distributed over telephone lines to home telephones; and (b) information distributed over the Internet to personal computers. The link connecting the Personal Information Access subsystem to "wide area wireless" communication represents the flow of information to a cellular phone.
This step serves two purposes. First, it provides an overview of the technical framework that the regional architecture must support. And second, it provides a broader context for the ITS deployment under consideration, showing how the individual market packages fits into the overall National Architecture framework. In short, this step helps provide a link between the technically-defined National Architecture framework and the institutionally-defined regional architecture framework.

**Step 3: Identify the Institutions**

This step was previously completed in section 5.4.2.3. The same nine institutions that contributed to the provision of the former Traveler Information service will be involved in deploying the new service. To review, the nine institutions included the State Turnpike Authority, the three Traffic Operations Centers, the three transit agencies, the Jefferson Airport Council, and WJAM Newsradio. Each institution has some knowledge of regional traffic conditions; taken together, they provide a relatively complete traffic information picture. For a more complete discussion of the institutions involved, please refer back to Step 3 of section 5.4.2.3.

**Step 4: Make decisions concerning institutional relationships**

As Chapter 5 noted, this step involves addressing three basic questions. First, will the service be provide by existing institutions? Second, who will control the provision of the service? And third, how will information be distributed among the various institutions? The following paragraphs will address these questions in sequence.

*Will the service be provided by existing institutions?* It seems clear that the region already has the resources to adequately provide traffic information via radio. However, no one is currently providing traffic information via telephone or Internet. The region has basically two options for providing these services: (1) Require the radio station to expand its responsibilities; or (1) Create a new entity to fulfill the new responsibilities.

The most reasonable approach seems to be the latter. It is very unlikely that WJAM Newsradio will want to expand its services. Although the provision of traffic information
via radio is a logical extension of the agency’s capabilities, the dissemination of information via phone and Internet is not. Thus, the region will probably need to create a new regional information service provider to handle the new responsibilities. For purposes of this scenario, the new agency will be called “IntelliGuide”.

The creation of a new entity raises another question: What kinds of capabilities (other than broadcasting) should IntelliGuide have? In this scenario, the region will provide IntelliGuide with a series of roadside cameras positioned to overlook busy intersections. In this way, the agency will have some of its own equipment to supplement and verify the information received from other agencies.

**Who will control the provision of the service?**

The previous paragraphs noted that a new institution will be required to provide traffic information via telephone and Internet. However, one question remains—Should WJAM Newsradio continue to control the provision of traffic information via radio? There appear to be three ways of answering this question; these options are discussed below. The discussion makes the following assumption: Under current conditions (i.e. the conditions established in the original regional architecture), there is no net cost to WJAM for providing the traffic and incident information service. That is, the costs that WJAM incurs in providing the service are offset by the benefits received from increased numbers of listeners. For this reason, no government subsidy is involved in the service.

**Option 1: WJAM continues its current service, while IntelliGuide introduces the “supplemental” service.**

The advantage of this option is that it causes minimal disruption to the current method of service provision. WJAM would continue to function as prescribed in the regional architecture. The region would simply need to insert IntelliGuide into the existing information distribution scheme.

The disadvantage of this option is that it could set the two agencies up to be competitors. Both agencies provide similar information, and both benefit from people that “pa-
tronize” their information service. People that prefer one service may neglect the other, and the “neglected” agency would end up suffering financially.

This could particularly become a problem if the government were to offer a substantial subsidy to IntelliGuide—a likely possibility, given that the institution will need a “jump start” of some sort. It is very likely that WJAM would oppose this policy. The subsidized service could draw some listeners away from the radio station, which in turn would decrease the station’s appeal as an advertising medium. Thus, the “co-provision” of traveler information could face the opposition of WJAM.

**Option 2:** WJAM contracts out its traffic information service to IntelliGuide. IntelliGuide provides the service, while WJAM provides the airwaves and the airtime.

This option has three advantages. First of all, it would simplify the data flows that support the new services. Under this option, all institutions would provide traffic and incident information to IntelliGuide alone, rather than distributing it to both traffic information agencies. Second, this option could permit some economies by allotting all information processing capabilities to a single institution. Third, this option would avoid the threat of competition by establishing a cooperative relationship between WJAM and IntelliGuide.

However, this option also has two disadvantages. First of all, WJAM would lose control over the quality of the traffic information broadcasts. Although they depend on good broadcasts (in part) to attract listeners, they would not be able to control the quality with which the broadcasts were presented. Second, this option would result in some “sunk costs” for WJAM. The station has already paid for the communication links into the station, and they have hired the staff to monitor and process the incoming information. Thus, ceding responsibility for broadcasting traffic information would cause WJAM to undergo some potentially unsettling structural changes.

**Option 3:** WJAM gives up the traveler information service altogether. IntelliGuide picks up the service by offering continuous traffic reports over a local AM frequency.
The advantages of this option are similar to those of option 2. It would simplify data flows, consolidate information-processing capabilities, and avoid potentially harmful competitive forces.

However, this option also has two disadvantages. The first disadvantage was mentioned earlier—if WJAM gives up traffic information, it could lead to some significant changes in their organizational structure. The second disadvantage is that service would be disrupted from the perspective of the public. The people that had grown accustomed to WJAM’s service would need to adjust to a different station and a different routine.

For purposes of this scenario, it is assumed that the region will select option 1. There are three reasons for this decision.

- First, the region wants WJAM to continue to provide its traffic information service. The region feels that WJAM’s broadcast provides a good example of a market-based service, and it doesn’t want to disrupt its operations.
- Second, this option minimizes the government’s expenditure on the project. That is, by having WJAM continue its broadcasts, the government avoids the need to subsidize IntelliGuide’s efforts to develop a radio broadcast capability.
- And third, the region does not feel that IntelliGuide’s services will compete with WJAM’s services. In other words, it is unlikely that people will turn off their radios just because of the existence of alternate methods of acquiring traffic information.

So far, this section has covered a significant amount of information in its effort to develop a service architecture for the “new and improved” Broadcast Traveler Information user service. At this point, it will be helpful to review our progress.

- The first step was to extract the “Broadcast Traveler Information” market package from the National Architecture.
- The second step was to take the subsystems identified in the market package diagram and map them to the physical architecture diagram. This step also involved identifying the types of services that the region would like to deploy. In this case, the
The region chose to deploy information via three different media: radio, telephone, and the Internet.

The third step was to identify the nine institutions that will participate in the provision of the service.

The fourth step was to determine how these nine institutions will relate to one another as they provide the service. This required the region’s planners to answer three questions.

The first question was—Will the service be provided by existing institutions? The answer to this question was “No”; a new information service provider (named IntelliGuide) would be created.

The second question was—Who will control provision of the service? The answer to this question was that WJAM would continue to provide information over the radio, while IntelliGuide would provide information via telephone and the Internet.

The third question was—How will information be distributed among various institutions? The next segment will address this question.

How will information be distributed among various institutions?

This question is more complex now that there are two providers of traveler information. One could envision four different ways in which information could be distributed.

Option 1. Each agency that possesses traffic information distributes this data to both information service providers. This would essentially double the amount of communication links and data flows needed to support the “broadcast traveler information” service.

Option 2. Each agency sends their information to the radio station. The radio station would then consolidate the information and pass it on the IntelliGuide. This option would take advantage of the fact that all institutions already distribute information to WJAM. Thus, the only additional communication requirement would be the addition of a link between WJAM and IntelliGuide.
Option 3. Each agency sends its information to IntelliGuide. IntelliGuide would then consolidate the raw data and pass it on to WJAM Newsradio. This option would be good from IntelliGuide’s perspective. After all, IntelliGuide is expected to provide a higher-quality, route-specific traffic information service. To do this effectively, they should receive the information directly from the source. However, this option would also require the construction of numerous new communication lines from the existing agencies to the new entity.

Option 4. Some agencies send their information to WJAM, while others send it to IntelliGuide. WJAM and IntelliGuide would then exchange information to provide each other with a complete picture of traffic information. This would constitute a “compromise” approach. For example, IntelliGuide would have access to some first-hand information, but not all of it. Moreover, some new communication links would need to be constructed, but it would not require as many new lines as options 1 and 3.

For purposes of this scenario, it is assumed that the region will select option 3. There are four reasons for this selection.

- First, it provides the best service for the customer. As mentioned above, this option provides IntelliGuide with immediate access to traffic conditions, enabling them to update their information in real time. In other words, if IntelliGuide is expected to offer a higher quality of service than WJAM, it should have better access to information than WJAM.
- Second, this method should not hinder the quality of the radio broadcast. This option would require IntelliGuide to pass on information frequently enough to allow WJAM to update its traffic reports (currently given every 10 minutes).
- Third, this option keeps the total number of communication links to a minimum.
- Fourth, this option would allow WJAM to partially benefit from the subsidy to IntelliGuide. This option should reduce WJAM’s costs, since they would have fewer incoming communication links to monitor.
**Step 5: Construct the “service architecture”**

So far, the user service analysis process has (a) identified the institutions involved; (b) assigned responsibility for providing the service; and (c) identified how the institutions will relate to one another as they provide the service. All of these decisions are “architecture choices” that shape the service architecture. Figure 6-8 is one possible service architecture that follows from these decisions.

![Diagram of service architecture](image)

**Figure 6-8: New “Broadcast Traveler Information” User Service**

This architecture closely resembles the original “Broadcast Traveler Information” service architecture, depicted in Figure 5-7. The two major differences are highlighted below:
• First, all information is distributed to IntelliGuide, rather than to WJAM Newsradio. WJAM still receives all the raw data, but (a) it receives this data from a single source, and (b) it receives the information secondhand, which means that the information will be slightly delayed.

• Second, WJAM is now being asked to share some of the information that it gathers with its own resources (i.e. the traffic-helicopter and the “WJAM cell-phone force”). This could be a point of contention with WJAM; that is, they may not be eager to provide more information to an already subsidized service. However, WJAM may be willing to share the information if, in turn, IntelliGuide provides WJAM with information gathered by its own resources (i.e. the roadside cameras observing busy intersections). The advantage of this arrangement is that it provides the best service for traveling public, for it calls for the free distribution of traffic information throughout the network.

6.3.2. Implications of the new service architecture for the existing regional architecture

Section 6.3.1 covered the first two stages of the four-stage regional architecture development process. Stage III requires the analysis of the non-ITS services, and stage IV involves the aggregation of the service architectures into the regional architecture. In this example, it is assumed that the region simply wants to upgrade one of its ITS services; no non-ITS services are involved. Therefore, it is appropriate to proceed directly to stage IV.

When one tries to overlay the new service architecture (depicted in Figure 6-8) onto the old regional architecture (depicted in Figure 5-14), one encounters an immediate problem—some of the information flows have changed. Originally, the three Traffic Operations Centers, the three transit agencies, the Jefferson Airport Council, and the State Turnpike Authority all delivered their traffic information to WJAM. Under the new structure, they must shift these data flows from WJAM to IntelliGuide. Thus, integration of the new service architecture will require at least four changes: (1) the addition of a new institution (IntelliGuide); (2) the addition of a new service (traffic information via phone
and Internet); (3) the addition of new data flows (from IntelliGuide to WJAM, and from WJAM to IntelliGuide); and (4) the rerouting of old data flows (as mentioned above).

However, the potential changes to the regional architecture extend beyond the “cosmetic” changes of adding some new institutional boxes and changing some information flow arrows. Two other factors must also be considered. First, the region must look at how WJAM’s role might change with respect to other services. And second, the region must evaluate the impact that the new institution could have on other services. These two factors will be discussed below.

- **WJAM’s role in other services.** Currently, WJAM is involved in one other service—Incident Management. Its role in the provision of this service is (a) to receive incident information from each of the three Traffic Operations Centers, and (b) to broadcast traffic incident information to the public. The flow of information for this service is depicted in Figure 5-10.

The region should consider changing the “Incident Management” service architecture to reflect the changes in the “Broadcast Traveler Information” service architecture. It wouldn’t make sense for the TOCs to distribute traffic information to IntelliGuide while distributing incident information to WJAM. Instead, the three TOCs should simply pass the incident information to IntelliGuide. IntelliGuide can then (a) update their call-in and Internet service data, and (b) pass the data on to WJAM.

- **IntelliGuide’s role in other services.** IntelliGuide could also serve as a facilitator of information coordination with the Incident Management service. Currently, each institution coordinates for assistance with each of the other TOCs. This means that, when a major incident occurs within one city, that city’s TOC must contact two different agencies to acquire the support it needs. The time taken to make this coordination effort could be very costly during a serious accident.

IntelliGuide could streamline this coordination process. Under a slightly different service arrangement, a Traffic Operations Center requiring assistance could notify
IntelliGuide of a serious incident. IntelliGuide could, in turn, notify the other Traffic Operations Centers of the request for assistance. This would simplify the data flows and place less of a communication burden on the individual TOCs.

Moreover, IntelliGuide could serve as an “incident information clearinghouse”. Currently, the State Turnpike Authority must report incident information to each of the three TOCs. Since IntelliGuide has a direct link with each of the TOCs, the State Turnpike Authority could simply distribute all turnpike incident information to IntelliGuide. IntelliGuide would then pass the information along to the appropriate TOC.

Figure 6-9 illustrates how the service architecture for Incident Management might change if the region were to consider the two factors mentioned above.
Figure 6-8: Possible “Incident Management” Service Architecture With IntelliGuide
In summary, two lessons can be drawn concerning the deployment of additional or improved services over time. First, it will result in additions to the existing regional architecture. This will likely involve additional services, additional data flows, and possibly additional institutions as well. Second, the delayed deployment of additional or improved services may change the existing regional architecture. Such changes can come from two sources—modifications to the existing data flows due to the fact that a new entity is replacing an existing one, and modifications to other service architectures due to the additional capabilities of a new entity.

Thus, if a region chooses to add or upgrade its services over time, it must revisit its regional architecture. Most planners understand that adding new infrastructure will affect the performance of adjacent infrastructure. For example, if a region chooses to improve its port facilities, then it should anticipate that the roads leading to the port may experience increased congestion. In the same way, adding new services can impact the way in which other similar services are provided. Regional planners should recognize this, and they should adjust the overall framework for service provisions (i.e. the regional architecture) accordingly.

6.4. Conclusions

This chapter has examined three implications of the regional architecture design process described in Chapter 5. These three implications are summarized below.

- In the process of assembling a regional architecture from several “service architectures”, one may fail to notice that some institutions are providing a disproportionate amount of information. This lack of “information balance” could result in long-term instability for the regional architecture.

- The process of constructing a regional architecture “piece-by-piece” may overlook the opportunity for significant institutional change. The political and economic costs of creating a new entity may not be justified on the basis of one service alone. However, these benefits may be justified when one considers the ways in which this new entity could contribute to multiple services.
When a region wishes to add a new service at a later date, the region will probably not be able to simply construct a new service architecture and "superimpose" it on the existing regional architecture. There are three reasons for this. First, the new service may cause some of the "original" data flows to be rerouted. Secondly, the new service may cause some of the existing institutions to change roles and responsibilities. And third, if the new service results in the creation of a new institution, the new institution could have an impact on the way in which other services are provided.

These three implications suggest that two additional stages should be incorporated into the regional architecture development process. These two stages—Stage V and Stage VI—are described below:

**Stage V: Evaluate the Regional Architecture**

This stage would occur after the regional architecture has been assembled in Stage IV. It would consist of two steps:

- **Step 1:** Identify the institutions that may be contributing a disproportionate share of information.
  
  This step would require transportation planners to examine the institutional architectures to see if any institutions are being required to distribute much more information than they receive.\(^{106}\) If so, the planners should consider how to rectify the imbalance. This could be done in one of three ways. The first way would be to offer the "dispensing institution" some monetary compensation. The second way would be to require the other agencies in the region to provide a service that would benefit the dispensing institutions. Finally, the third way would be to introduce a new service that would be beneficial to the "dispensing institution".

- **Step 2:** Reconsider opportunities to create new institutions.
  
  This step would require transportation planners to see what (if any) new institutions were considered. If the region can identify a new institution that could con-

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\(^{106}\) The institutional architecture concept was introduced in Section 5.4.2.6. They provide the same information as the regional architecture, but they do so from the perspective of a single institution.
tribute to multiple services, then the region should reconsider the costs and benefits of creating that institution. Perhaps, when considered in the broader context of multiple services, the region may be able to justify the creation of a new institution.

**Stage VI: Revisit the Regional Architecture over Time**

This stage would require transportation planners to reexamine the regional architecture as new services are introduced at a later date. Whenever a new service is created, or an existing service is upgrade, a new service architecture should be constructed. If the new service architecture calls for the creation of a new entity, then the region should consider how other existing services might also benefit from this new entity. The region should also consider how the current roles of the existing institutions might be modified due to the additional capabilities of the new entity.

To summarize, this chapter has concluded that the regional architecture development process described in Chapter 5 is insufficient. Two additional stages must be incorporated into the procedure in order to account for some of the problems related to superimposing service architectures. Stage V is done one time, when the regional architecture is initially developed; Stage VI is done on a continuing basis over time.

The next chapter will take a step back and look at the “bigger picture”. It will attempt to answer two new questions. First, how does the regional architecture development process fit into the broader strategic transportation planning process? And second, how do regional architectures enhance the transportation planning process?
Chapter 7
Regional Architectures and the Planning Process

The previous two chapters provided an extended discussion of the definition of a regional architecture. Its primary goal was to describe how to construct a regional architecture. However, while Chapters 5 and 6 treated regional architectures as an “end”, this chapter will treat them as a means to an end. The basic premise of this chapter is that a regional architecture’s value is ultimately measured by its contribution to the development of an effective strategic transportation plan. Therefore, this chapter will discuss the role that regional architectures can play in the transportation planning process.

This chapter will consist of three basic sections.

- Section 7.1 will propose a general structure for regional strategic transportation planning, and it will discuss, in detail, each component of that structure. This section will highlight the important role that regional architectures play within the broader strategic planning process.
- Section 7.2 will briefly review some of the observed shortcomings in the contemporary regional strategic planning, and it will discuss some of the ways in which regional architectures address these shortcomings.
- Finally, section 7.3 will provide a brief summary of the chapter.
7.1. A Proposed Strategic Planning Structure

Figure 7-1 provides a proposed structure for the regional strategic transportation planning process.

The planning framework depicted in Figure 7-1 was developed under the auspices of an MIT research project called ReS/SITE: Regional Strategies for the Sustainable Intermodal Transportation Enterprise. The project aspires to developing a new framework for regional strategic transportation planning; Figure 7-1 takes a step toward developing that framework.

Figure 7-1 consists of 6 basic components: Scenarios, the Regional Strategic Transportation Plan (RTSP), the Regional Infrastructure, the Regional Architecture, System Management, and feedback loops. The subsections that follow will discuss each component in detail.
7.1.1. Scenarios

In this conceptual framework, scenarios are considered to be the engine of the regional strategic planning process. The process of scenario building identifies, in a structured manner, different ways in which the future may unfold. More specifically, it attempts to project, through a logical process of cause-and-effect analysis, two to four different future scenarios; these scenarios provide the context in which the regional transportation system of the future must operate. The object of the planning process, therefore, is to develop a transportation system that will perform well across a broad range of future scenarios.

7.1.2. Regional Strategic Transportation Plan

The regional strategic transportation plan (RSTP) is the document that charts the course for the region’s transportation system. It provides a concept and a vision for a transportation system that is responsive to the range of future demands suggested by the scenario development process. This document is produced through the “traditional” strategic planning process, assisted by information provided by the scenarios.

Yang, Sussman, and Martland, in their work entitled Toward the Development of a Strategic Transportation Plan for Mendoza, propose a comprehensive seven-step strategic planning process that can serve as a model for the development of the Regional Strategic Transportation Plan. This process is summarized briefly below.

Step 1: Establish the vision

Yang notes that “The classic strategic plan begins with a vision of what is to be accomplished”. This vision provides a broad outline of the region’s long-term aspirations. It begins to answer this fundamental question: What type of transportation system is

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107 Diagram extracted from presentation entitled “ReS/SITE: Regional Strategies for the Sustainable Intermodal Transportation Enterprise”, given by Prof. Joseph Sussman to the University Transportation Center, 2 March 1998.
needed in order for the region to achieve goals? In other words, how can the regional transportation system advance the region's broader social, economic, and political objectives?

**Step 2: Document the context**

The purpose of this step is to "identify the major factors both external and internal to the [region] that impact upon the viability of the strategic plan". This step requires the planner to analyze five different contexts in which the region's transportation system must operate. These include the current *international* context, *institutional* context, *economics and finance* context, *environmental* context, and *technology* context. Furthermore, with the assistance of input from the scenario development process, this step can also consider how the existing contexts may change in the future.

**Step 3: Inventory the current situation**

Yang describes the third step in the transportation planning process as follows:

"In the transportation context, we need to inventory transportation facilities of various kinds, including both infrastructure and rolling stock. Further, we must consider the various organizations either directly or indirectly involved with the transportation system."

Yang proceeds to describe the various types of data that planners should acquire during the inventory process. These include the following:

- Regional transportation statistics (vehicle miles traveled, percentage of congested highway miles, ton-miles of freight traffic, freight traffic by mode of transportation, origin and destination of truck shipments, rail passenger traffic, water freight volume by commodity group, etc.)
- Transportation-related economic data (consumer spending on transportation products and services annually, transportation as a share of consumer spending, growth of exports and imports of merchandise, etc.)

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110 This section will summarize the procedure described in pages 25 through 38 of Yang et al's work. For purposes of clarity of presentation, individual quotes from this work will not be footnoted.
- Environmental data (relationship between traffic and CO\textsubscript{2} emissions, tons of volatile organic compounds emitted per summer day by light duty motor vehicles, etc.)
- Energy data (oil as a percentage of all energy consumption at the regional level)

This step recognizes that the existing transportation system provides the foundation upon which the transportation system of the future will be built. It asserts that knowledge of the current system provides a starting point for developing the strategic plan. Stated another way, just as the vision provides the “end point” (describing where the region would like to go), the “inventory” provides the starting point (describing where the region is right now). The task of the strategic plan is to plot the course that moves the region from the start point to the end point.

**Step 4: Identify regional strengths, weaknesses, opportunities, and threats (SWOT)**

Yang writes that “Part of the traditional strategic planning framework is an assessment of the strengths and weaknesses relative to the tasks to be accomplished and the opportunities for and threats to achieving its vision of the future.” With this in mind, this step pursues two objectives.

- First, it identifies *internal* strengths and weaknesses that may affect the region’s pursuit of its vision. For example, if a region’s vision included substantially shifting regional freight movements from truck to rail, then a weakness would be the absence of well-maintained rail infrastructure. The presence of well-maintained rail infrastructure, by contrast, would be a “strength”.
- Second, it identifies *external* opportunities and threats that may affect the region’s pursuit of its vision. These would include such things as growing international trade (an opportunity for regional economic growth), national political instability (a potential threat to regional development), and an oil crisis (also a potential threat to regional development, if the region is highly dependent on fossil fuels). The ability to identify opportunities and threats is assisted by the scenario development process, which attempts to foresee the potential impacts that emerging national and global trends will have on a particular region’s prosperity and stability.
Step 5: Identify and Evaluate Potential Futures
According to Yang et al, the next step in the strategic planning process is to “map out various ways in which the vision specified earlier can be achieved”. This step identifies different options for developing the region’s transportation system. The goal is to outline a transportation development path that (a) supports the region’s vision, and (b) can be realistically implemented. This step concludes with the selection of one of the proposed development paths to implement.

Step 6: Develop a Plan of Action
According to Yang, the seventh step of the transportation process is to develop a more detailed plan of action. This step adds some “flesh” to the “bones” of the development path specified in step 5. The plan of action should consist of at least four elements: (1) definition of particular projects; (2) plans for financing the projects; (3) development of time lines; and (4) establishment of the roles and responsibilities of various organizations. Within the ReS/SITE framework, the “plan of action” manifests itself in two outputs—the Regional Architecture and the Regional Infrastructure.

Step 7: Establish a Continuing Process
The last step of Yang’s framework involves the establishment of strategic planning as an ongoing process. This step recognizes that strategic planners must constantly revisit their plan, accounting for and reacting to changes in the social, political, and economic environment. As Yang puts it, planning should be “an iterative process, as we cycle back through various stages as new information becomes available and situations change.” Within the ReS/SITE framework, this step is supported by the systems management component.

7.1.3. Regional Infrastructure
The regional infrastructure, which represents the physical component of the regional transportation system, is one of two basic outputs of the Regional Strategic Transportation Plan. It includes three basic elements. The first element is conventional infra-
structure. This includes all regional highways, airports, waterways, railways, and intermodal interfaces that carry people and goods through the transportation network. The second element is ITS infrastructure. This includes all advanced technologies used to sense vehicles, communication data, and process information in support of ITS user services. The second element is rolling stock. This includes buses, subways, containers, snowplows, and other mobile elements that perform services and transport people and goods over the conventional infrastructure.

The regional infrastructure is representative of the “traditional” output of the transportation planning process. Virtually all transportation plans provide a “wish list” of new infrastructure that the region would like to have. However, the ReS/SITE framework advocates that regions consider a second output to the planning process—a regional architecture. This output is described in the next subsection.

7.1.4. Regional Architecture

The regional architecture—defined in detail in Chapter 5—represents the institutional component of the regional transportation system. It describes how the region’s institutions must relate to one another in order to provide transportation services. In doing so, it defines the interactions of the institutions that own, maintain, and operate the physical elements identified in the regional infrastructure. Thus, the regional architecture and the regional infrastructure are complementary documents. Both support the deployment of services—one from a physical standpoint, and the other from an institutional standpoint.

It is important to note that the regional architecture development process (described in Chapters 5 and 6) is a subset of the “RSTP” component of the ReS/SITE framework. That is, the process that is used to develop the regional architecture occurs within the broader strategic transportation planning process. To illustrate:

• Step 5 of the strategic planning process described in Section 7.1.2 requires the planner to identify various “transportation development paths”. This process of identifying and evaluating various transportation options manifests itself in “Stage 1” of
the regional architecture development process, in which regional planners determine which services are needed in order to enable the region to pursue its vision.

- Step 6 of the strategic planning process requires the planner to “develop a plan of action” that implements the transportation development path selected in Step 5. This step manifests itself in stages 4 and 5 of the architecture development process, in which planners assemble and refine the regional architecture document.

Thus, the ReS/SITE framework distinguishes between the planning process and the planning outputs. The “Regional Strategic Transportation Plan” component of the diagram represents the planning process. The “regional architecture” and “regional infrastructure” components represent the outputs (i.e. documents) that emerge from the planning process. The relationship between the strategic planning process, the regional architecture development process, and the regional architecture is depicted graphically in Figure 7-2.

![Figure 7-2: Relationship between the Strategic Transportation Planning Process and the Regional Architecture Development Process](image)
The following bullets summarize the components of the ReS/SITE framework that have been discussed so far:

- **Scenarios** are the driver of the strategic planning process. They help project possible futures which, in turn, suggest basic characteristics of a particular region’s transportation system.

- The **Regional Strategic Transportation Plan** is informed by scenarios and is produced through the traditional strategic planning process. The strategic planning process produces two outputs: the regional infrastructure and the regional architecture.

- The **Regional Infrastructure** represents the facilities comprising the physical component of the regional transportation system. It includes the collection of conventional infrastructure, ITS infrastructure, and rolling stock that facilitate the movement of people and goods through the region.

- The **Regional Architecture** represents the institutions that operate, maintain, and manage the regional infrastructure. It defines how the various institutions will interact in order to both plan and provide transportation services to the region.

The regional architecture describes how institutions will interact as they operate the system. The “operations plan” described in the regional architecture is executed through the system management function, which is described in the following subsection.

**7.1.5. System Management**

The “system management” component of the diagram represents the operation of the transportation system. It is a function that provides transportation services by blending institutional capabilities (noted in the regional architecture) with transportation facilities (noted in the regional infrastructure). The “system management” component reflects the recognition that transportation systems are not simply created; they are also operated and maintained. System management, therefore, is an ongoing process that endures long after the physical facilities are constructed. In this sense, the system man-
agement function supports Step 7 of the Strategic Planning Process, which requires the region to “establish a continuing process” (see Section 7.1.2).

One of the tasks of the system management function is to monitor the performance of the transportation system. This would include at least two elements: an assessment of the performance of the physical facilities, and a review of the effectiveness of institutional interactions. Feedback from this review process would serve two purposes.

- In the short term, it would help to shape future iterations of the transportation plan. For example, feedback on the performance of the physical facilities could inform the planners on the extent to which the region is attaining the vision described in the plan. Furthermore, feedback on the effectiveness of institutional cooperation could inform the planners on the extent to which the region should seek to modify institutional interactions. This type of feedback is represented by the feedback loop from the system management function to the RSTP, and it should take place on an annual or biannual basis.

- In the long term, feedback from the system management review process would help to inform a future round of scenario development and strategic planning. One of the tasks of the system management function would be to collect data on the performance of the transportation system in order to identify long-term trends. Planners could use this information to help determine which of the projected scenarios has emerged as “dominant”. By comparing past projections with past performance, transportation planners can establish a more informed “scenario baseline” from which another round of scenario development and transportation planning could be launched. This type of feedback is represented by the feedback loop from the system management function to the scenario component, and it should take place over a longer period (perhaps 5-8 years, or as needed when conditions change dramatically).

7.1.6. **Reviewing the ReS/SITE Framework**

The ReS/SITE planning framework proposes to improve the state-of-the-art in regional strategic planning in two ways.
• First, the ReS/SITE framework proposes to better inform the strategic planning process by introducing the *scenario development process*. Scenarios contribute to the strategic planning process by helping planners anticipate the future environment in which the region’s transportation system will need to operate.

• Second, the ReS/SITE framework identifies the need for an additional output to the strategic planning process—the *regional architecture*. This output explicitly recognizes that transportation systems are not simply built; they are also operated and maintained. The regional architecture provides structure to the region’s transportation institutions, enabling them to effectively operate the regional transportation system.

In short, this section has proposed a new framework for strategic transportation planning, and it has illustrated where regional architectures fit into this framework. The next section will briefly discuss some specific ways in which the regional architecture concept advances the state-of-the-art in strategic transportation planning.

### 7.2. Regional Architectures as Good Transportation Planning Practice

The overarching theme of this thesis is that *the use of the regional architecture concept is good transportation planning practice*. It recognizes that transportation services can play an important role in addressing shortcomings in transportation systems. It recognizes that institutional cooperation is essential if these services are to be deployed effectively. It recognizes that transportation is largely driven by economic activity, and that transportation therefore should be managed on the same geographic scale at which economic activity occurs. And it recognizes that, when information is shared in a timely and cooperative manner, the transportation system “whole” can be significantly greater than the sum of its parts.
The ReS/SITE research team at MIT has performed case studies on a number of state and regional transportation plans. The works reviewed by the ReS/SITE team include the following:

- Long range transportation plans for the states of Maine, Virginia, Colorado, Massachusetts, Wyoming, Iowa, New Mexico, Washington, and Mississippi.
- Regional transportation plans for Boston, New York City, and New England.
- A series of "Enhanced Planning Reviews", conducted by the Volpe Center, which critiqued the planning processes of several Metropolitan Planning Organizations throughout the United States.\(^{111}\)
- Reviews of transportation planning practices in overseas regions, including Amsterdam, the United Kingdom, and the broader European Union.

A detailed analysis of these plans revealed a series of shortcomings in strategic transportation planning. These shortcomings include:

- Lack of consideration of intermodal connections;
- Failure to survey new and emerging technologies;
- Extensive focus on passenger transportation needs, to the substantial exclusion of freight transportation needs;
- Failure to explicitly consider the relationship between transportation and economic growth;
- Failure to explicitly consider operational issues;
- Lack of public/private interaction in the planning process; and
- Lack of consideration of the need to develop transportation professionals who are equipped to handle emerging transportation challenges.\(^{112}\)

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\(^{111}\) The regions whose Enhanced Planning Reviews were studied by the ReS/SITE team include San Francisco, New York City, Newark, and St. Louis.

The four subsections below will briefly describe how the regional architecture development process (as part of the strategic transportation planning process) is responsive to some of these observed shortcomings.

7.2.1. Regional Architectures and Intermodalism

Traditionally, transportation plans have evaluated the various transportation modes independently, without much consideration of the interactions among them. The regional architecture development process can be a means of bringing intermodal issues to the forefront. The regional architecture concept stems, at least in part, from two basic ideas. The first idea is that transportation modes are not simply *constructed*; rather, they are also *operated* by particular institutions. The second idea is that the ability of institutions to operate these modes and provide a quality transportation service can be enhanced by institutional coordination. Thus, a regional architecture supports intermodalism by bringing together the institutions that operate the various modes.

One can envision several ways in which a regional architecture could foster intermodalism. For example, if a region desired more park-and-ride lots, the regional architecture development process could assist by bringing together the State DOT (which operates the interstate highway) with the various municipalities (which operate the connecting arterials). If a region wanted to improve safety at railroad grade crossings, the regional architecture development process could assist by bringing together the municipalities (which operate the warning signals) with the railroads (which operate the trains). If a region wanted to improve access to its airport, then the regional architecture development process could assist by bringing together the airport authority (which operates the airport access roads) with the regional transit providers (which operate the vehicles that bring people to the airport).

In short, the process of constructing and revising a regional architecture provides a forum for the region’s transportation institutions to assemble and discuss the ways in which they should interact. The process of improving institutional interactions will ultimately assist in the performance of modal interactions.
7.2.2. Regional Architectures and Technology Scanning

Strategic transportation plans often fail to identify emerging technologies that could be integrated into the regional transportation system. Part of this problem stems from the fact that most transportation plans are developed by the public sector, which has historically been averse to readily adopting new technology.\textsuperscript{113}

Regional architectures respond to these shortcomings in two ways. First, the regional architecture concept was initially motivated by the development of a National ITS System Architecture. The National Architecture helps a region translate practical problems (such as congestion at truck stops) into technological solutions (such as weigh-in-motion and electronic credentialing). Therefore, because of its ITS “heritage”, the regional architecture development process is inherently oriented toward the identification and integration of emerging technologies into the regional transportation system.

Regional architectures can also help introduce technology “through the back door”. The regional architecture development process provides a forum that can potentially bring technologically sophisticated private institutions to the strategic planning table. When this happens, public sector transportation planners should take advantage of the opportunity to inquire about emerging technologies and their potential relevance to transportation needs.

7.2.3. Regional Architectures and Public/Private Interaction

Public/private partnerships are an emerging paradigm in the world of transportation. Examples abound of transportation projects that have been constructed through the joint efforts of public and private sector organizations. For example:

- By privatizing the region’s air cargo facilities, the Port Authority of New York and New Jersey generated $200 million in private funding in 1996 to redevelop the region’s air cargo infrastructure at Kennedy International Airport and Newark International Airport.
In 1987, the Government of Canada invited the private sector to design, construct, finance, and operate a bridge across the Northumberland Strait in order to connect the provinces of Prince Edward Island and New Brunswick. The bridge was completed in June of 1997.

The Alameda Corridor—a road and rail improvement program that will link the Ports of Los Angeles and Long Beach to rail facilities in downtown Los Angeles—is currently under constructing, drawing on the financial resources of both the public and private sectors.\(^{114}\)

However, as these few examples reveal, most public/private interaction in the transportation world has taken place at the project level. By contrast, very little interaction has taken place at the strategic planning level. However, the planning level represents an area in which public/private partnerships can unite the region and advance regional goals. Numerous private sector agencies provide transportation services, and still more are users of transportation services. Transportation planners can therefore use the planning process as a means of “integrating the region” by bringing regional institutions together in pursuit of common transportation goals.

The regional architecture development process provides transportation planners with an opportunity to bring private-sector service providers to the planning table. The process provides these entities with an opportunity to express (a) how their operational abilities may be enhanced by cooperating with other institutions, and (b) how they might be able to contribute to the integration of regional transportation services. In short, regional architectures provide the private sector with an opportunity to shape the way in which regional transportation services are planned and provided. This is something that the current planning process generally does not offer.


\(^{114}\) For an extended treatment of public/private partnerships as they relate to transportation, see Sussman et al (1997), pp. 183-214.
7.2.4. Regional Architectures and an Operational Focus

Traditionally, transportation plans have focused almost exclusively on infrastructure. These plans often follow a similar format. First, they identify the existing infrastructure in the region. Second, they identify (typically from a level-of-service standpoint) the shortcomings in the performance of the existing infrastructure. Finally, they propose new infrastructure that is required in order to alleviate these shortcomings. The primary output of this process is a “wish list” of new transportation infrastructure that the region would like to construct over the next 15 to 20 years.

This “format” is missing one critical element—explicit consideration of how one might address transportation problems by improving the operation of the existing infrastructure. The regional architecture development process can help provide this missing element. The regional architecture is inherently focused on improving system performance. It seeks ways to resolve transportation problems through improved services, as opposed to expanded infrastructure. It strives to get the most out of the existing physical facilities through institutional cooperation and information sharing. In short, the regional architecture provides an operational focus to transportation planning by describing how the region’s institutions should interact as they operate the existing system. Instead of calling for construction, it calls for collaboration.

In summary, this section contends that the incorporation of a regional architecture development process constitutes good transportation practice. It calls attention to intermodal opportunities by bringing together the institutions that operate these modes. It provides a forum in which regional planners can discuss opportunities for integrating new and emerging technologies into the transportation system. It gives the private sector an opportunity to participate in the transportation planning process. And it provides an operational focus to transportation planning to balance the traditional “capital focus”. In short, the regional architecture development process confronts, in a very di-
rect way, many of the observed shortcomings in the strategic transportation planning process.

7.3. Chapter Summary

The six previous chapters have focused primarily on defining “regional architecture”. This chapter has taken a step back and placed the regional architecture within a broader context. The following bullets summarize the main points made by this chapter:

- The ReS/SITE framework introduces two new elements to the traditional strategic planning process—scenarios and regional architectures. Scenarios are an input to the planning process, whereas regional architectures are an output of the process.
- The regional architecture is one of two fundamental outputs of the transportation planning process (the other being the “regional infrastructure”). Its basic task is to describe how the region’s institutions should interact with one another in order to provide an integrated series of transportation services to the region.
- Regional architecture development should be an integral element of the broader strategic planning process.
- Regional architectures broaden the scope of traditional transportation planning by focusing on institutions, rather than simply focusing on infrastructure. Whereas the regional infrastructure supports the construction of facilities, the regional architecture supports the provision of services.
- The regional architecture concept constitutes good transportation planning practice. Incorporating regional architectures into the transportation planning process can effectively address many of the current shortcomings in regional strategic planning.

This chapter concludes the main body of this thesis. Chapter 8 will summarize the thesis, reviewing the key points and identifying potential areas for future research.
Chapter 8
Summary, Conclusions, and Suggestions for Future Research

This thesis has pursued three basic objectives.

- The first objective was to define the term “regional architecture”. This was the subject of Chapters 2, through 4, as well as the first three sections of Chapter 5.
- The second objective was to describe and illustrate a procedure by which a region could construct a regional architecture. This was the subject of Section 5.4 and Chapter 6.
- The third objective was to describe how a region might integrate regional architectures into the strategic transportation planning process. This was the subject of Chapter 7.

This chapter will briefly summarize the material that has been covered in this thesis. It will consist of four parts. Section 8.1 will review the key motivations for this thesis. Section 8.2 will reiterate the key ideas presented in each chapter. Section 8.3 will review the key contributions of this research. Finally, Section 8.4 will suggest some areas for further research.

8.1. Motivation for this thesis

There were two basic motivations for this thesis. The first motivation stemmed from the ISTEA reauthorization legislation that is currently pending in Congress. This legislation, it appears, will continue substantial Federal involvement in the development and deployment of Intelligent Transportation Systems (ITS). However, Federal ITS funding will likely require regions to develop “regional architectures” that are “consistent” with the National Architecture. This requirement raises an important question—What exactly is a “regional architecture”? One goal of this thesis was to shed some light on this question.
The second motivation stemmed from prior research on strategic transportation planning conducted at MIT. It is evident from this research that some important changes need to be made to current planning practices. This MIT ReS/SITE research team, which has analyzed numerous state and regional transportation plans, has noted a number of shortcomings in contemporary transportation planning. A second goal of this thesis was to explore the “regional architecture” concept as a useful tool for addressing some of these shortcomings.

8.2. Summary of Chapters 2 through 7

Chapter 1 introduced the three primary objectives of the thesis: to define “regional architecture”, to illustrate how one might construct a regional architecture, and to describe how regional architectures fit into the strategic transportation planning process.

The next two chapters broke the term “regional architecture” down into its component parts. Chapter 2 provided an extended treatment of the term “architecture”. The computer science realm adopted the architecture concept in the 1960’s in order to describe the underlying structure of computer systems. Broadly speaking, a computer system architecture served three purposes. First, it identified the major components of the computer system. Second, it described the roles of the various components and the locations of major processing capabilities. And third, it described the method by which information would be distributed throughout the system.

The concept was adopted by the transportation world with the advent of Intelligent Transportation Systems. ITS sought to apply emerging information technologies to transportation in order to improve the efficiency of the existing infrastructure. In essence, ITS envisioned that vehicles and infrastructure could function together as a coherent system. The “pioneers” of ITS recognized that a system architecture would be needed to govern the interactions between vehicle and infrastructure systems. Thus, the US Department of Transportation sponsored the construction of a National ITS System Architecture.
Originally published in June of 1996, the National ITS Architecture was a mammoth series of documents comprising over 5800 pages. Despite its length, the content of the National Architecture could be boiled down into five basic elements. First, it identified a series of services that the architecture should support. These were termed “user services”. Second, it identified the basic components that would implement these services. These were termed “subsystems”, of which there were nineteen. Third, it specified the functions that each subsystem should be able to perform in order to implement the services. These functions were referred to as “equipment packages”. Fourth, it identified the various types of communication links that would tie these subsystems together. These included wireline communication, dedicated short-range communication, wide area wireless communication, and vehicle-to-vehicle communication. Fifth, it identified the various types of information that would need to be exchanged over these links in order to enable the subsystems to perform their assigned functions. For example, in order for an information service provider to distribute information on turnpike traffic conditions, it would need to receive traffic data from the turnpike authority.

These five elements—services, components, functionality, communication links, and information flows—comprised the basic elements of an ITS system architecture.

The National Architecture provided a tremendous amount of detail concerning the technical integration of ITS systems. However, the National Architecture provided very little detail concerning how one might integrate the institutions that operate these systems. Generally speaking, the National Architecture did not explicitly acknowledge that, in order for technical systems to share data with one another and coordinate their operations, the institutions that operate these systems must first agree to pursue such coordination. Clearly, what was needed was a mechanism that more fully recognized (a) the important role that institutions would play in the day-to-day operation of ITS services, and (b) the implications that the architecture concept would have for institutional relationships. Chapter 2 concluded by noting that a regional architecture, properly defined, could provide such a mechanism.
Chapter 3 examined the former half of the term “regional architecture”. The chapter was oriented toward answering one basic question: What is a region? And more specifically, what is the appropriate geographic scale at which a “regional architecture” should be constructed?

The basic premise behind this chapter was that transportation activity is intrinsically linked with economic activity. In fact, one could view transportation activity as a mirror of economic activity. If this is true, then it follows that transportation and economic activity occur on approximately the same geographic scale. Therefore, it is important to understand the appropriate geographic scale for analyzing economic activity.

Traditionally, politicians and economists have tended to suggest that economies and political jurisdictions coexist geographically. This fact that politicians speak at length about the strength of the “national economy” is evidence of how firmly ingrained this notion is. However, many authors—such as Jane Jacobs, Neal Peirce, and Kenichi Ohmae—have challenged the “nation as economy” viewpoint by contending that economic activity is, in fact, a “regional” phenomenon. They argue that the “national economy” is in fact a constellation of regional economies, each of which possesses its own economic characteristics and its own level of prosperity. Authors have devised a variety of names for these regional economies—“subnational economies”, “cities and city regions”, “citistates”, and “region states” are but a few of the proposed labels. However, most “regional” authors would agree that these regional economies share some basic characteristics:

- They are centered on an urban core, which serves as the heart of regional economic activity.
- They extend geographically to the urban core’s “hinterlands”, defined as the immediately surrounding areas that experience a strong economic linkage to the metropolitan core.
- Their borders are extremely difficult to define precisely. Since the borders are defined economically, and it is very difficult to define where one region’s economic ac-
activity “ends” and another’s “begins”. A more accurate term for a regional economy’s borders might be “sphere of influence”.

- Regions compete with other regions for the increasingly mobile resources of the global economy.
- Regional borders do not adhere to jurisdictional borders. The economic “sphere of influence” of city-based regions routinely transcends city, state, and national borders.

Jacobs, Peirce, and Ohmae would all agree that regional borders are difficult to define precisely. However, if the regional concept is going to be useful from the standpoint of transportation planning, then it is necessary to arrive at a working geographical definition of “region”. After all, transportation facilities occur in real space, and so transportation planning must occur in real (as opposed to “economic”) space. Thus, the second half of Chapter 3 examined some of the various “regional designations” that have been researched and establish by the Federal government. The goal was to find the regional designation that most closely corresponded to the notion of an “economic region” proposed in the first half of the chapter.

Chapter 3 concluded that the Bureau of Economic Analysis’ “Component Economic Areas” (or “CEAs”) corresponded most closely with the proposed definition of an economic region. Each CEA consists of two basic elements. The first element is a “Metropolitan Statistical Area”, or MSA. A Metropolitan Statistical Area—defined as a county (or group of adjoining counties) that contains at least one urbanized area of 50,000 or more inhabitants—is at the core of each CEA. The second element is the collection of non-metropolitan counties that (a) surround the MSA, and (b) experience an economic linkage to the MSA.

The following two points summarize the key ideas brought out in Chapter 3.
- Transportation should be planned and managed on the same geographic scale at which economic activity occurs. Since economic activity occurs at the regional level, transportation planning should also occur at the regional level.
The “Component Economic Area” designation, established by the Bureau of Economic Analysis, provides a good geographical approximation of an economic region. Transportation planning should occur, if at all possible, at this scale.

Chapter 2 introduced the reader to ITS, and Chapter 3 introduced the reader to the “economic region”. The juxtaposition of these two concepts leads to a critical idea: Intelligent Transportation Systems technologies enable one to manage transportation at a regional scale. However, ITS encompasses a broad array of technologies; they support a broad range of services; and they produce a tremendous amount of information. Thus, an organizing mechanism is needed in order to foster the integration of transportation systems at the regional level. Moreover, since regions transcend political borders, this mechanism will need to coordinate the efforts of institutions that reside in different jurisdictions.

The authors of the National Architecture recognized the need for regional integration of ITS technologies, and they noted that “regional architectures” should be developed in order to support this integration. Chapter 4 summarized and critiqued the manner in which the National Architecture defined the “regional architecture” concept.

The National Architecture foresaw “regional architectures” as a “new product” of the transportation planning process. Currently, a large gap exists between the identification of desired user services and the identification of specific ITS projects that could provide these services. ITS technologies comprise a staggering array of diverse systems that must be deployed in a coordinated fashion in order to provide a coherent service to the public. A regional architecture can provide an underlying structure to the deployment of these technologies. In doing so, a regional architecture can help “bridge the gap” between the identification of services and the deployment of projects.

With this in mind, the National Architecture suggested that a regional architecture should consist of the following elements:

- A list of the user services that the region would like to deploy;
The regional transportation institutions that would provide these user services;
- The communication links between these institutions;
- The appropriate level of interoperability that should apply to these communication links; and
- The data flows that travel over these communication links.

After describing some of the key characteristics of a regional architecture, the National Architecture provided two examples—one from Southern California, the other from Dallas—of what a regional architecture might actually look like. These examples essentially represented a “first cut” at developing a regional architecture. However, after critically reviewing these examples, Chapter 4 noted a number of shortcomings, including the following:

- The examples involved a confusing combination of subsystems and institutions on the same diagram. In cases where one institution performed the functions defined for one subsystem, the combination worked fine. However, in some cases, one institution performed functions identified in multiple subsystems. In other cases, multiple institutions performed the functions defined by a single subsystem. When this happened, the process of mapping institutions to subsystems became very confusing.
- The examples did not identify the user services to be supported or the data to flows to be distributed among the institutions.
- The examples did not give any guidance on the development of decision-making structures. They did not explicitly address some fundamental questions such as—Would the region’s institutions deploy the user services in a centralized or decentralized fashion? If multiple institutions needed to combine their efforts to deploy a service, which institution would ultimately be responsible for the deployment?
- The examples did describe the relationship among the user services. For example, one could not readily discern from these diagrams whether the information generated by the electronic toll collection service would be used to support the traffic information distribution service.
In response to these shortcomings identified in the National Architecture, Chapter 4 identified a series of characteristics that a regional architecture should embody. These characteristics, which were originally presented in Table 5-6, are summarized below.

<table>
<thead>
<tr>
<th>Proposed Characteristics of a Regional Architecture</th>
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<tbody>
<tr>
<td>• A regional architecture should consist of the following 5 elements:</td>
</tr>
<tr>
<td>- User services</td>
</tr>
<tr>
<td>- Regional institutions</td>
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<tr>
<td>- Lines of responsibility</td>
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<tr>
<td>- Lines of communication</td>
</tr>
<tr>
<td>- Data flows</td>
</tr>
<tr>
<td>• The regional architecture development process should include:</td>
</tr>
<tr>
<td>d) Identifying the user services/market packages that the region wishes to deploy;</td>
</tr>
<tr>
<td>e) Identifying which National Architecture-defined subsystems are needed in order to implement these services; and</td>
</tr>
<tr>
<td>f) Identifying which regional institutions will perform the functions defined by these subsystems.</td>
</tr>
<tr>
<td>• Subsystems should not be a part of the final regional architecture.</td>
</tr>
<tr>
<td>• In developing a regional architecture, one must address the following questions:</td>
</tr>
<tr>
<td>- How will information be distributed? Centralized? Decentralized? Hybrid?</td>
</tr>
<tr>
<td>- In what way will costs place a constraint on the architecture?</td>
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<tr>
<td>- How will multiple entities performing similar functions relate to one another? With centralized control? Decentralized control?</td>
</tr>
<tr>
<td>- In what way will the region accommodate the additional responsibilities created by ITS deployments? By assigning them to existing entities? Or creating a new entity?</td>
</tr>
<tr>
<td>- What will be the geographic scope of the architecture?</td>
</tr>
<tr>
<td>- What sorts of compatibility requirements does the architecture present? Which interfaces require national interoperability? Regional interoperability? No interoperability?</td>
</tr>
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</table>

Chapter 5 performed two basic tasks. First, it assembled the material presented in Chapters 2 through 4 en route to developing a working definition of “regional architecture”. And second, it illustrated how a region might actually construct a regional architecture.

115 In his Masters thesis, Rodriguez referred to questions like these as “Architecture Aspects”. The set of responses to these questions constituted the “Architecture Attributes".
In the course of developing a more comprehensive definition of regional architecture, Chapter 5 advanced two key ideas. The first idea was that regional architectures should extend beyond the “ITS-only” orientation prescribed by the National Architecture. In other words, a regional architecture should be designed to support all services—both ITS and non-ITS—in which the exchange of information among institutions can improve the performance of the transportation system. This approach recognizes that (a) the provision of nearly all transportation services is fragmented; and (b) an instrument that fosters institutional cooperation at the regional level can be of assistance in the provision of these services.

The second key idea advance by Chapter 5 was that a regional architecture, properly defined, could support the adoption of a systems perspective to transportation. In the past, the “Interstate model” has dominated transportation planning and policy at the congressional level. This model has two defining characteristics: (1) it contends that the answer to all transportation problems is the provision of more infrastructure; and (2) it views each mode in isolation, failing to see how the modes might interact as a broader transportation system. The regional architecture concept responds to this model in two ways. First, by focusing on transportation services, a regional architecture presents a forum in which a region can consider alternate solutions (i.e. besides more infrastructure) to transportation problems. And second, by explicitly considering ways in which various transportation institutions may interact more effectively, a regional architecture also considers ways in which the various modes can interact more effectively.

After reviewing Chapters 2 through 4 and advancing these two ideas, Chapter 5 proposed the following definition of a regional architecture:

A regional architecture is a framework that describes how various transportation institutions will interact in order to provide an integrated series of transportation services in a metropolitan-based region. It consists of five basis elements—user services, institutions, lines of responsibility, lines of communication, and data flows.
This definition was responsive to some of the observed shortcomings in the National Architecture, and it advanced the two key ideas noted above. However, it still left two critical questions unanswered. First, what does a regional architecture (according to this definition) actually look like? And second, how would a region go about constructing a regional architecture? Section 5.4 addressed both of these questions by proposing a 4-stage “regional architecture development process”.

Stage I of the proposed process would require the region to identify the user services that it would like to implement. The regional transportation planning community would typically determine this through public outreach. Subsection 5.4.2.1 illustrated how a region might conduct this stage of the process.

Stage II of the process would require the region to analyze and construct a “service architecture” for each ITS service. The “service architecture” would provide a framework for describing how the region’s institutions should interact in order to provide a single transportation service. The service architecture would contain the same 5 basic elements of a regional architecture, the only difference being that it would only support the implementation of one service.

Section 5.4 proposed a 5-step procedure for performing this analysis; this procedure drew, in part, on the information provided by the National Architecture. For more details on this procedure, the reader is advised to consult Section 5.4.2. Subsections 5.4.2.2 through 5.4.2.4 gave examples of how this procedure could be conducted. After completing Stage II of the regional architecture development process, the region should have a collection of service architectures—one architecture per ITS service.

Stage III of the process would require the region to analyze and construct a “service architecture” for each non-ITS service. The procedure for this analysis differed slightly from the procedure used to analyze ITS services, given that no guidance for this process exists in the National Architecture. Subsection 5.4.2.5 gave an example of how this procedure could be conducted.
Finally, *Stage IV* of the process called for the region to combine the service architectures to create the regional architecture. Expressed mathematically, one could say that the regional architecture equals the sum total of all service architectures. Subsection 5.4.2.6 aggregated the service architectures developed in the previous subsections, and provided an example of a regional architecture in Figure 5-14.

Chapter 5 noted that a regional architecture compresses a tremendous amount of information into a single diagram. This can be overwhelming to someone who is seeing the diagram for the first time, and it can be confusing to someone who is unfamiliar with the regional architecture concept. In an effort to clarify the presentation of the regional architecture, the chapter proposed breaking the diagram down by institutions. By doing so, one could construct a series “institutional architectures”—one for each institution included in the regional architecture. Each institutional architecture would include four components: (1) the institution itself; (2) the user services for which the institution is responsible (if any); (3) all communication links to other institutions; and (4) the information flows along these communication links. Figures 5-15 through 5-24 provided several examples of “institutional architectures”.

In Chapter 5, the process of aggregating service architectures was presented without any discussion of its potential implications. Chapter 6 took a step back and asked a basic question: might something get lost in the aggregation process? In other words, might the simple process of “superimposing” service architectures overlook some key elements that a regional architecture should consider?

In the process of answering this question, Chapter 6 identified three important implications of the aggregation process.

- First of all, as one assembles a regional architecture from several “service architectures”, one may fail to notice that some institutions are providing a disproportionate amount of information. In the long term this could result in long-term instability among the region’s institutions.
• Second, the aggregation process may overlook the opportunity for significant institutional change. When one develops a service architecture, one makes important institutional decisions (such as whether or not to create a new entity) based on the costs and benefits of deploying a single service. However, this may not be an appropriate method for deciding whether or not to initiate institutional reform. While the costs of creating new entities are incurred one time, the benefits of creating a new entity may extend to several different services. In other words, the cost of creating a new entity is essentially the same, whether it supports one service or multiple services.

• Third, when a region wishes to add a new service at a later date, the region may not be able to simply construct a new service architecture and “superimpose” it on the regional architecture. The service architecture for the new service might (1) cause some of the “original” data flows to be rerouted; (2) cause some of the existing institutions to change roles and responsibilities; and (3) change the way that other services are provided.

In response to these three implications of the service architecture aggregation process, Chapter 6 proposed that two additional stages be added to the regional architecture development process.

• **Stage V**, entitled “Evaluate the Regional Architecture”, would be a two-step procedure that would be performed immediately after the assembling of the regional architecture in Stage IV. **Step 1** would require transportation planners to examine the institutional architectures to see if any institutions are being required to distribute much more information than they receive. If so, the planners would need to consider how to rectify the imbalance. **Step 2** would require transportation planners to see what (if any) new institutions were considered. If the region can identify a new institution that could contribute to multiple services, then the region should reconsider the costs and benefits of creating that institution in the context of multiple services.
Stage VI, entitled "Revisit the Regional Architecture over Time", would require transportation planners to reexamine the regional architecture as new services are introduced at a later date. If the service architecture that supports the new service calls for the creation of a new entity, then the region should consider how other existing services might also benefit from this new entity. The region should also consider how the current roles of the existing institutions might be modified due to the additional capabilities of the new entity.

Chapters 2 through 6 achieved the first two objectives of the thesis—to define what a regional architecture is, and to describe how a region might construct a regional architecture. Chapter 7 took a step back and considered the third objective. It asked a basic question—How do regional architectures fit into the transportation planning process?

In order to answer this question, Chapter 7 proposed a new framework for conducting regional strategic transportation planning. This framework, originally depicted in Figure 7-1, is reproduced in Figure 8-1 below.

![Figure 8-1: ReS/SITE Framework for Strategic Transportation Planning](image-url)
This diagram represents a conceptual framework for strategic transportation planning proposed by MIT's ReS/SITE research project.\textsuperscript{116} According to this framework, the regional architecture is one of two fundamental outputs of the strategic planning process. Whereas the “regional infrastructure” component details the physical facilities that carry people and goods through the transportation network, the “regional architecture” component describes the interactions of the institutions that own, maintain, and operate these physical facilities. The two outputs support the deployment of transportation services in a complementary manner—one from an physical standpoint, the other from an institutional standpoint.

After describing how regional architectures fit into a broader framework for transportation planning, Chapter 7 confronted a crucial question—In what ways can the regional architecture concept strengthen the strategic transportation planning process? The chapter identified four key areas in which regional architectures can advance the state-of-the-art in transportation planning. First of all, it can help address intermodal issues by providing a forum in which the region’s transportation institutions can assemble and discuss the ways in which they should interact. Second, it can help introduce new and emerging technologies into the regional transportation system by (1) identifying potential ITS solutions to transportation problems; and (2) bringing technologically sophisticated private sector institutions inside the planning process. Third, it can help broaden the scope of transportation planning by providing an opportunity for private sector transportation providers to contribute to the planning process. And fourth, it can incorporate an operational focus into the transportation planning process that has typically been characterized by capital planning.

8.3. Unresolved Issues Pertaining to Regional Architectures

This section will address two issues pertaining to regional architectures that need to be explored in greater depth. Section 8.3.1 will ask the question—is the regional architecture concept really helpful, or do they confuse more than they simplify? Section 8.3.2 will ask the question—might there be a better way to define “regional architecture”?

\textsuperscript{116} Section 7.1 describes the ReS/SITE framework in more detail.
8.3.1. Is the regional architecture concept really helpful?

This thesis has define what a regional architecture is; it has proposed a method for constructing a regional architecture; and it has described the role that regional architectures could play within the broader transportation planning process. It has introduced a relatively new idea to transportation planners, and it has described how planners might use this idea to address some of the institutional issues related to the provision of transportation services. In short, this thesis has suggested a new way of thinking about aspects of the strategic transportation planning enterprise.

However, one critical question remains—Is the regional architecture concept (as described in this thesis) truly helpful to the transportation planning community? Figure 5-14, which depicted a possible regional architecture for the Jefferson region, is a very complex diagram. Even though the region was comprised of only 14 institutions, and even though the region only chose to deploy four different services, the regional architecture diagram ended up being extremely intricate. It is likely that many planners, viewing this diagram for the first time, would dismiss it immediately without taking the effort to understand the information that it conveys.

Thus, perhaps this thesis has created the same sort of problem that it attempted to simplify. This thesis noted that the term “regional architecture” was originally presented in the National ITS System Architecture; furthermore, it noted that the National Architecture was a very complex series of technical documents that were largely inaccessible to the transportation planner. In response, this thesis has endeavored to (1) “extract” regional architectures from the very technical context of the National Architecture, and (2) make regional architectures accessible to the transportation planning community. However, it is possible—given the somewhat intimidating nature of Figure 5-14—that the regional architecture development process described in this thesis represents a return to complexity.
In short this thesis has argued that regional architectures confront two critical issues related to transportation planning: (1) the need to plan for services as well as infrastructure; and (2) the need to address the institutional relationships that underlie the provision of transportation services. However, it is possible that the regional architecture concept described in this thesis is not the best way to confront these two important issues. It is possible that the procedure complicates these two issues, rather than simplifying them.

8.3.2. **Might there be a better way to define “regional architecture”?**

This thesis has defined “regional architecture” in two ways:

- First, it provided a core definition: *A regional architecture is a framework that describes how various transportation institutions will interact in order to provide an integrated series of transportation services in a metropolitan-based region.*
- Second, it provided the details that describe what a regional architecture should include. This thesis proposed five key elements: (1) user services; (2) the institutions that will provide the user services; (3) lines of responsibility designating which institutions will be responsible for each user service; (4) lines of communication connecting the institutions; and (5) data flows.

However, by establishing a single level of detail, this definition may unnecessarily restrict the applicability of the regional architecture concept. For example, consider a situation in which a State Department of Transportation constructs a regional architecture that supports the provision of transportation services throughout the state. Is a single definition of regional architecture really appropriate in this situation? Does the Secretary of Transportation need to have the same detailed understanding of the regional architecture that, say, a regional transit authority would need to know? Does the manager of a Turnpike Authority need to have the same level of detail as his technician, who may be responsible for forwarding specific turnpike traffic information to a local radio station? Or should the regional architecture provide different levels of detail to people residing at different levels of responsibility?
Questions such as these seem to indicate that a more versatile approach to defining "regional architecture" may be appropriate. This approach would maintain the "core definition" of a regional architecture (noted above), but it would convey different levels of detail to different people. Figure 8-2 depicts the general concept of this approach.

Figure 8-2: Alternate Approach to Regional Architecture Definition

To explain:
- The central column represents the \textbf{core definition} of "regional architecture". This definition will be applicable at all levels of detail.
- The shaded triangular portions represent \textbf{details}. These details would provide specific information on the types of services provided, the institutions involved, and the data that is exchanged. As one progresses down the diagram, one encounters increasing levels of detail.
- The crosscutting lines (labeled A and B) represent \textbf{different definitions of "regional architecture"}. Line A would represent the definition of "regional architecture" needed for the aforementioned technician working for the turnpike authority, who must know (a) exactly what information he must distribute, and (b) the appropriate individual to whom the information must be sent. Line B would represent the
definition of “regional architecture” needed for an upper-level manager, who must simply know (a) the types of information being distributed (i.e. “traffic information”), and (b) the different institutions to which this information must be sent (i.e. “WJAM Newsradio”). In short, the lines that are nearer the top represent definitions that are comprised of less detail.

- In general, the level of detail that one needs decreases as one assumes greater levels of administrative responsibility. The people who physically deploy the system will need extensive information on the types of information that will be exchanged and the level of coordination that will be pursued. The upper-level managers may need to know some basic information (such as the institutions and services involved), but they will not require as many specifics as the people that actually deploy the system will require.

This approach, in theory, may be more appropriate than the “single definition” approach described in this thesis. The difficult aspect of this approach will be to define which details are appropriate for each level of responsibility.

8.4. Key Contributions of this Research

This research has provided five important contributions to the strategic transportation planning enterprise.

- **First**, this thesis has advanced the regional architecture concept as a new idea that can strengthen the transportation planning process. In doing so, this thesis defined regional architecture in a system and comprehensive manner.

- **Second**, it has helped advance a more systems-oriented approach to transportation planning. By considering how transportation services can be used to address transportation problems, the regional architecture development process moves away from the “build more infrastructure” mentality that characterizes many strategic plans.
Third, it has provided some initial guidance to state and regional transportation planners on how to construct a regional architecture. This guidance may be modified, and some may be discarded, but it at least provides a starting point.

Fourth, it has discussed how regions might use the regional architecture development process to help facilitate institutional change. In doing this, the thesis hopes to provide a tool for addressing one of the fundamental barriers to ITS deployments—the lack of institutional cooperation and interaction.

Fifth, it has helped advance a new framework for regional strategic planning. It has provided a detailed description of the “regional architecture” component of the proposed ReS/SITE framework, and it has described how this component may be integrated into the broader strategic planning process.

8.5. Suggestions for Further Research

A logical follow-up to this research would be to construct a regional architecture for a real-world region. Doing this in a region that (a) wants to deploy more services, and (b) includes more institutions may highlight some yet unnoticed shortcomings in the proposed architecture development process.

This research has considered how one component of the ReS/SITE framework might be applied within an illustrative regional context. The next logical step from a research perspective would be to see how the entire ReS/SITE framework might be applied within a real-world regional context.

It would be interesting to further explore how one might draw private sector institutions into the regional architecture development process. The planning process can be long and tedious, and the private sector might be reluctant to be drawn into it. Future research should provide more specifics on potential incentives for bringing the private sector “inside” the planning process. Real-world examples of where this is being done would be helpful.

This research has established that the regional architecture development process constitutes good transportation planning practice. The next question is—how does
one promote this practice? Should the Federal government require the development of regional architectures as a prerequisite for Federal funding? Or should they sponsor the development of some “model regional architectures”? Or should they offer incentives for regions to develop regional architectures? Or should they simply recommend (with no strings attached) that regional architectures be developed in accordance with good transportation planning practice? These questions could be addressed by future research.

- Another important question to address is this: How does one make the resources of the National Architecture accessible to the transportation planning community? Most planners are intimidated by both the size and the technical orientation of the National Architecture. However, it contains many resources that could potentially be useful to transportation planners. This thesis has highlighted some of these resources; further research could highlight more.

This thesis has attempted to advance the state-of-the-art in regional strategic planning by proposing a new output of the planning process—a regional architecture. The author hopes that this research will generate interest in taking a more “service-oriented” approach to planning regional transportation systems.
Appendix A

A Survey of the Technical Aspects of the National Architecture

The National Architecture is, in many respects, a very technical document. Although it devotes some effort to discussing “softer” topics such as transportation planning, the vast majority of the document’s 5800 pages are committed to explaining the technical processes that underlie ITS deployments. This can make the document very difficult for a non-technical person to understand. Transportation planners may be intimidated by the sheer size and complexity of the National Architecture, and thus may avoid looking at the document altogether.

The purpose of this appendix is to provide a small window into the contents of the National Architecture. While the main body of this thesis explained the purpose of the National Architecture, this appendix will briefly explain its structure. With this in mind, this appendix will pursue three goals. First, it will seek to shed some light on some of the terminology employed in the National Architecture. Second, it will illustrate some basic ways in which one might navigate through the National Architecture documentation. And third, it will help distinguish between the information that transportation planners should be familiar with, and the information that belongs more exclusively in the “technical” domain.

This appendix will proceed in the following manner:

- **Section A.1** will list the various documents that comprise the National Architecture.
- **Section A.2** will use Figure 5-2 as an illustrative starting point to pursue three objectives. First, it will describe the relationship between market packages and user services. Second, it will define three key terms: Market Packages, Equipment Packages, and Subsystems. And third, it will describe how one might examine various documents within the National Architecture in order to find more information about these terms.
Finally, Section A.3 will discuss an important issue that is implied in this thesis: The need to draw a line between information that is relevant to the strategic transportation planner, and information that is best left in the hands of the “techies”.

A.1 A Review of the Architecture Documents

The National Architecture is not a single document. Rather, it is a collection of 17 documents, each of which is referred to as a “deliverable”. Furthermore, these documents are not arranged in any particular order. Although the documents are interrelated to a certain extent, the authors recognized that different people would seek different information from the National Architecture. For this reason, it is more appropriate to think of the set of documents as an “anthology” to be read in pieces than as a “novel” to be read in sequence.

The National Architecture groups the deliverables into five different categories. These categories, along with the title and page length of each of the deliverables, are listed in the table below. The categories are listed in bold print; the document titles are listed in italics. The documents which are reference in the thesis are denoted with a “*” after the number of pages.

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A.2 A Review of National Architecture Terminology

Section 5.4.2.1 extracted a diagram from the Implementation Strategy that was intended to describe how one might deploy the “Surface Street Control” market package. It will be helpful to take a closer look at this diagram (reproduced in Figure A-1 below) and discuss its basic components in more detail.

![Diagram of Surface Street Control Market Package](image)

Figure A-1: Surface Street Control Market Package

This diagram consists of four elements: market packages, subsystem, equipment packages, and data flows. The paragraphs that follow will discuss each element in more detail.

A.2.1 Market Packages.

The purpose of Figure A-1 is to describe how one might deploy, within the National Architecture framework, a specific ITS service entitled “Surface Street Control”. In the Implementation Strategy, services such as these are referred to as “market packages”. The Implementation Strategy identifies a total of 56 different market packages that a region could consider deploying; they are listed in Table A-1. The market packages are divided into seven different categories: Advanced Traffic Management System (ATMS), Advanced Public Transportation Systems (APTS), Advanced Traveler Information Systems (ATIS), Advanced Vehicle Safety Systems (AVSS), Commercial Vehicle Operations (CVO), Emergency Management (EM), and ITS Planning (ITS1).

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117 Extracted from National ITS Architecture, Implementation Strategy, pg. A-6
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Table A-1: Market Package Summary

\[118\] Extracted from National ITS Architecture, Executive Summary, pg. A-1.
Section 2.3.4.1 listed the 30 user services that the National Architecture was designed to support. As this section noted, the designers of the National Architecture considered these services to be the foundation of the Architecture development effort. However, the designers also noted that some of these services lacked specificity. For example, the user service entitled “Route Guidance” could be implemented in a variety of ways. At one end of the effectiveness spectrum, one could use an autonomous device that prescribes routes based on dead reckoning. At the more technologically advanced end of the spectrum, one could conceivably employ an interactive in-vehicle device, designed to receive input from a control center that prescribes routes based on traffic conditions and system optimization needs. In other words, the “user services” are general in nature, and provide little detail concerning how they might be deployed. A region that determined to deploy a “Route Guidance” service would need to also determine which technical approach it would like to take in order to deploy this service.

In order to provide a more “fine-grained” look at the user services, the designers of the National Architecture constructed a more comprehensive set of “market packages”. Generally speaking, these market packages provide some technical and functional specificity to the more generally-defined user services. Consider, for example, the “Traffic Control” user service. The series of market packages outlined in the National Architecture provide three different options by which a region could deploy this service:

- **Surface Street Control:** This is the market package identified in Figure A-1. As the name implies, it provides the communication links and the signal control equipment that would enable local control over surface streets. This market package could manifest itself in the form of arterial signalization control, managed by a local traffic operations center.119

- **Freeway Control:** Another way in which a region could deploy the “Traffic Control” user service would be to implement some means of controlling traffic flows on the region’s limited access highways. This market package is distinguished from the “Surface Street Control” market package for two reasons. First, the types of instru-

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ments used to control flow over freeways (i.e. ramp meters and lane controls) are much different than those used to control flow over surface streets (i.e. traffic lights). Second, freeways and surface streets are generally owned and managed by different institutions. A freeway typically falls under the control of a state highway department or a turnpike authority, while surface streets are typically the responsibility of a particular municipality.

- **Regional Traffic Control:** This market package, in the words of the *Implementation Strategy*, is designed to “advance the Surface Street Control and Freeway Control market packages by allowing integrated interjurisdictional traffic control.” In other words, this market package would allow two different cities to integrate their management of surface streets and freeways. For example, if an interstate ran through two adjacent cities, both of which sought to deploy ramp meters, this market package which support the integration of the ramp meter light cycles in support of area-wide interstate traffic flows.

The previous discussion would seem to indicate that a strict hierarchical relationship exists between user services and market packages. In other words, it appears that each market package simply provides a specific deployment option for a particular user service. If this were true, then there would be a “one-to-many” relationship between market packages and user services. That is, each user service would have a corresponding set of market packages that would provide a range of options for deploying that service.

In reality, however, the relationship between the two is more complex. Some market packages actually support multiple user services. For example, the market package entitled “In-Vehicle Signing” actually supports three different user services. First, it supports the “En-Route Driver Information” service in that the in-vehicle sign can convey real-time traffic information to the driver. Second, it supports the “Traffic Control” service in that it can provide a medium through which a traffic management center could direct a driver around a particular accident. And third, it supports the “Highway-Rail Inter-

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section" service in that the in-vehicle device can warn the driver about trains that are approaching a particular intersection.

Therefore, the relationship between market packages and user services is, in fact, a "many to many" relationship. On the one hand, one user service can be implemented using multiple market packages. And on the other hand, one market package can support the implementation of multiple user services.

Table A-2 on the following page is an extract from the *Implementation Strategy* that summarizes the relationships between market packages and user services.
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Table A-2: Market Package to User Service Relationships
For more information on market packages, the reader can consult Appendix A of the *Implementation Strategy*.

**A.2.2 Subsystems.**

Each of the 56 market packages is implemented through interactions among subsystems. Two subsystems are identified in Figure A-1: *Traffic Management* and *Roadway*. They are represented in the diagram by the large shaded boxes.

As section 2.3.4.3 mentioned, the National Architecture defines 19 different subsystems, and it puts them into four general categories:

- **Center** subsystems deal with functions that are typically assigned to administrative, management, or planning agencies. The names of the center subsystems correspond closely with names of transportation-oriented institutions.

- **Roadside** subsystems deal with functions that are typically performed by roadside infrastructure. Sensors, signals, and programmable signs are all examples of roadside subsystems.

- **Vehicle** subsystems perform in-vehicle functions. A transponder used for electronic toll collection would be an example of a vehicle subsystem.

- **Traveler** subsystems, in the words of the *Executive Summary* document, “represent platforms for ITS functions of interest to travelers or carriers in support of multimodal traveling.”121 These platforms can be either fixed (such as a kiosk or a home computer) or mobile (such as a cellular phone or a palm-top computer). Travelers interact with these subsystems in order to receive travel information, such as traffic information or transit schedules.

In essence, subsystems can be defined in one of two ways. The first way is by the *functions that the subsystem performs*. The National Architecture focuses primarily on this definition, in that it provides tremendous amounts of detail concerning the specific tasks that each subsystem should perform. It also identifies the type of equipment that is needed in order to perform each of these tasks. In fact, each subsystem has a des-

121 *National ITS Architecture, Executive Summary*, pg. 9.
ignated set of “equipment packages” that further categorize the functions that each subsystem must perform. Equipment packages will be discussed further below.

The second way in which a subsystem can be defined is by the equipment that it employs in order to perform its designated functions. For example, an autonomous in-vehicle route guidance device would be considered a “vehicle subsystem”. The responsibility for choosing equipment lies with the local institutions that will implement the system. At no point does the National Architecture specify a particular piece of hardware for a particular function. In short, the National Architecture defines subsystems in terms of functions, while local institutions define subsystems in terms of equipment.

For an overview of the functions and responsibilities of each subsystem, the reader can consult Chapter 2 of the Implementation Strategy, pages 2-5 through 2-12. The Executive Summary also provides a brief description of the functions of each subsystem on pages 6 through 8. An excerpt from the Implementation Strategy that describes the “Traffic Management” subsystem is reproduced below:

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Traffic Management Subsystem

The Traffic Management Subsystem operates within a traffic management center or other fixed location. This subsystem communicates with the Roadway Subsystem to monitor and manage traffic flow. Incidents are detected and verified and incident information is provided to the Emergency Management Subsystem, travelers (through Roadway Subsystem Highway Advisory Radio and Variable Message Signs), and to third party providers. The subsystem supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The subsystem monitors and manages maintenance work and disseminates maintenance work schedules and road closures. The subsystem also manages reversible lane facilities, and process probe vehicle information. The subsystem communicates with other Traffic Management Subsystems to coordinate traffic information and control strategies in neighboring jurisdictions. It also coordinates with rail operations to support safer and more efficient highway traffic management at highway-rail intersections. Finally, the Traffic Management Subsystem provides the capabilities to exercise control over those devices utilized for AHS traffic and vehicle control.⁻²

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A.2.3 Equipment Packages

Equipment packages comprise the most detailed elements of the Physical Architecture. The National Architecture defines 111 different equipment packages, and it describes them as “a set of equipment/capabilities which are likely to be purchased by an end-user to achieve a desire capability.” They are depicted in Figure A-1 as the clear boxes that lie within the shaded subsystem boxes.

Each subsystem is composed of a designated set of equipment packages. Figure A-1 identifies two equipment packages—TMC Basic Signal Control and Traffic Maintenance—which are part of the Traffic Management subsystem. In actuality, the Traffic Management subsystem is comprised of nineteen different equipment packages. However, only two of these actually contribute to implementation of the Surface Street Control market package. Equipment packages are unique to a subsystem; that is, no two subsystems share a common equipment package.

Equipment packages are also used to define market packages. Each market package is composed of a unique combination of equipment packages. Although some equipment packages may be used in multiple market packages, no two market packages contain exactly the same equipment packages. For example, the “Surface Street Control” market package is comprised of three equipment packages—TMC Basic Signal Control, Traffic Maintenance, and Roadway Signal Controls. No other market package has these three (and only these three) equipment packages.

In short, equipment packages define both subsystems and market packages. Figure A-2, which is extracted from the Implementation Strategy document, illustrates the relationship between market packages, subsystems, and equipment packages.

In Figure A-2, the rows represent market packages, the columns represent subsystems, and the center section of the table identifies the associated equipment packages. One could use a chart such as this in order to determine the equipment packages and subsystems needed to deploy a particular market package.

Say, for example, that a particular agency wanted to deploy the “Broadcast-Based ATIS” market package. In order to identify the Physical Architecture elements that are needed to deploy this service, the agency must first identify the market package in the left-hand column.\textsuperscript{125} Reading to the right, the agency would then identify all of the equipment packages needed to support that market package. According to Figure A-2,

\begin{itemize}
  \item \textsuperscript{124} National ITS Architecture, Implementation Strategy, pg. 2-25.
  \item \textsuperscript{125} For a more detailed description of the Physical Architecture, please see Section 2.3.4.4 and Section 2.5.
\end{itemize}
the market package involves 3 equipment packages—Basic Information Broadcast, Basic Vehicle Reception, and Personal Basic Information Reception. Once each equipment package is identified, the agency can move vertically through the chart to identify the subsystem that is responsible for operating that equipment package.

The diagram extracted in Figure A-2 is purely illustrative. A complete mapping of market packages, equipment packages, and subsystems is available on pages 2-27 and 2-28 of the Implementation Strategy.

The use of the term “equipment package” by the National Architecture may be somewhat misleading. The National Architecture does not actually specify any equipment in its discussion of equipment packages. Rather, it simply provides a detailed description of the functions that each equipment package should perform. As was the case with subsystems, it is the responsibility of the institutions that are deploying the service to select the physical equipment that will perform these functions.

The text that follows is extracted from the Physical Architecture document. It provides a description of the “TMC Basic Signal Control” equipment package, which Figure A-1 identified as part of the Traffic Management subsystem.

TMC Basic Signal Control
This Equipment package provides the capability to traffic managers to monitor and manage the traffic flow in major intersections and on main highways for urban areas as well as alleviate traffic related problems of rural areas with the primary concern of detecting and verifying incidents and providing this information to emergency management service providers. This capability includes analyzing and reducing the collected data from traffic surveillance equipment as feedback to control processes and for control strategies.

1.2.2.2 Determine Indicator State for Road Management
Overview: This process shall be responsible for implementing selected traffic control strategies and transit priority on some or all of the indicators covering the road (surface street) network served by the Manage Traffic function. It shall implement the strategies only using the indicators (intersection and pedestrian controllers, variable message signs (VMS), etc.) that are specified in the implementation request and shall coordinate its actions with those of the processes that control the freeway network and the ramps that give access to the freeway network.
1.2.4.1 Output Control Data for Roads
Overview: This process shall be responsible for the transfer of data to processes responsible for controlling equipment located at the roadside within the road (surface street) network served by the Manage Traffic function. This data shall contain outputs for use by roadside indicators, such as intersection and pedestrian controllers, variable message signs (VMS), etc. Data for use by in-vehicle signage equipment shall be sent to another process for output to roadside processes. All data shall have been sent to this process by processes within the Manage Traffic function. This process shall also be responsible for the monitoring of input data showing the way in which the indicators are responding to the data that they are being sent, and the reporting of any errors in their responses as faults to the Collect and Process Indicator Fault Data facility within the Manage Traffic function. All output and input data shall be sent by the process to another process in the Manage Traffic function to be loaded into the store of long term data.

1.2.1 Select Strategy
Overview: This process shall be responsible for selecting the appropriate traffic control strategy to be implemented over the road and freeway network served by the Manage Traffic function. The strategy shall be selected by the process from a number that are available, e.g. adaptive control, fixed time control, local operations, etc. The selected strategy shall be passed by the process to the actual control processes for implementation according to the part of the network to which it is to be applied, i.e. roads, freeways, ramps and parking lots. When part of the selected strategy, or at the request of the traffic operations personnel, the process shall send commands to the traffic sensor data process to change the operating parameters of video cameras used to provide traffic data. The process shall make it possible for the current strategy selection to be modified to accommodate the effects of such things as incidents, emergency vehicle green waves, the passage of commercial vehicles with unusual loads, equipment faults and over rides from the traffic operations personnel. The selected strategy shall be sent to the process within the Provide Traffic Surveillance facility responsible for maintaining the store of long term data.

It is evident from reviewing this text that the equipment package does not specify any particular equipment. Rather, it outlines a series of functions that the equipment package should be able to perform. These functions are known in the National Architecture as “Process Specifications”, and they are noted in the text by numerical designation. For example, the “Output Control Data for Roads” function noted in the excerpt above is known as Process Specification 1.2.4.1. Process Specifications, which are addressed in detail in the Logical Architecture, represent the lowest level of functional decomposition in the National Architecture. The following text describes the “Output Control Data for Roads” process specification, as extracted from the Logical Architecture deliverable.
Output Control Data for Roads

Input Flows

- hri_guidance_for_vms
- indicator_input_data_from_roads
- indicator_road_requested_state
- parking_guidance_for_vms
- static_data_for_road_control
- vehicle_pollution_message_for_roads
- vms_updates_for_roads

Output Flows

- indicator_control_data_for_roads
- indicator_control_monitoring_data_for_roads
- indicator_control_storage_data_for_roads
- indicator_data_fault_for_roads
- indicator_input_state_for_roads
- indicator_input_storage_data_for_roads
- indicator_sign_control_data_for_hri
- vehicle_sign_data_for_roads

Description

Overview: This process shall be responsible for the transfer of data to processes responsible for controlling equipment located at the roadside within the road (surface street) network served by the Manage Traffic function. This data shall contain outputs for use by roadside indicators, such as intersection and pedestrian controllers, variable message signs (vms), etc. Data for use by in-vehicle signage equipment shall be sent to another process for output to roadside processes. All data shall have been sent to this process by processes within the Manage Traffic function. This process shall also be responsible for the monitoring of input data showing the way in which the indicators are responding to the data that they are being sent, and the reporting of any errors in their responses as faults to the Collect and Process Indicator Fault Data facility within the Manage Traffic function. All output and input data shall be sent by the process to another process in the Manage Traffic function to be loaded into the store of long term data.

Unsolicited Input Processing: This process shall receive the following unsolicited input data flows:
(a) 'indicator_input_data';
(b) 'indicator_highway_requested_state';
(c) 'indicator_road_requested_state';
(d) 'ramp_signal_state';
(e) 'vehicle_pollution_message';
(f) 'vms_parking_guidance';
(g) 'vms_updates'.

Solicited Input Processing: This process shall receive the following data flows as a result of requests for data retrieval from local data stores:
(a) 'static_data_for_control'.

Solicited Output Processing: This process shall provide the following output flows as a result of the above inputs being received:
(a) 'indicator_control_data';
(b) 'indicator_control_monitoring_data';
(c) 'indicator_control_storage_data';
(d) 'indicator_data_fault';
(e) 'indicator_input_state';
(f) 'indicator_input_storage_data';
(g) 'vehicle_sign_data'.

Functional Requirements: This process shall meet the following functional requirements:
(a) continuously monitor for receipt of the unsolicited input flows listed above;
(b) when any change occurs to the input data, change the appropriate indicator output data;
(c) as a result of (b), update the vehicle signage data, adding the location and identity of the route segments from which the indicator data can be seen from the static data for VMS allocation;
(d) maintain communication with all indicators so that they will continue to obey the data contained in the data that is being sent to them;
(e) immediately report all indicators that fail to respond to the commands in the data that they have been sent to the processes responsible for fault management.

**User Service Requirements**

USR = 1.0;
USR = 1.6;
USR = 1.6.0;
USR = 1.6.2;
USR = 1.6.1.2.1;
USR = 1.6.1.4;
USR = 1.6.3;
USR = 1.6.3.3;
USR = 1.6.3.3.1;
USR = 1.6.3.3.2;
USR = 1.6.3.3.3;
USR = 1.6.3.3.4;
USR = 1.6.3.4;
USR = 1.6.3.4.1;
USR = 1.10;
USR = 1.10.3;
USR = 1.10.3.3;
USR = 1.10.3.3.5;
USR = 1.10.5;
USR = 1.10.5.2;
USR = 1.10.5.2.6;

**Output Flow Dynamics Assumptions:**

indicator_control_data_for_roads = 1;
indicator_control_monitoring_data_for_roads = 1;
indicator_control_storage_data_for_roads = 1;
indicator_data_fault_for_roads = (INTERSECTIONS+PEDESTRIANS+CROSSINGS+GRADE_CROSSINGS+SIGNS+RAMPS)/60/60/24/7/52;
indicator_input_state_for_roads = 1;
indicator_input_storage_data_for_roads = 1;
vehicle_sign_data_for_roads = 1;
indicator_sign_control_data_for_hri = 1;

One can discern from just a quick glance at this excerpt that the Logical Architecture is a very technical document. Not only does the Logical Architecture describe the processes which are needed to support a particular equipment package, but it also defines some specific data flows that are needed to support the process. In this example alone, at least 15 different data flows (7 input flows and 8 output flows) are identified as critical to supporting the “Output Control Data for Roads” process specification.
Figure A-3 summarizes the structure of the National Architecture in terms of the various levels of detail that it defines. At the top of the structure are "user services"—the 30 core services that the National Architecture must ultimately support. The next level of detail is "market packages"; the 56 market packages provide a finer-grained view of the more generally-defined user services. The third level of detail is "equipment packages", of which there are 111. Market packages are made up of unique combinations of equipment packages. The fourth level of detail is "process specifications". Equipment packages are defined by a particular set of process specifications, each of which provides information on the data flows needed to support a particular function. Each process specification is supported by numerous specific data flows.

Figure A-3: Progressive Levels of National Architecture Detail
A.2.4 Data Flows

The fourth component of Figure A-1 is data flows. The previous section mentioned data flows in the context of process specifications. However, the data flows described in Figure A-1 are much more general in nature. They simply describe the types of data that must be exchanged between subsystems in order to support the service provided by the market package. Figure A-1 specifies only two types of data flow: The Traffic Management subsystem must provide signal control data to the Roadway subsystem, and the Roadside subsystem must respond by providing a signal control status to the Traffic Management subsystem.

It will be important to distinguish between the data flows depicted on the market package diagrams, and those described in the process specification documentation. Because they are more general in nature, this thesis will refer to the market package data flows as “macro-data flows”. This thesis will refer to the process specification flows, by contrast, as “micro-data flows”.\textsuperscript{126}

Note that Figure A-1 does not specify the communication medium over which the data travels. In other words, the figure depicts a data exchange, but it doesn’t describe how that data is transmitted. This information is provided by the Physical Architecture diagram, which was depicted in Figure 2-8. This figure is reproduced as Figure A-4:

\textsuperscript{126} This distinction between data flow types is made by this thesis, not by the National Architecture.
Figure A-4 contains both subsystems identified in Figure A-1. The “Traffic Management” subsystem is part of the “Center” system, and the “Roadway” subsystem is part of the “Roadside” system. A boldfaced line connects the two entities; this line represents the communication medium over which the two subsystems communication information. In this case, the data is transmitted via “wireline”.

The National Architecture is somewhat vague about what constitutes “wireline” communication. By the Architecture’s definition, any communication medium that connects two fixed points (such as a control center and a loop detector) is considered a “wireline”. Typically, this would involve coaxial cable or fiber optics. However, it could also include terrestrial microwave links, spread spectrum radio, or an area radio network. In the words of the Architecture itself, “[If] wireless communications technologies...are used to
provide fixed-to-fixed communications...the architecture recognizes them as wireline communications media.  

A.3 Drawing the Line: What the Transportation Planner Needs to Know

This Appendix has provided considerable detail on the National Architecture documentation. The key question now becomes, How much of this does the transportation planning community really need to know as they construct the regional architecture?

The view of this thesis is that the planner should be familiar with these details down to the macro-data flow level. That is to say, the transportation planner should be familiar with (a) the 19 different subsystems, (b) the 30 different user services, (c) the 56 different market packages, and (d) the macro-data flows that are exchanged between subsystems as they provide the services outlined in the market packages. The planner does not necessarily need to understand the details behind market packages, process specification, and micro-data flows.

There are three reasons for taking this approach to architecture detail.

1. The first reason is that this approach is consistent with the FHWA’s working recommendation, which states that regional architectures should be “defined at the level of subsystems and architecture [i.e. data] flows”. By “architecture flows”, the FHWA is referring to the macro-data flows outlined in the market package diagrams (one of which is depicted Figure A-1).

In order to illustrate their concept of the appropriate level of detail for a regional architecture, the FHWA produced the following diagram, depicted in Figure A-5.

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127 National ITS Architecture, Executive Summary, pg. 10.
In this diagram, the FHWA has taken two fictitious regional elements and mapped them directly into two different subsystems defined by the National Architecture. In this case, the FHWA created a regional institution (the Metro Traffic Operations Center) and mapped it into the “Traffic Management” subsystem. Likewise, it took some regional roadside infrastructure (designated as “Metro Field Elements) and mapped them into the “Roadway” subsystem.

The purpose of this section is not to discuss the “rightness” or “wrongness” of the FHWA’s concept of what a regional architecture should look like. It is simply important to note that, based on the guidance provided by this diagram, it is evident that the FHWA does not expect regional planners to understand the “nitty-gritty” detailed data flows outlined in the Logical Architecture. Rather, the FHWA seems content to let planners consider the types of data that will be exchanges between institutions. These data flow types—what this section is terming “macro-data flows”—can be drawn, in large part, from the market package diagrams provided in Appendix A of the Implementation Strategy document.

2. The second reason for limiting the scope of detail is that these restrictions are necessary in order to make the National Architecture accessible to the planning community. The National Architecture is a huge series of documents that most planners

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Figure A-5: FHWA’s Conception for Regional Architecture Detail

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129 This diagram was copied from a slide presented at the FHWA’s “National ITS Architecture Consistency Seminar: Boston Area Outreach Meeting”, held in February 1998.
will eschew. However, the National Architecture contains a great deal of information that planners may find beneficial. Specifying the level of detail that a planner should be familiar with should render the National Architecture less intimidating. In fact, a transportation planner could become sufficiently familiar with the aforementioned level of detail by simply reading two documents: the *Executive Summary*, and the *Implementation Strategy*.

3. The third reason for limiting the scope of detail with which planners should be familiar is that this level of detail is sufficient for enabling one to construct a regional architecture as described in this thesis. As Chapter 5 pointed out, a regional architecture should consist of 5 components: user services, institutions, lines of responsibility, lines of communication, and data flows. These elements are determined by combining background information from the National Architecture with specific knowledge of regional desires and institutional capabilities. The level of detail specified in this Appendix (requiring familiarity with subsystems, user services, market packages, and macro-data flows) provides sufficient technical background knowledge to support the development of the five regional architecture components.

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130 For a more detailed treatment of the Logical Architecture, please see Section 2.3.4.2 and Section 2.5.
Appendix B

Regional Architectures and the “Consistency” Requirement

The ISTEA reauthorization bill, which is being considered by Congress at the time of the writing of this thesis, is likely to require all regions wishing to receive Federal ITS funding to construct a regional architecture. Moreover, the bill is likely to require these regional architectures to be “consistent” with the National Architecture. However, it is still unclear what “consistency” actually entails from the Federal perspective. In fact, the Federal Highway Administration recently conducted 10 outreach seminars across the country, soliciting the feedback of transportation professionals on what appropriate “consistency” requirements should be.

The purpose of this appendix is to inform the current “consistency” discussion. Section B.1 will provide a general discussion of what “consistency” means, while section B.2 will propose some potential “consistency” guidelines.

B.1 Defining “consistency”

Webster’s dictionary defines “consistency” as follows:

a. agreement or harmony of parts or features to one another or a whole: correspondence; specifically, ability to be asserted together without contradiction

b. harmony of conduct or practice with profession

The two key phrases in this definition are “harmony of practice” and “without contradiction”. In order for item A to be “consistent” with B, it must harmonize with item B without contradicting it in any way. In other words, item A should support at least some of the same objectives that item B supports, and it should not support any contradictory objectives.

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132 http://www.m-w.com/cgi-bin/dictionary
This thesis adopts the viewpoint that “consistency” essentially means *conformance to the principles and objectives of the National Architecture*. The National Architecture implicitly establishes five different principles that should guide the development of regional architectures. In order to be “consistent” with the National Architecture, a regional architecture should reflect *all* of these principles without contradicting *any* of them. In short, these principles should serve as a measuring stick for evaluating the “consistency” of a regional architecture.

The reader should keep in mind that these principles are *not* explicitly outlined in any of the National Architecture documents. Rather, these principles are drawn by inference from a thorough review of the National Architecture. They represent the viewpoint of this thesis; they do *not* necessarily represent the viewpoint of the writers of the National Architecture.

*Consistency Principle #1: A regional architecture should support the interoperability standards defined by the National Architecture.*

Section 4.3.2 described three different levels of compatibility that a regional architecture should consider—national, regional, and none. To review, *national* compatibility applies to services that involve mobile subsystems (such as personal autos and commercial vehicles). That is, mobile systems should be able to interact with local infrastructure throughout the country. *Regional* compatibility applies to deployments in which regional coordination is critical. A traffic signalization system, for example, should be integrated throughout the region. *Finally, no* compatibility requirements need to be specified for interfaces that occur among systems that are owned and operated exclusively by the private sector. The companies that operate and manage private transport fleets, for example, should be free to develop the protocols that govern the interfaces involved in their fleet management systems.\(^{134}\)

\(^{133}\) National interoperability, however, would not be appropriate for such a system; traffic lights in New York City, for example, do not need to be synchronized with those in San Francisco.

\(^{134}\) It should be noted that some fleet and freight management functions call for interaction with public infrastructure. For example, the *Physical Architecture* document states that “the capability to purchase credentials electronically
A regional architecture should be consistent with these specifications. If the region wishes to deploy dynamic route guidance, for example, then the region should require the deployment to support national interoperability. Of course, the force of this requirement should be limited by available standards. If no standard is available for dynamic route guidance, then this requirement cannot be sustained.

**Consistency Principle #2: A regional architecture should be a consensus-based document that has the approval of all participating institutions.**

This principle is implicit in the National Architecture documents. The *Implementation Strategy* states that a regional architecture should (a) identify the institutions to be included in regional ITS deployments, and (b) specify a degree of coordination among these institutions. However, the planners who are responsible for developing the regional architecture do not have the statutory authority to require the institutions to adhere to the specified levels of coordination. Therefore, in order for the regional architecture to be effective, it must have the collective approval of all institutions that provide the specified transportation services.

In practice, a region may find it very challenging to abide by this principle. There are at least three reasons for this.

- First, the transportation realm encompasses a very broad array of stakeholders, and getting them to all agree to anything can be difficult.
- Second, transportation institutions can be very large. Although the institutional representatives that participated in the planning process may support the regional architecture, the “rank and file” may not be so keen on institutional cooperation.
- Third, the regional architecture development process can be very time consuming. Decisions about who will be in charge of a particular service, and how information will be distributed among the institutions, will require a significant amount of thought and consideration. This could tend to drive away the support of private sector trans-

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shall be provided by the Fleet and Freight Management subsystem" (pg. 2.3-21). In situations such as these, public sector involvement in the defining of interoperability standards is appropriate.

portation institutions, which may not be able to spare the personnel to engage in the lengthy process.

Thus, the notion of the regional architecture being a “consensus document” is easier said than done. One may actually find varying “degrees of consistency” with regard to this principle, since some regional architectures will inevitably garner more widespread support than others will. Nevertheless, consensus with respect to the regional architecture is a goal to which each region should aspire.

**Consistency Principle #3: A regional architecture should describe the types of information that will be exchanged among the region’s institutions.**

The National Architecture goes to great lengths to specify how data should be distributed in order to support the deployment of ITS services. The *Implementation Strategy*, for example, describes the information flows that are needed to support all 56 “market packages” defined by the National Architecture. The *Logical Architecture* provides extensive detail concerning the specific types of information that should be exchanged among ITS subsystems.¹³⁶

This requirement for information distribution should manifest itself in the regional architecture as *institutional communication*. A regional architecture should describe, at a high level, the types of information that will be distributed among the region’s institutions. These information flows are the life-blood of institutional coordination. Institutional integration is not achieved simply by constructing a communication link between two institutions. Rather, institutional integration can only be achieved when information is distributed over this link. Therefore, a description of data flows is necessary to reveal the region’s commitment to institutional cooperation and coordination. Although communication alone will not be sufficient to integrate the region’s institutions, it is a necessary prerequisite for achieving this objective.

¹³⁶ For more information on the Logical Architecture, please see Section 2.3.4.2, Section 2.5, and Appendix A.
According to this standard, the three regional architectures examined in Daniel Rodriguez’ thesis—that is, the TRANSCOM architecture in New York, the Boston regional architecture, and Houston’s Transtar system architecture—would all be considered “inconsistent” with the National Architecture. They each describe the physical links that exist between the region’s institutions, but they do not specify the information that should travel along these links. Therefore, one can discern very little about the extent of institutional integration that these regional architectures attempt to achieve.

**Consistency Principle #4: A regional architecture should support the integration of user services.**

Chapter 2 noted that an ITS system architecture performs two fundamental functions.

- First, it describes how multiple *subsystems* should interact with one another in order to provide a coherent *service*. For example, it describes how a transponder, toll-booth, and control center should interact with one another to provide an electronic toll collection service.

- Second, it describes how multiple *services* should interact with one another in order to provide a coherent *transportation system*. For example, it describes how the “electronic toll collection” service and the “broadcast traveler information” service can interact with one another to their mutual benefit. The electronic toll collection service produces traffic information data that can be broadcast to travelers; traffic information, in turn, can be used to dynamically adjust tolls as a demand management tool.

In order to support the second function of an ITS system architecture, a regional architecture should describe how the region’s institutions will communicate with one another in support of the integration of transportation services. In other words, in order for a regional architecture to be considered “consistent” with the National Architecture, it must integrate the region’s user services. “Integration” in this sense involves, at a minimum, the exchange of information that is generated by one service and used by another.

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137 See Rodriguez, pp. 101, 131, and 163.
service. More advanced levels of integration would involve sharing control as well as sharing information.

This requirement is best illustrated with an example. Consider a region that is considering two ITS deployments—electronic toll collection (to be deployed by a turnpike authority) and broadcast traveler information (to be deployed by an independent information service provider, such as IntelliGuide in Chapter 6, or such as SmartRoutes® in the Boston and Cincinnati regions). In this scenario, each agency contains information that is of benefit to the other. The turnpike authority can calculate average turnpike speeds based on data gathered from the transponders; this would be of use to the information service provider. Likewise, the information service provider has information on local traffic conditions; this would be of interest to the turnpike authority, which could pass on this information to turnpike travelers via variable message signs or highway advisory radio.

In this example, in order to be "consistent" with the National Architecture, the regional architecture that governs these deployments must enable the sharing of information between the turnpike authority and the information service provider. Stated another way, if the regional architecture enables these two institutions to deploy their systems independently, then that architecture should be considered "inconsistent" with the intent of the National Architecture. The only time that a regional architecture should enable two institutions to deploy their services independently is when neither institution possesses information that would be of benefit to the other.

In practice, one will actually find varying "degrees" of consistency with this principle. Some private institutions may not wish to share data for proprietary reasons. Other agencies may wish to be paid for their information. (A quasi-public turnpike authority, for example, could reasonably demand some compensation for providing information to a private Information Service Provider.) Therefore, a regional architecture must respect proprietary information, and it must leave room for market forces to work. Nevertheless,

138 For more information on SmartRoutes®, see the company’s home page (http://www.smartroute.com).
the regional architecture should urge institutions to collaborate to the fullest reasonable extent.

**Consistency Principle #5: The geographic scale of a regional architecture should transcend political jurisdictional boundaries.**

This requirement stems from the National Architecture’s recognition that effective ITS deployments must take place at the regional level. That is, the geographical scope of ITS deployments must transcend jurisdictional boundaries, acknowledging that transportation activity is not confined by city limits. Thus, it is reasonable to conclude that, if a regional architecture is to be consistent with the National Architecture’s vision, it should require some degree of cooperation among institutions from different jurisdictions.

A region could satisfy the requirements of this principle in at least three different ways. First, it could describe the flow of information between entities that operate in different jurisdictions. The exchange of data between two municipal traffic operations centers would be an example of this method of “regional interaction”. Second, the regional architecture could describe the flow of information between a regional entity (such as a turnpike authority, whose jurisdiction is not limited to a particular town or city) and a municipal entity (such as a traffic operations center). Third, the regional architecture could create a regional entity whose responsibilities would transcend any single political jurisdiction. All three of these “regional interaction” options promote the notion that transportation should be managed at a regional scale, which has been a major motivation for this research.

To illustrate this criterion, consider a region that would like to implement an incident management service. If the regional architecture specifies that each municipality will deploy the service independently, with no communication among the cities, then that architecture should be considered “inconsistent” with the National Architecture. If, however, the architecture provides a communications link that permits the cities to alert one
another concerning major traffic incidents, then the architecture should be considered “consistent”.

To summarize, the National Architecture implies five important principles that should guide the development of a regional architecture. First, a regional architecture should support the interoperability standards defined by the National Architecture. Second, a regional architecture should be a consensus-based document that has the approval of all participating institutions. Third, a regional architecture should describe how the region’s transportation institutions plan to communicate with one another. Fourth, a regional architecture should support the integration of user services. And fifth, the functional scope of a regional architecture should transcend jurisdictional boundaries. A regional architecture that conforms to these principles should be considered “consistent” with the National Architecture.
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- Executive Summary
- Mission Definition
- Physical Architecture
- Logical Architecture
- Implementation Strategy


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