Concept for an e-Transit Reference Enterprise Architecture

DETAILS

50 pages | | PAPERBACK
ISBN 978-0-309-42743-2 | DOI 10.17226/23351

AUTHORS

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 84

e-Transit: Electronic Business Strategies for Public Transportation
Volume 5

Concept for an e-Transit Reference Enterprise Architecture

MITRETEK SYSTEMS
Falls Church, VA

SUBJECT AREAS
Planning and Administration • Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2004
www.trb.org

TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA; the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

TCRP REPORT 84: Volume 5

Project J-09 FY'00
ISSN 1073-4872
ISBN 0-309-06766-9
Library of Congress Control Number 2002112858

Price $19.00

NOTICE

The project that is the subject of this report was a part of the Transit Cooperative Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the project concerned is appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

To save time and money in disseminating the research findings, the report is essentially the original text as submitted by the research agency. This report has not been edited by TRB.

Special Notice

The Transportation Research Board, the National Research Council, the Transit Development Corporation, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at
http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board's varied activities annually engage more than 5,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

COOPERATIVE RESEARCH PROGRAMS STAFF FOR TCRP REPORT 84

ROBERT J. REILLY, *Director, Cooperative Research Programs*
CHRISTOPHER W. JENKS, *TCRP Manager*
GWEN CHISHOLM-SMITH, *Senior Program Officer*
EILEEN P. DELANEY, *Managing Editor*
BETH HATCH, *Assistant Editor*

TCRP PROJECT J-09 PANEL
Field of Special Projects

PAUL A. TOLIVER, *King County Metro, WA* (Chair)
GORDON AOYAGI, *Montgomery County Government, MD*
RONALD L. BARNES, *Central Ohio Transit Authority*
ROBIN CODY, *San Francisco Bay Area Rapid Transit*
RAYMOND H. ELLIS, *AECOM Consulting Transportation Group, Inc., Fairfax, VA*
RICARDO ERNST, *Georgetown University*
LAWRENCE J. HARMAN, *Harman Consulting, Boston, MA*
EVA LERNER-LAM, *Palisades Consulting Group, Inc., Tenafly, NJ*
*S*HAWN M. MARCELL, *Gladwyne, PA*
PATRICIA S. NETTLESHIP, *TNG, Inc., Santa Monica, CA*
DANIEL ROTH, *Freightdesk.com, Bethesda, MD*
ROBIN STEVENS, *New York, NY*
LINDA S. WATSON, *Corpus Christi Regional Transit Authority, TX*
NIGEL H. M. WILSON, *Massachusetts Institute of Technology*
ANTHONY M. KOUNESKI, *APTA Liaison Representative*
THOMAS PALMERLEE, *TRB Liaison Representative*

FOREWORD

By Gwen Chisholm-Smith
Staff Officer
Transportation Research Board

TCRP Report 84: e-Transit: Electronic Business Strategies for Public Transportation documents principles, techniques, and strategies that are used in electronic business for public transportation. *TCRP Report 84* will be published as multiple volumes; *Volume 5: Concept for an e-Transit Reference Enterprise Architecture* explains the need for and uses of a reference enterprise architecture; the process for its development based on using systems engineering concepts and practices; the basic concepts behind systems engineering and enterprise architecture; and the transit-specific task associated with creating an e-transit reference enterprise architecture. This report may be used by chief information officers, general mangers, and senior managers.

The Internet and other new information and communication technologies are revolutionizing the way services are delivered and organizations are structured. Electronic business processes change the ways organizations operate and conduct business. Opportunities to lower transaction costs and improve efficiency have changed relationships between transit agencies and their suppliers and customers, and electronic business processes are likely to change industry structures in the long term. Portals for transactions in government-to-government and business-to-government marketplaces are offered through diverse organizations. Numerous transit agencies are preparing to offer customized itinerary planning and fare media purchasing over the Internet.

The declining costs of communications, data storage, and data retrieval are accelerating the opportunities spawned by the Internet and other information and communications technologies. Choosing and sequencing investments in technologies, processes, and people to reduce costs and increase productivity present challenges to the transit manager, who must weigh the costs, benefits, and risks of changing the ways services are delivered. To assist in meeting such challenges, TCRP Project J-09 produces a multiple-volume series under *TCRP Report 84.* The research program identifies, develops, and provides flexible, ongoing, quick-response research designed to bring electronic business strategies to public transportation and mobility management.

Concept for an e-Transit Reference Enterprise Architecture is the fifth volume in the *TCRP Report 84* multiple-volume series. Mitretek Systems prepared this report. This report summarizes systems engineering procedures and enterprise architecture concepts and provides a detailed overview of the approach that may be used during the development of an architecture reference model for a transit agency. The report also includes an overview of tools needed to support an e-transit reference enterprise architecture.

Volumes issued under *TCRP Report 84* may be found on the TRB website at http://www4.trb.org/trb/onlinepub.nsf/web/crp. (Click on "Transit Cooperative Research Program" under the "Project Reports" heading.)

CONTENTS

1 CHAPTER 1 Introduction

1.1 Defining e-Transit, 2
1.2 Systems Engineering and Enterprise Architecture, 2
1.3 Proposed Enterprise Architecture Products, 4
1.4 Document Overview, 4

5 CHAPTER 2 Summary of Systems Engineering and Enterprise Architecture Concepts

2.1 Overview of Enterprise Architecture Concepts, 5
2.2 Overview of Systems Engineering Concepts, 9

13 CHAPTER 3 Approach: e-Transit Reference Enterprise Architecture Development

3.1 Approach, 13
3.1.1 Using Systems Engineering within the Enterprise Architecture Framework, 13
3.1.2 Defining e-Transit Re-Visited, 16
3.1.3 As Is "Transit Today" Scenario, 18
3.1.4 To Be "Transit of Tomorrow" Scenario, 20
3.1.5 Coordination with the National ITS Architecture, Security, and Other Related Efforts, 23
3.2 Potential Inputs and Resources for Developing the Reference Enterprise Architecture, 25
3.3 Proposed Phase II Products, 28
3.3.1 e-Transit Reference Enterprise Architecture, 28
3.3.2 e-Transit Reference Enterprise Architecture User's Guide, 29
3.3.3 Online Forum and E-Mail Exchange, 30

32 CHAPTER 4 Phase II Research Plan

4.1 Task 1: Project Management and Detailed Research Plan, 32
4.2 Task 2: TCRP Research Digest Summary of Concept Paper (Optional), 32
4.3 Task 3: Collaboration Forum and Participants, 32
4.4 Task 4: Transit Industry Information Collection, 33
4.5 Task 5: Emerging e-Concepts, 33
4.6 Task 6: e-Transit Concept of Operations, 34
4.7 Task 7: e-Transit Reference Enterprise Architecture, 34
4.8 Task 8: Guidance on Using the Reference e-Transit Enterprise Architecture, 35
4.9 Task 9: Recommendations for Update and Maintenance of the e-Transit Reference Architecture, 35
4.10 Task 10: Final Project Report, 36

A-1 APPENDIX Overview of Potential Enterprise Architecture Application Tools and Recommendations

CHAPTER 1

INTRODUCTION

The declining costs of information processing, data storage, communications, and data retrieval, combined with the Internet and other new communications technologies, are revolutionizing the way services are delivered and organizations are structured throughout U.S. society. They also can enhance the services that transit agencies deliver, the ways in which these services are delivered, and the expectations and perceptions of transit patrons and business partners. Ready or not, transit agencies must address the forces that are pushing them into the age of e-commerce and e-government. These changes in technologies, potential services, and customer expectations present significant challenges to transit agency managers who must make decisions regarding investments in technologies, processes, and people to reduce costs and increase productivity while weighing the costs, benefits, and risks of changing the way services are delivered.[1]

Recognizing the rapidly changing technological environment within which transit agencies must operate and the challenges it presents, TCRP initiated the e-transit research in 2001 to identify, develop, and promote research to maximize the benefits of e-commerce and other new technology applications for public transportation and mobility management, with the objective to provide flexible, ongoing, quick-response research designed to bring electronic business strategies to public transportation and mobility management.[2]

Since the start of the e-transit effort, the application of new transit technologies and services has continued to advance at a rapid rate, while significant changes in the overall fields of information technologies (IT), communications, and electronic business have also occurred. Some business models have not worked out. Many companies have gone out of business, merged, or drastically changed their services in order to survive. Peregrine Systems, Inc., a company offering enterprise-wide asset management solutions to transportation firms, experienced accounting irregularities. The company's subsequent bankruptcy may be the most highly visible transit-related default that took place in 2002. Smart Traveler, an independent service provider (ISP) of multimodal traveler information, also closed the doors of its Washington, D.C., operations in 2003, and the business model behind using ISPs for provision of traveler information has been widely questioned. Likewise, many of the en vogue approaches of the past, including the use of application service providers (ASPs), are no longer viable options for most applications. Along with ongoing realignment, new technologies and services also continue to emerge. New telecom services and devices appear every day to process and display information. For example, it is expected that the new next-generation (2.5G and 3G) services may provide up to a tenfold increase in the data that can be exchanged with transit vehicles and mobile individuals. These new capabilities offer new opportunities for e-transit that are only beginning to be explored. Because of the increase in data that can be exchanged, concepts and potential options for e-transit that were considered promising as little as 2 years ago are loosing viability, and concepts and options that were not even conceived of at the start of the effort are now becoming a reality. Consequently, while the e-transit project has produced excellent products,[3] the issues that these products address and the information included within them is often dated by the time that they have been officially reviewed and published.

Simply monitoring the IT, transit, and e-commerce/e-government trends and developments and initiating new J-09 e-transit investigations can only result in continuing to providing today's answers to yesterday's questions. Consequently, there is a need to provide an overall context and a reference framework that can be used to quickly assess the impacts and potential opportunities of changes and new developments in order to do the following:

- Examine e-transit opportunities and impacts for further investigation in the J-09 e-Transit Program with respect to
  - Their impact on the services provided,
  - The business processes and functions that are carried out within transit agencies,
  - The organizational structure of the agency and employee responsibilities within it,
  - Relationships to the customer and other organizations, and
  - Other issues (e.g., sustainability, liability, life cycle, and potential obsolescence).
- Monitor current and future developments in the IT and other industries for potential transfer to transit applications.
- Assist transit operators in assessing the potential application of e-transit options to meet the particular needs and situation of the operators.

[1] Transit Cooperative Research Program, "Research Project Statement Project J-09, FY 2000—e-Transit: Electronic Business Strategies for Public Transportation," page 1 (Transportation Research Board, Washington D.C., January 2001).

[2] Ibid.

[3] *TCRP Report 84: e-Transit: Electronic Business Strategies for Public Transportation:* Volume 1, "Supply Chain: Parts and Inventory Management"; Volume 2, "Application Service Provider Implementation Guidelines"; Volume 3, "Using the Internet for Transit Training and Certification"; and Volume 4, "Advanced Features of Transit Websites."

An e-transit reference enterprise architecture developed at a level of detail that both captures the business objectives, functions, and processes and yet can still be easily explored and updated to assess potential e-transit applications meets this need.

This concept paper is the result of Phase I of the development of a transit business model and e-transit reference enterprise architecture for assessing e-transit options. This Phase I work was proposed in Mitretek's 2003 "Proposal for Task 8: A Systems Engineering Approach to e-Transit: A Concept Paper." This paper includes a discussion of what e-transit is and how it fits into the overall operation and business of transit agencies. An overview of the basic concepts behind systems engineering and enterprise architecture and their use in the development of an e-transit reference enterprise architecture is also provided. Finally, this paper describes the tasks, approach, and products of Phase II in which an e-transit reference enterprise architecture will be developed.

1.1 DEFINING e-TRANSIT

To develop and apply a framework for assessing emerging e-transit technologies and services, we must come to a general agreement on what e-transit is. e-Transit is more than just simply the implementation of e-commerce and e-purchasing within transit agencies. The initial TCRP e-transit statement of work included the following subject areas within e-transit:

- Supply Chain: Parts Management/Inventory Management,
- Regulatory Issues of e-Business within Transit,
- Application Service Providers,
- Customer Information,
- Electronic Payment and Receipts,
- Training and Certification, and
- Outreach (e-Zine).

As seen from the above, e-transit is much more than the e-commerce business-to-business (B2B) and business-to-customer (B2C) functions of transactional processing and relationships (e.g., purchasing, contracting, and information provision). It also extends into the e-government functions of government-to-citizen (G2C), government-to-employee (G2E), and government-to-government (G2G). The public nature of transit service also changes the focus and measures of success for e-transit. Public Technology, Inc., lists the goals of e-government as promote democracy, encourage economic activity, and enhance service delivery to citizens.[4] The focus of e-transit shifts to one of service to customers, collaboration, and efficient service delivery, not competitive advantage and market share. G2E services are becoming increasingly important as transit agencies compete for employees with needed technical skills and work to train existing employees in a rapidly changing environment. The importance of providing an information portal and forum for citizen input also becomes a critical e-transit function, especially when major investment or New Start projects are underway. Applying the broad roles of e-government and e-business to transit, e-transit should therefore be considered "The use of digital technologies to transform government operations in order to improve effectiveness, efficiency, and service delivery."[5]

In the book *e-Business: Roadmap for Success,* Ravi Kalakota and Marcia Robinson equate e-business with "structural transformation."[6] The same principle applies to e-transit. e-Transit is not a simple set of functions and services that can be readily implemented and transferred from one agency to another. The Gartner Group cautions that moving to an e-world is as much about process re-engineering and developing new ways of doing things as it is about technology. Simply moving old processes to the Internet is bound to fail. Gartner defines four phases of e-government that also apply to e-transit:

1. Presence,
2. Interaction,
3. Transaction, and
4. Transformation.

Evolving through these phases requires a strategy for change (though a single agency may be at different phases for different functions and may skip phases in its deployment). The need to assess the overall impacts on the transit agency's organization and business functions and provide paths of development is one of the central principles behind the proposed use of systems engineering and enterprise architecture to develop the e-transit reference framework.

1.2 SYSTEMS ENGINEERING AND ENTERPRISE ARCHITECTURE

Systems engineering and enterprise architecture concepts are at the core of the proposed approach to develop a transit business model and reference framework for assessing e-transit. Systems engineering provides the principles and process for defining the fully integrated e-transit agency of the future. However, systems engineering for the most part focuses on the systems and functions required to meet a particular system's goals and objectives. Enterprise architectures provide the means to capture and document the overall impacts of a new technology or service on the transit agency as a whole, including its people, processes, technologies, and business requirements. Using a reference architecture to capture transit agencies of today and the envisioned transit agencies of the future creates a foundation for assessing all the impacts of e-transit (on people, on processes, on technologies, and on systems) and how they might be transformed.

[4] Public Technology, Inc., website 6 January 2003, http:/pti.nw.dc.us.

[5] Mark Forman, OMB Associate Director for IT and *e*Government, September 2001.

[6] Ravi Kalakota and Marcia Robinson, *e-Business: Roadmap for Success*, Addison-Wesley, Reading, MA, 1999.

Systems engineering as a discipline and process evolved during the 1960s and 1970s to assist the developers of the defense program and other complex high-technology systems in identifying and tracing requirements, examining tradeoffs, and evaluating risks to ensure that once the systems were implemented they worked as planned. Systems engineering provides a disciplined environment to design quality into complex systems from the very beginning. Key to the success of systems engineering is the involvement of all the stakeholders and users of the system throughout the process to correctly identify what the system is supposed to do. This collective involvement provides a mechanism to view the provision of transit services as a business practice, focusing on needs and goals, addressing operational requirements and ways to accomplish them, examining alternatives, and tracing impacts through the system to see the results. Systems engineering becomes increasingly important as provision of transit service shifts from independent operation within a single transit agency to dependence on coordinated operation of complex systems (e.g., automatic vehicle location/computer-aided dispatch, communications, automatic passenger counters, and signal priority) across numerous providers and modes (e.g., multiple local transit agencies, trains, intelligent transportation systems [ITS], traffic networks, and information providers) using computerized procurement, maintenance, asset management, and delivery systems to provide mobility management to customers.[7]

The steps found in the overall systems engineering process are as follows:

1. Identify the concept of operations (through users and stakeholders), including
   a. Needs and goals,
   b. External factors (e.g., environment, constraints, and policies),
   c. Initial operational concepts, and
   d. Initial operational scenarios (e.g., peak, off-peak, inclement weather, and emergency/disaster).
2. Develop operational requirements (e.g., functions, process, performance, and verification).
3. Identify and evaluate alternatives (e.g., according to feasibility risk, uncertainty, reliability, and costs).
4. Trace impacts on existing organizations and processes.
5. Integrate and implement system components.
6. Provide for verification and validation.
7. Incorporate feedback and iteration into development and design (i.e., refine).
8. Manage the implementation and operation of the integrated system, and incorporate changes as they occur.

Enterprise architectures evolved out of the business process re-engineering and IT strategic planning of the late 1980s and early 1990s. John Zachman originally proposed the idea of an enterprise architecture in 1987. Since then, the "Zachman Framework" has been refined and variants have emerged (e.g., the Popkin Process, the Federal Enterprise Architecture Process, and the National Institute of Standards and Technology [NIST] Five-Layered Architecture Structure). All variants, however, are multilayered strategic representations of an organization or organizations that capture the mission and business practices. Enterprise architectures go beyond systems engineering by linking mission needs, strategic plans, business processes, information content, information technology, people, and infrastructure across the agency or organization as a whole. Thus, a well-structured and comprehensive enterprise architecture provides a means of developing and maintaining documentation of a business's operations, technologies, and decision making from different levels and perspectives and tracing them back to the organization's mission and goals. More importantly, it provides the capability to quickly identify how changes or the impacts of proposed decisions propagate throughout the system (e.g., processes, practices, and organization). Consequently, enterprise architectures are becoming more and more central to helping managers and business/government leaders in general answer questions: How? When? Where? Why? Who does what? What tools do they need to do it? And how can business and government leaders manage change in an increasingly integrated and complex world? For example, enterprise architectures have become a key component of the federal e-government initiative.[8]

Figure 1-1 shows how systems engineering and enterprise architecture will work together in the development of a transit business model and reference framework for assessing e-transit. The transit today (base case) and transit future (e-transit vision) business requirements and relationships between people, processes, and technology/systems for a typical large urban transit agency will be captured and represented within an enterprise architecture. As this reference enterprise architecture is developed, systems engineering will be used to help determine the needs and goals of today's transit "business" and how they evolve to meet transit's future vision; the concepts of operation as we move toward the future vision; the associated business functions and their requirements; and future e-transit opportunities and how they might be implemented. The effort will focus on capturing the incorporation of emerging technology in support of integrated G2G, G2B, and G2C e-commerce in the transition to the transit future vision. The development of the future e-transit architecture will be based on sound systems engineering practices and, once complete, should help guide the future activities of the e-transit panel. This is explained more fully in Chapter 2.

Special attention will also be given to developing the architecture at the level of detail that is general enough to apply to the industry as a whole but specific enough that potential e-transit applications can be quickly incorporated and their implications assessed. If the architecture is developed at too general a level, it will not capture enough of the operations and interrelationships to be useful. If it is developed at too specific a level, it will become too tied to the technologies, software applications, and processes associated with a partic-

[7]See *TCRP Research Results Digest 55,* December 2002.

[8]Mark Forman, OMB Associate Director for IT and *e*Government, September 2001.

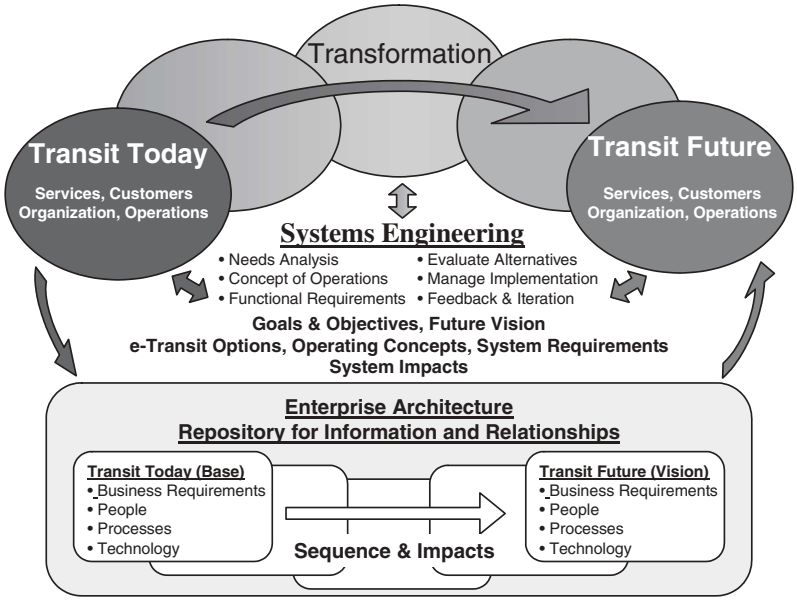

Figure 1-1. A reference transit framework using systems engineering and enterprise architecture.

ular situation or agency to be generally applicable to others, and assessing new potential e-transit applications will become unwieldy and time consuming.

1.3 PROPOSED ENTERPRISE ARCHITECTURE PRODUCTS

Three major products are envisioned for this effort. First, as discussed above, is the creation of an e-transit reference enterprise architecture that captures the following:

- The As Is "Transit Today" base case business requirements and operations of a typical large transit agency serving a major metropolitan area.
- The To Be "Transit of the Future" vision based upon the TCRP J-08 New Paradigms for Public Transit results and the implementation of integrated e-transit applications.
- A typical sequence of actions and their impacts for making the transition from the today base case to the future vision.

The second envisioned product, since the reference enterprise architecture is meant to help analyze, plan, and implement potential e-transit applications, is the preparation of guidance on its use. The guidance will include both documentation of the reference enterprise architecture and development of a user's guide and example applications. The user's guide will include specific guidance on how to use the reference enterprise architecture at the national level to identify research needs and emerging opportunities and on how to use the architecture at the local level to analyze potential e-transit applications or to develop an agency-specific enterprise architecture for e-transit planning and implementation.

The last envisioned product is the creation of an online collaboration forum and e-mail exchange that will be used to identify emerging issues and make recommendations to the J-09 e-Transit Project Panel for additional investigations under the e-transit program. It will also be used as a repository for e-transit–related literature and news articles and as a feedback forum for draft products and results.

1.4 DOCUMENT OVERVIEW

This introductory section briefly discussed the following: why it is important to develop a business model and reference enterprise architecture for assessing potential e-transit opportunities, the proposed approach and its use of systems engineering and enterprise architecture, and the products that will result. Chapter 2 summarizes systems engineering procedures and enterprise architecture concepts as they support a controlled, coordinated transition to e-transit by transit agencies. Chapter 3 provides a more detailed overview of the approach that will be used during the development of an architecture reference model for a transit agency and how specific issues such as the coordination with the National ITS Architecture and ongoing homeland security efforts will be addressed. Chapter 4 presents the proposed Phase II research plan to develop the e-transit reference enterprise architecture and produce its associated guidance. The appendix provides an overview of the enterprise architecture tool assessment and recommendations for this effort.

CHAPTER **2**

SUMMARY OF SYSTEMS ENGINEERING AND ENTERPRISE ARCHITECTURE CONCEPTS

This chapter explains the essential relationship between systems engineering procedures, or disciplines, and how they relate to and support the concept of an e-transit reference enterprise architecture. General guidelines for the development of the e-transit reference enterprise architecture and its use by a typical transit agency once it is developed will be explored. Figure 2-1 presents the question that this section discusses.

An enterprise architecture is a communications tool that allows non-engineers and business leaders to understand the whole enterprise in a more integrated manner. The role of the enterprise architecture[9] is to respond to business leaders when they ask "How?", "When?", "Where?", "Why?", "Who does what?", and "What resources or tools do they need to do it?" The enterprise architecture models the important pieces of the entire actual system and allows others to see what is happening within the enterprise and to examine what can happen in the future enterprise.

The creation of an enterprise architecture is supported by the underlying systems engineering procedures of operational requirements definition and analysis, evaluation of alternatives, design and implementation, testing, incorporation of feedback, and iteration. However, systems engineering and the tools that have been developed to support it aim at specific technical systems or functions within the organization and do not encompass the overall operations of the business. Enterprise architectures and the tools that support them are designed to capture this larger perspective.

A useful enterprise architecture for an operational transit system will be sufficiently complex that it cannot be effectively created or maintained without the use of a computer application. An enterprise architecture tool must support sound engineering practices associated with creating models of established systems, showing the linkage of those systems, and modeling established data and process flows.

A useful enterprise architecture must have several desirable qualities. It must be good enough, but not perfect. It must be flexible and sustainable. It must address the important pieces of the enterprise, and it must support rapid iteration. Management and control of the systems engineering processes are necessary to produce a useful, flexible, sustainable enterprise architecture for an e-transit organization that serves the needs of its business leaders.

[9]Building the Enterprise Architecture: The Popkin Process, Version 1.0.

Several computer applications to support both systems engineering and enterprise architectures were surveyed and evaluated in the development of this concept paper. The tools developed to support the systems engineering processes typically focus on narrowly scoped areas and can be very effective in dealing with their little piece of the enterprise architecture. Complicating matters is that these separate tools often do not work well together while they work to optimize their specific areas with little or no understanding of the entire enterprise. As a result, such a collection of engineering tools cannot address all the important pieces of an entire enterprise in a comprehensive yet useful manner. The tools developed to support enterprise architectures overcome these issues. Depending on an organization's needs, either Metis by Computas or System Architect by Popkin would be a good choice. The appendix presents details of the enterprise architecture tool evaluation.

2.1 OVERVIEW OF ENTERPRISE ARCHITECTURE CONCEPTS

Enterprise architectures are widely used as a tool for managing and planning the evolution of large, complex "enterprises." An "enterprise" can be any complex entity or group of entities that share a common set of purposes. Some examples are a commercial company, a government agency, a large nonprofit organization. Enterprise architectures evolved out of the business process re-engineering and IT strategic planning of the late 1980s and early 1990s. John Zachman originally proposed the idea of an enterprise architecture in 1987.[10] His representation of a general enterprise architecture is the Zachman Framework.[11]

As it applies to enterprises, the framework is simply a logical structure for classifying and organizing the descriptive representations and views of an enterprise from different perspectives that are significant to the management of the enterprise as well as to the development of the enterprise's systems. The rows capture the views and perspectives of the different major roles in maintaining and operating any enterprise. They move from Row 1's highest contextual perspec-

[10]"A Framework for Information Systems Architecture," J. A. Zachman, *IBM Systems Journal,* Volume 26, Number 3, 1987, and "Extending and Formalizing the Framework for Information Systems Architecture," J. F. Sowa & J. A. Zachman, *IBM Systems Journal,* Volume 31, Number 3, 1992.

[11]URL: http://www.zifa.com, © John A. Zachman, Zachman International.

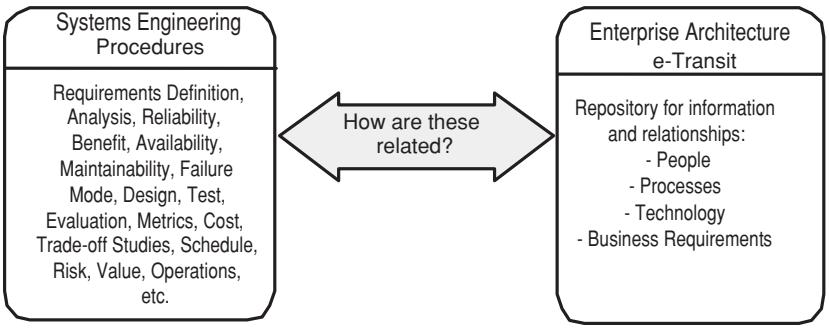

Figure 2-1. How do systems engineering procedures relate to enterprise architecture?

tive of the planner—which captures what is important to the enterprise; the context in which the enterprise operates; its mission, goals, and objectives and how and when the enterprise meets them; and its important stakeholders—to Row 5's detailed representations and descriptions of the data, technologies, and software applications needed for implementing and operating the functions and processes of the business. Each successive row provides more details needed to implement the requirements and constraints from the rows above.

The columns capture the answers to "What?", "How?", "Where?", "Who?" "When?", and "Why?" from each row's perspective. The column order does not represent any particular sequence, and the columns can be rearranged in any order that best meets the needs of the enterprise architecture being developed. However, Zachman's original paper only presented the "What?", "How?", and "Where?" columns. The remaining "Who?", "When?", and "Why" columns help provide the context and constraints of the business at each level.

Since originally proposed, the Zachman Framework has been refined and variants have emerged (e.g., the Popkin Process, the Federal Enterprise Architecture Process, and the NIST Five-Layered Architecture Structure). All variants relate back to the original framework, but may be tailored to meet specific needs and purposes of the enterprise architectures they are used for. Not all the rows or columns of the Zachman Framework are necessary for all applications, and what is included should be scoped to address the issues being raised using the resources and time available for the effort. For example, a reference enterprise architecture typically includes the Row 1, "Contextual, Planner," and Row 2, "Conceptual, Owner," and sometimes parts of Row 3, "Logical, Designer," views of the enterprise. The remaining rows apply to site-specific design and development issues. They focus on the design and engineering details associated with a specific business and its operations and therefore usually cannot even be incorporated into a reference architecture. Likewise, the information associated with a specific business in the "who" and "when" columns may not be appropriate for a reference architecture.

An enterprise architecture models important aspects of the enterprise, representing them and their interrelationships in a way that supports communication, analysis, and planning (see Figure 2-2). Enterprise architectures typically capture, at a minimum, information about people, business processes (i.e., functions), data, and supporting infrastructure. Additional elements may include location and time. The relationships between these aspects must also be captured to understand the enterprise as a whole and make the architecture valuable.

A reference architecture, or generic blueprint, provides guidance for developing an agency-specific enterprise architecture. A reference architecture tailored for e-transit will facilitate a transit agency's self-examination and modeling of the important pieces and relationships of the whole transit enterprise in a descriptive framework. Guidance in using an e-transit reference architecture will help ensure that the resulting e-transit enterprise architecture for a specific organi-

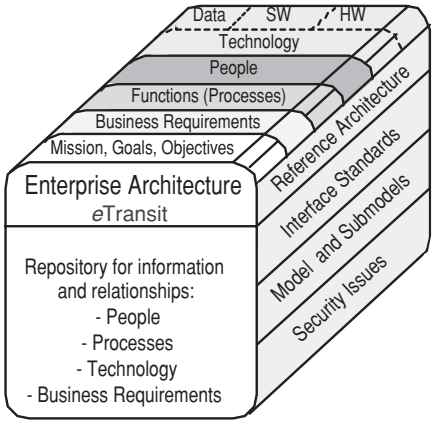

Figure 2-2. An enterprise architecture models the organization.

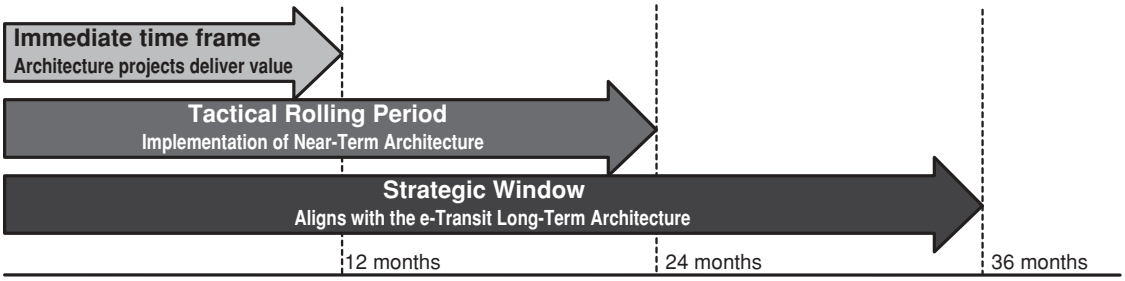

Figure 2-3. Time frames suggested in the reference enterprise architecture.

Figure 2-4. Stabilizing role of an operations architecture.

zation has the characteristics of a good enterprise architecture and that the enterprise architecture is useful for understanding the enterprise and analyzing alternative responses to business changes and emerging technology. The reference architecture will address techniques such as knowledge management, business (re)engineering, data warehousing, and alignment of business and IT strategy—all techniques crucial to the success of e-transit.

The reference architecture will also include the functions and responsibilities needed to provide governance and management of the evolution toward the future "To Be" scenario. This governance process may also provide an example for agency-specific e-transit enterprise architectures for managing change and in the organization's priorities, new technologies, or external factors.

A good enough architecture covers the immediate time frame and provides guidelines, models, interfaces, definitions, and protocols for immediate use by business leaders in managing and planning processes and systems engineers in the design and integration processes.[12]

A design goal of any reference enterprise architecture should be the flexibility to respond to changing business and technology drivers. The phases of development and implementation captured within a reference enterprise architecture are shown in Figure 2-3. Along with the overall vision for an organization's long-term e-transit enterprise architecture, smaller pieces will be implemented to provide value in the immediate time frame. Larger pieces will be planned and implemented over a tactical period of 12 to 24 months. Over the strategic period of 36 months, changes due to new business requirements or emerging technology may be made to the e-transit enterprise architecture.

The e-transit reference enterprise architecture may also be used as a foundation and starting point for specific transit agency enterprise architectures. The most important pieces of an agency's e-transit enterprise architecture depend on the specific conditions and priorities that the agency faces. For one agency, interoperability and integration may be high-priority architecture work. For another agency, ease of customer access or ease of exchanging information may be the high priority.

A useful enterprise architecture is also one that is easily changed over time to respond to changes in business drivers and emerging technology. A practical enterprise architecture is more important than the ultimate vision or the perfect enterprise architecture. The underlying assumption is that the enterprise architecture will need to be amended often. The design of the enterprise architecture must incorporate governance, an organizational structure, and a process to ensure that it is updated as often as necessary. Certainly, excessive change to an architecture diminishes its value; however, frequent, regular change to respond to evolving needs and opportunities is healthy. Thus, an enterprise architecture should have program rather than project status. This will aid continuity of process and retention of corporate knowledge associated with sustaining and using an enterprise architecture for business management, design, and integration.

One method of developing and modeling an enterprise architecture uses an operations architecture that focuses on the immediate (or near-term) time frame and acts as a stabilizing conduit between the current (or legacy) business processes and the future enterprise architecture. Figure 2-4 shows how the use of a sound operations architecture is a practical approach that facilitates construction of a useful overall enterprise architecture.

Transit organizations may find that business logic necessary to sustain established operations is hidden in legacy ap-

[12]Schulman, J. Defining "Good Enough" Architecture, Gartner Research Note, COM-20-2743, July 1, 2003.

plications and poorly documented processes. The e-transit components of the future enterprise architecture may have substantial impact on the organization's ability to both remain competitive and change. The e-transit, IT, and other components of an operations architecture can perform a dual role of maintaining essential stability while fostering change.[13] The goal is to manage the cost of the operations while improving the availability and performance of business processes in a changing environment where e-transit and IT become integrated into the business process. The enterprise architecture must become flexible and sustainable through the use of appropriate systems management tools.

Defining the operations architecture and making it the core of the transition plan can help the enterprise architects, developers, and operators all become part of a common team.[14] This can help the enterprise architects address the effects of architectural complexity and its impact on manageability so the complexity does not lead to poor manageability, lower quality of service, and higher costs.

John A. Zachman defines enterprise architecture as

> the set of descriptive representations (i.e., models) that are relevant for describing an Enterprise such that it can be produced to management's requirements (quality) and maintained over the period of its useful life (changed).[15]

An important consideration in the development of enterprise architectures is the scope. Whatever is left out of the enterprise architecture will not be subjected to analysis or planning using that enterprise architecture. But the scope does not need to be the entire organization. There is no minimum or maximum size of an architecture. There is no requirement that all components be within the same organization or that the enterprise be an entire organization. One of the first challenges of an enterprise architecture is to establish the boundaries of the enterprise, an issue that will be addressed in the next phase of this work.

Suppose, however, a policy decision is made to include everything, however briefly, in the enterprise architecture. The models should be developed at a high (i.e., general) level to contain the effort to create the architecture but detailed enough in the areas of interest to provide sufficient fidelity that the models and architecture are useful and practical for their intended purpose. A balance is necessary to enable a practical, useful enterprise architecture. For e-transit, level of detail is a critical issue, since it is easy to capture extraneous detail beyond what will be useful in some areas of the framework. The reference enterprise architecture and the guidelines will help achieve balance.

In summary, it is important to be realistic about which levels of the enterprise architecture are developed. Develop only the highest (i.e., most general) level, and the architecture has limited usefulness. Develop the architecture down to too low a level (i.e., too specific a level) and it will never be able to be completed before it is obsolete. The balance is found in capturing additional detail only in those areas that are impacted by new business rules or new technology in the near term.

Development of an enterprise architecture, including the current and future architectures and the transition plan for evolution, is a complex process. Typical architecture projects begin with the development of the current architecture using a team composed of domain experts and facilitators with architectural development expertise. Once the current architecture is developed, a combination of strategic requirements from domain experts and system engineering is required to develop the future architecture. Similarly, the team develops the operations architecture, which is the core of the transition plan. As discussed next, most of the effort should be allocated to the operations architecture and transition plan for near-term use. The team must identify and investigate alternatives. Priorities must be set and may include interoperability, sharing, reuse, and service-oriented metrics.

Important issues to be addressed include the following:

- How to relate the cells in the framework?
- How to use the framework to capture data and reveal the enterprise architecture?
- How to choose supporting systems engineering tools and when to use them?
- How to produce the designs and deliverables necessary to achieve the goals of the transit organization?

Consider a transit enterprise architecture as the product of an effort (performed by systems engineers using systems engineering concepts described in the next sub-section) to systematically describe and model transit services and relate them to the people, processes, and technology needed to satisfy the performance metrics of business requirements. Here technology expands to include data, software (applications), and hardware. Processes expand, for example, to provide customer service, assess condition/status, perform planning, authorize use, implement actions, monitor actions, manage compliance, manage work, and sustain the transit organization. Figure 2-5 shows an internal set of relationships in these enterprise architecture building blocks:

- The transit mission and business requirements define business functions (i.e., processes).

[13]Govekar, M., Enterprise Architecture Builds on Operations Architecture, Gartner Research Note COM-16-8215, June 19, 2002.

[14]Ibid.

[15]As quoted in "Building an Enterprise Architecture: The Popkin Process Version 1.0," Popkin Software, Inc., date unknown, obtained at www.popkin.com. The white paper does not provide a specific citation for the quote. It does provide the following in its reference section:

Zachman, John A. "A Framework for Information Systems Architecture." *IBM Systems Journal*, 26 (No. 3, 1987) [IBM Publication G321-5298. 914-945-3836 or 914-945-2018 fax.].

Sowa, J.F. and J. A. Zachman. "Extending and Formalizing the Framework for Information Systems Architecture." *IBM Systems Journal*, 31 (No. 3, 1992).

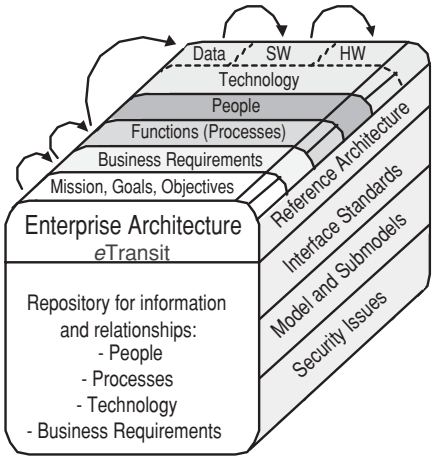

Figure 2-5. A logical sequence for developing content in enterprise architecture building blocks.

- Processes define data (i.e., operational, administrative, engineering, and other).
- Processes and data define applications (i.e., software).
- Processes, data, and applications define the transit and technology infrastructure (i.e., hardware).

Logic suggests that defining the business processes should precede defining data, which in turn should precede applications. In practice, capturing the current transit architecture and transitioning to a new architecture may proceed on multiple building blocks simultaneously. It may appear less than systematic to have a mixture of long-term (i.e., enterprise) efforts and short-term efforts that bridge gaps between where we are and where we want to be. For most customers, the transit system will continue to operate and serve them well while some architectural magic occurs.

Another important concept for enterprise architectures is the representation of evolution. For planning purposes, an "As Is" architecture is generally developed first. Then, a future goal architecture is developed based on strategic planning and the analysis of unmet requirements. An operational architecture and transition plan for evolution in the near term is developed that takes the "As Is" architecture and transforms it to the future architecture over a period of time, often in stages. This plan provides a road map for evolution and can be used to guide project planning and budgets. It is also practical because the "To Be" architecture can be somewhat general and subject to change as the near-term changes are implemented, while the business changes and technology continues to improve.

Other considerations that are important to capture in enterprise architecture development include security and coordination with other organizations. Security systems need to be part of the enterprise architecture. Current best practice is to include security within the rest of the framework, rather than develop a separate security architecture or separate security elements. Security requirements must be addressed wherever they are appropriate. Coordinated enterprise architectures among transportation entities will facilitate sharing and reuse within the transit community. Figure 2-6 shows a common external relationship for interoperability: compatible interface standards.

Current best practices in the development of enterprise architecture incorporate the use of tools because of the complexity of the architecture.[16] Two tools are currently used by many agencies within the federal government. System Architect by Popkin is frequently used to capture agency architectures and provides good linkage into the Office of Management and Budget's (OMB's) budget process. Metis by Computas is also widely used, especially for cross-agency projects. These tools provide many features that streamline the process of modeling the enterprise, provide better communication, and support management of the enterprise and development of the enterprise's systems.

2.2 OVERVIEW OF SYSTEMS ENGINEERING CONCEPTS

Enterprise architectures capture relationships and interactions between systems, business processes, people, and various disparate technologies in order to provide a cohesive and useful description of the enterprise. Systems engineering helps identify the goals and needs of the organizations and what the relationships should be.

Systems engineering evolved during the 1960s and 1970s to assist the developers of the defense program and other complex high-technology systems in identifying and tracing requirements, examining tradeoffs, and evaluating risks to ensure that once the systems were implemented they worked as planned. Systems engineering provides a disciplined environment to design quality into complex systems from the very beginning. Key to the success of systems engineering is the involvement of all the stakeholders and users of the system throughout the process to correctly identify what the system is supposed to do. This collective involvement provides a mechanism to view transit services as a business, focus on needs and goals, address the operational requirements and ways to accomplish them, examine alternatives, and trace impacts through the system to see the results. Systems engineering becomes increasingly important as provision of transit service shifts from independent operation within a single transit agency to dependence on coordinated operation of complex systems (e.g., automatic vehicle location/computer-aided dispatch, communications, automatic passenger counters, and signal priority) across numerous providers and modes

[16]See the appendix for a more complete discussion of enterprise architecture tools, their characteristics, and the selection criteria and recommendations for use in developing an e-transit reference enterprise architecture.

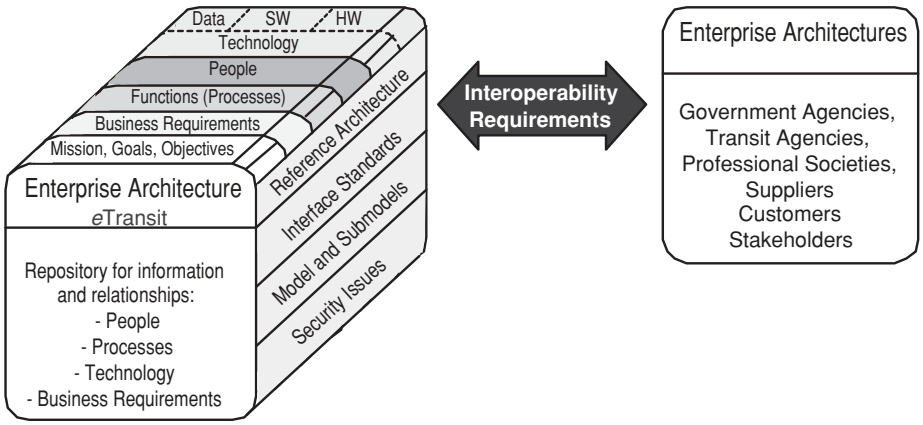

Figure 2-6. Interoperability prerequisite: compatible interface standards.

(e.g., multiple local transit agencies, trains, ITS, traffic networks, and information providers) using computerized procurement, maintenance, asset management, and delivery systems to provide mobility management to customers.[17]

The steps found in the overall systems engineering process are as follows:

1. Identify the concept of operations (through users and stakeholders), including
   a. Needs and goals,
   b. External factors (e.g., environment, constraints, and policies),
   c. Initial operational concepts, and
   d. Initial operational scenarios (e.g., peak, off-peak, inclement weather, and emergency/disaster).
2. Develop operational requirements (e.g., functions, process, performance, and verification).
3. Identify and evaluate alternatives (e.g., according to feasibility risk, uncertainty, reliability, and costs).
4. Trace impacts on existing organizations and processes.
5. Integrate and implement system components.
6. Provide for verification and validation.
7. Incorporate feedback and iteration into development and design (i.e., refine).
8. Manage the implementation and operation of the integrated system, and incorporate changes as they occur.

In general, there are two phases to systems engineering: (1) identifying "what" is to be built (i.e., goals, needs, and requirements) and (2) providing integration, testing, verification, validation, and change management as the system is implemented and operated. How systems engineering is applied and implemented (i.e., the level of detail, feedback and iteration methods, and appropriate software tools) depends on the purpose and focus of the project that it is being used for.[18] Figure 2-7 provides some examples of approaches to incorporating feedback and iteration within the process. These vary from a simple "waterfall" approach, moving from step to step with iteration at the next cycle of development; to a "Vee" model, with overlapping steps (e.g., needs analysis and concept of operations) and feedback/iteration between each step; to a "spiral" approach, with increasing levels of detail as needs and designs are refined.

For the development of the e-transit reference enterprise architecture, the focus of the systems engineering will be on the first phase of systems engineering: developing the needs, goals, and required functions and accounting for future contingencies, risks, and impacts on transit's business processes and organization. Consequently, since the ongoing implementation management, verification, validation, and feedback to incorporate change is not the focus of this effort, a waterfall or modified spiral process of feedback and refinement will likely be used.

In applying a systems engineering process to improve the business of providing public transportation services, the business processes associated with the business functions of transit agencies must be identified and examined. The systems engineering discipline can call upon any of numerous traditional engineering procedures that may be appropriate for a specific engineering project and may be performed for a specific transit system project.

When an enterprise architecture is used, systems engineering procedures employed may include

- Documenting and describing established systems with performance metrics,
- Creating models of established systems to an appropriate fidelity,

[17] See *TCRP Research Results Digest 55,* December 2002.

[18] "The Engineering Design of Systems: Models and Methods" (D. M. Buede, John Wiley & Sons, 2000) provides a general discussion.

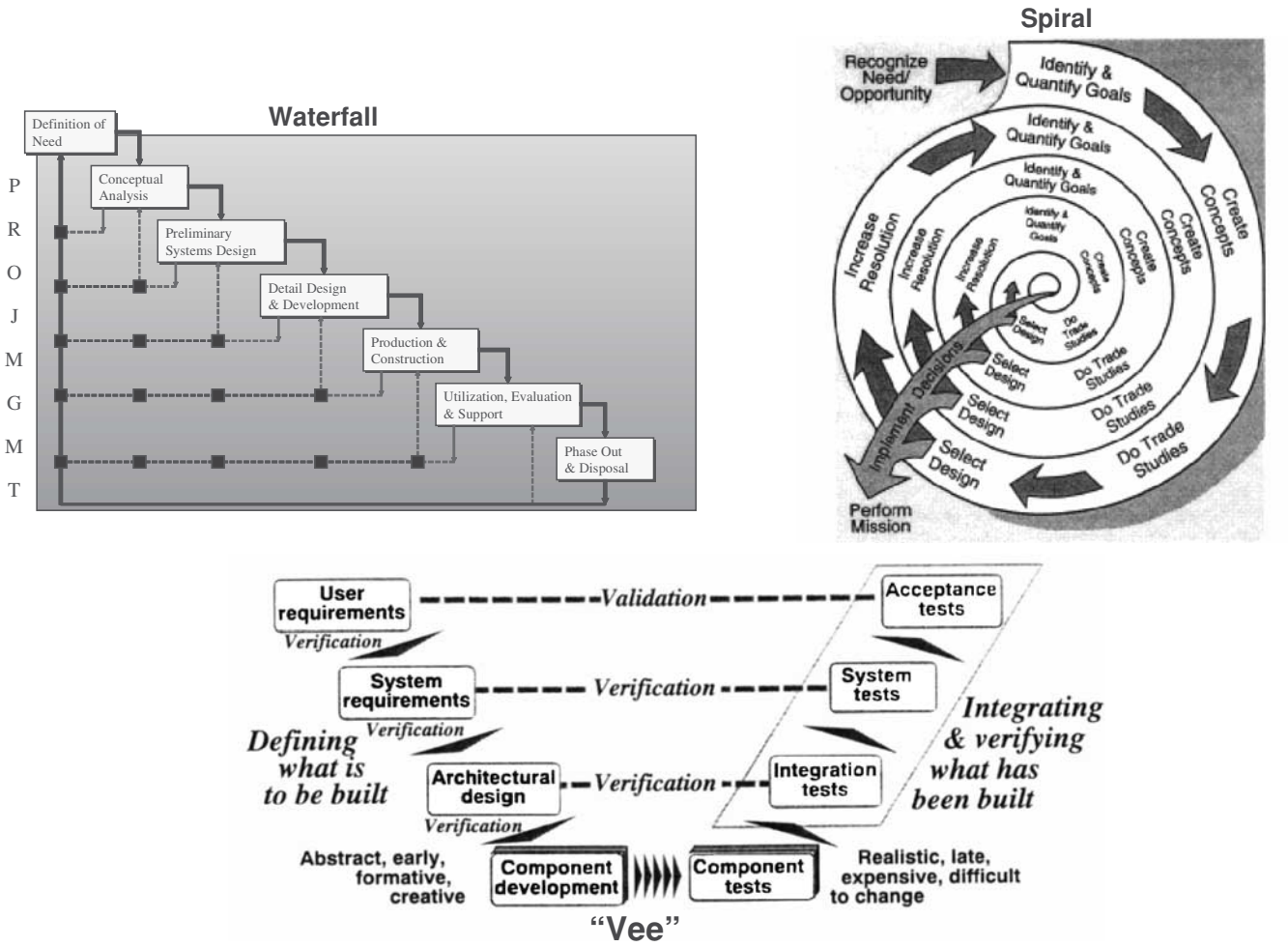

Figure 2-7. Approaches to feedback and iteration within systems engineering.[19]

- Documenting the relationships between established systems with appropriate metrics,
- Describing the linkages between modeled systems,
- Documenting established data and process flows,
- Modeling established data and process flows, and
- Following specialty and traditional engineering procedures for transit and IT that support the goal of the enterprise architecture and its use for communications and planning.

Another element that can characterize a good enterprise architecture is the amount of systems engineering effort that is expended on the current, near-term, and future architectures, as shown in Figure 2-8. Schulman[20] believes that 15 percent of the systems engineering effort needs to address the "As Is" architecture, 70 percent of the effort needs to address the near term, and 15 percent needs to address the "To Be" enterprise architecture. For the "As Is" effort, systems engineers document and analyze the current architecture. Engineering processes involved are creating models of established systems,

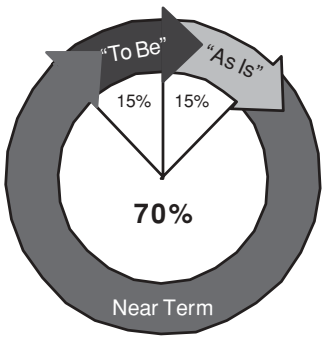

Figure 2-8. Apportioned systems engineering effort in enterprise architecture development.

[19]"The Systems Engineering Process & its Variants: A Quick Refresher including QFD, IDEF 0 & Design–ilities," Tutorial, Bob Lewis, Mitretek Systems Tutorial, Falls Church Virginia, 4 February 2002.

[20]Schulman, J. Defining "Good Enough" Architecture, Gartner Research Note, COM-20-2743, July 1, 2003.

showing the linkage of those systems, and modeling established data and process flows. The key to this process is predicting what will probably be useful and what will probably sit on the shelf unused.

Systems engineering and enterprise architects can derive great satisfaction from detailing a massive current architecture that fills binders that span a book shelf, but the downside is that the resulting overly detailed architecture project may live only on that shelf, unused and untouched. Enterprise architecture is an ongoing program that is subject to change, and it must be flexible to incorporate new business processes and emerging technology. This is the reason to apportion the effort involved in creating an abbreviated "As Is" architecture, a "To Be" architecture that is usually full of generalizations, and an operational architecture for use during the near term.

It is this good enough, near-term architecture that covers the immediate time frame and provides guidelines, models, interface definitions, and protocols for immediate use by systems engineers in the design and integration processes for e-transit operations.

CHAPTER 3

APPROACH: e-TRANSIT REFERENCE ENTERPRISE ARCHITECTURE DEVELOPMENT

This chapter explains the proposed approach for the Phase II development of the e-transit reference enterprise architecture, clarifies assumptions within the approach, and addresses potential issues that are known to exist. It also provides a list of potential resources and sources of information that may be used throughout the project and describes in more detail expected products and how they are intended to be used.

3.1 APPROACH

As stated in Chapter 1, a need exists to develop an overall context and framework that can be used to quickly assess the impacts and potential opportunities of changes and emerging technologies. An e-transit reference enterprise architecture will provide this context for identifying potential e-transit opportunities and a framework for examining changes triggered by government requirements and emerging technology. Systems engineering principles and practices will be used to help understand the relationships and inputs stored in the reference enterprise architecture. Thus, a simplified outline of the approach is as follows:

1. Collect information on current and planned transit agency business objectives, people and their roles, processes, technologies, and applications. Also identify existing and emerging e-transit applications and potential e-concepts from other industries.
2. Develop the As Is "Transit Today" base scenario by combining the above information with assumptions that define a "typical" major transit agency operating in a large urban region. Place the information and relationships that describe this scenario into an enterprise architecture model.
3. Use systems engineering principles and concepts and forecasts of industry and technology trends to define the To Be "Transit of the Future" scenario business goals, objectives, and concept of operations.
4. Develop the requirements and criteria for the transition from the As Is scenario to the To Be scenario. Use the scenarios for "gap analysis" and for evaluating different system configurations and e-transit applications for reaching the To Be future. Add the information and relationships that describe this To Be "Transit of the Future" scenario into the previous enterprise architecture model.
5. Use the resultant e-transit reference enterprise architecture as a tool to assess new e-transit applications and concepts and the impacts of these concepts on the business requirements, people and roles, processes, and technologies of today and the future.
6. Develop guidance and examples of typical applications of the reference enterprise architecture to help its use by the TCRP e-Transit Project Panel and the transit industry in general.

There are many different future scenarios that can be developed based upon different assumptions and priorities (i.e., goals, objectives, and visions of the future). This approach is an e-transit reference enterprise architecture rather than a generic transit enterprise architecture because of its emphasis on incorporating e-transit applications into the To Be "Transit of the Future" scenario. This emphasis will produce an e-transit–centric vision of the future system, with e-transit applied where it is found to be cost-effective, and capture how e-transit might transform the business processes, roles and responsibilities, applications, and technologies as a result. The approach also assumes continual collaboration with the TCRP e-Transit Project Panel and the transit industry in order to properly develop and represent both As Is and To Be scenarios.

Details and issues associated with the above approach are explained further below. These include further discussion of the relationship between enterprise architecture and systems engineering, the definition of e-transit and how it relates to ITS and other advanced technologies, the assumptions for defining the As Is and To Be scenarios, and ways to address the National ITS Architecture and other efforts that overlap or include e-transit.

3.1.1 Using Systems Engineering within the Enterprise Architecture Framework

Again, systems engineering practices and concepts will be used to help determine the needs and goals of today's transit "business" and how they evolve to meet transit's

future vision, define the concepts of operation as we move toward the future vision, define the business functions and their requirements, and assess future e-transit opportunities and how they might be implemented. The reference enterprise architecture is the repository for the information and relationships that result. The reference enterprise architecture for transit services would focus on capturing the outputs of the systems engineering process (e.g., missions, business cases, organizations, flows, functions, and users), including

- All transit business processes that support customer services as well as transit agency operations,
- Interface and data flow relationships for all processes,
- Who carries out each function and their motivation,
- Time requirements, and
- Transit and communications security concerns.

Both systems engineering and enterprise architecture are needed in order to visualize the complex relationships between people, processes, and technologies and how they relate to an agency's overall business requirements and to have the ability to quickly assess the impacts and opportunities of emerging e-transit concepts or other changes to the transit operating environment.

Systems engineering is often discussed and applied with respect to the development and implementation of specific projects and complex systems. Consequently, a significant part of traditional systems engineering application deals with determining requirements and design specifications, managing the project as it is implemented (i.e., managing change), and verifying and validating the system to ensure that it meets (or will meet) the original objectives.

Our development of a reference enterprise architecture is based on systems engineering applied at a higher conceptual level, which requires evaluating and selecting tools and techniques that focus more on the initial steps of the overall process (e.g., stakeholder identification and needs analysis, operational concept, and high-level functional requirements). An example is the creation of a "functional requirements model" (FRM) that maps stakeholders (both internal and external to a transit agency) and their operational roles and needs (i.e., business cases) in a three-dimensional framework. It captures who is impacted, what must be done, and the connections between them in order to meet each need. Figure 3-1 shows a conceptual FRM framework that Mitretek proposes for developing an e-transit reference architecture. For example, the cell for "Provide Reliable Transit Services (need), Plan Facilities and Services (functional role), for a Transit Agency Service Planner (Stakeholder)" would describe carrying out reliability analysis of existing routes, identifying causes of delays (e.g., recurring congestion, high-accident locations, and train crossing), and developing reroute and other strategies to overcome the delays. A vertical slice would show all of the functional roles, stakeholders that carry them out, and the functions (i.e., cell contents) that address a particular need or business objective.

The earlier question posed on how systems engineering is related to enterprise architecture is answered in Figure 3-2. Modeling skills dominate the procedures used to develop, sustain, adopt, and use an enterprise architecture that communicates to non-engineers and supports agency planning through its integrated view of the important pieces of the enterprise as a whole.

Systems engineering practices and principles will first be used to develop the As Is "Transit Today" base scenario concept of operations (i.e., constraints, needs, and goals) and business requirements and to identify the functions, people and their roles, and technologies that are used to meet the requirements and concept of operations. Again, the information and relationships that result will then be stored in the reference enterprise architecture. A similar exercise will also be conducted to define the e-transit–centric To Be "Transit of the future" scenario.

Because we are developing a conceptual planning tool, the e-transit reference enterprise architecture will remain at a high level, focusing on the requirements for information needs, functions, and types of applications and technologies needed to implement the e-transit concept of operations and not specific data formats, brands of technology, or software vendors and products. This focus is equivalent to the scope (i.e., contextual) and enterprise model (i.e., conceptual) layers of the Zachman Framework. This type and level of enterprise architecture can be captured by the following:[21]

- *Business Model.* Describes the business organization, requirements, and functions used in conducting the business (Row 1, "Planner, Conceptual," perspective of the Zachman Framework).
- *Information Architecture.* Defines the major kinds of information needed to support the business (Column 1, "What, Data," Rows 1 and 2, of the Zachman Framework).
- *Applications Architecture.* Defines the major kinds of applications needed to manage the information and support the business functions (Column 2, "How, Functions," Row 2, "Owner, Conceptual," of the Zachman Framework).
- *Technology Architecture.* Defines the technology platforms needed to provide the operational environment for the applications that manage the information and support the business functions (Column 3, "Where, Network," Row 2, "Owner, Conceptual," of the Zachman Framework).

The reference enterprise architecture that results should still be able to explore e-transit opportunities under a variety of situations (e.g., single agency or multiple agencies within

[21]Spewak, Steven H., and Steven C. Hill, *Enterprise Architecture Planning: Developing a Blueprint for Data, Applications and Technology*, A Wiley-QED Publication, John Wiley & Sons, Inc., New York, New York, 1992.

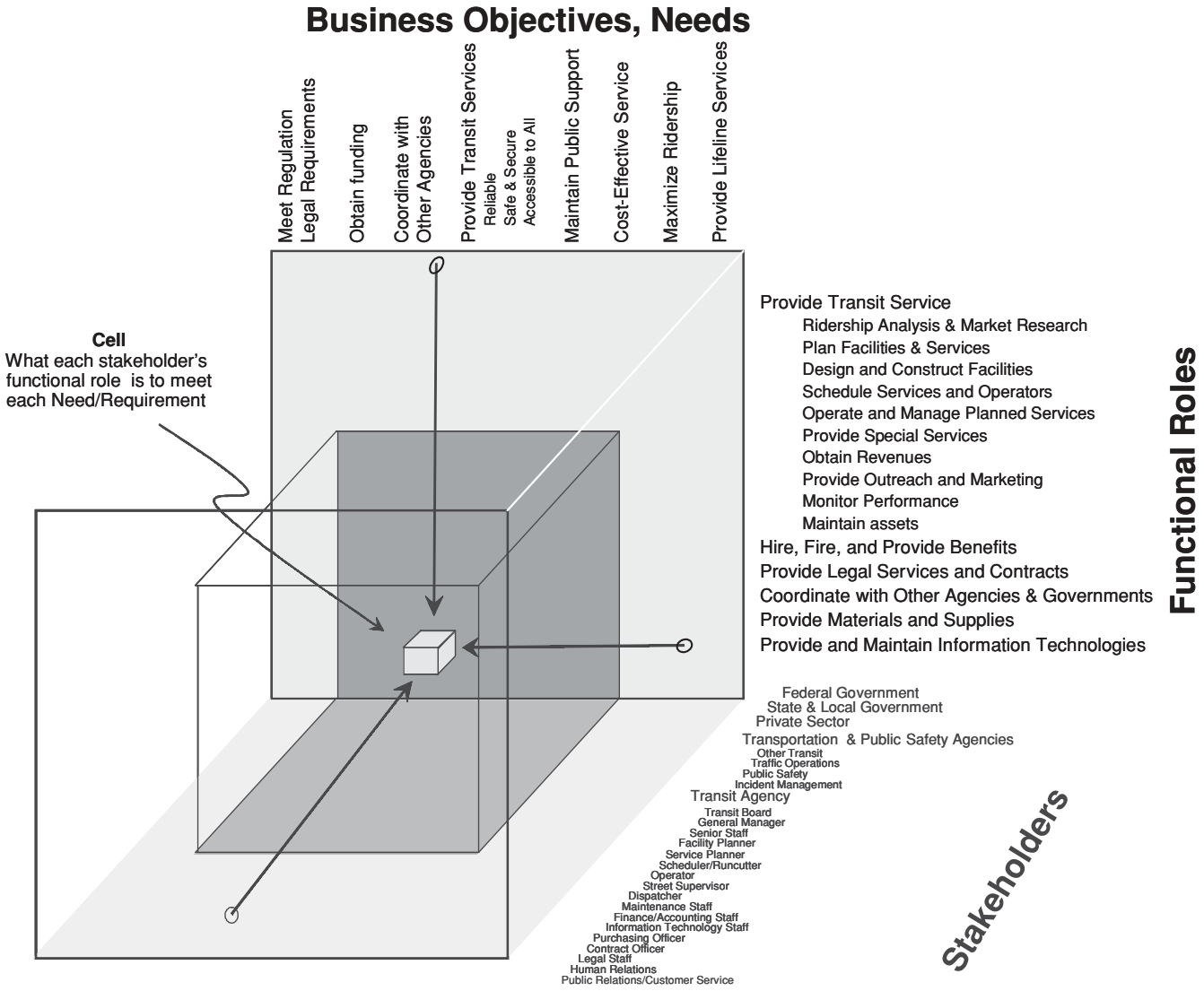

Figure 3-1. Functional requirements model framework proposed for e-transit.

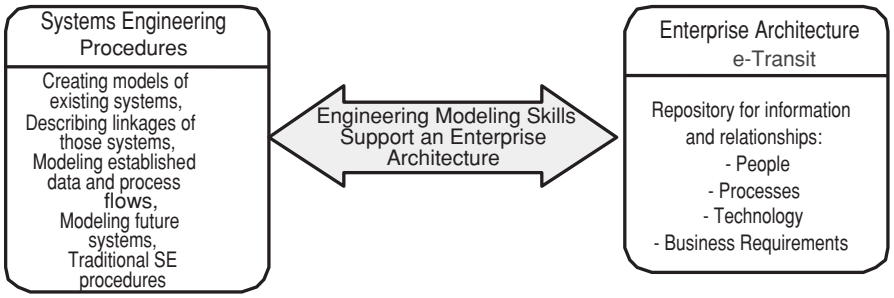

Figure 3-2. Systems engineering procedures that support e-transit enterprise architecture.

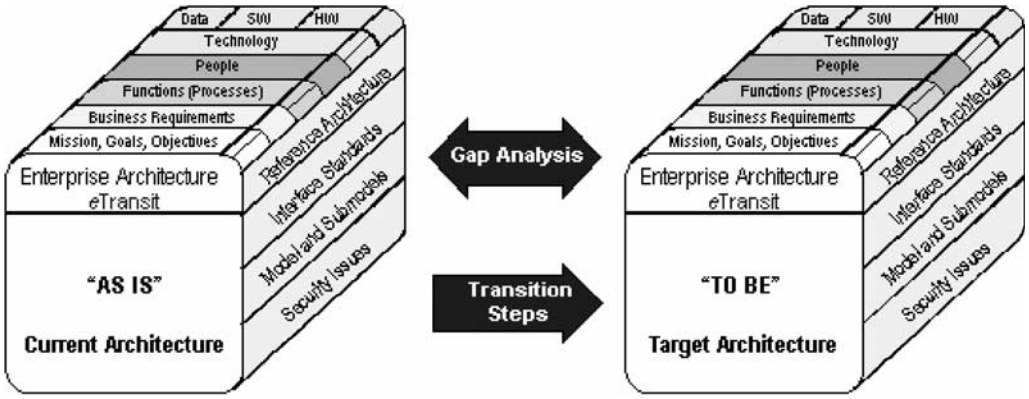

Figure 3-3. Implementing a target enterprise architecture using gap analysis.

a region; different combinations of bus, rail, or paratransit services; different levels of legacy technologies and systems; and different local government structures, regional organizations, and statutory mandates). Consequently, where possible the As Is base scenario will include sub-options and systems that may be isolated within the overall scenario to examine these questions.

Systems engineering principles and practices will then be used to prepare gap analyses between the two concepts of operation, to define the requirements and criteria for the evolution and transition of the system, and to develop and evaluate alternatives for making the transition. Care will also be taken to incorporate stages of technological development and the transition from one stage to another within the overall framework and evolution to the To Be "Transit of the Future" scenario. Figure 3-3 shows a high-level view of the gap analysis between the two architectures and the transition to a target enterprise architecture.

3.1.2 Defining e-Transit Re-Visited

One of the first tasks associated with any systems engineering or enterprise architecture effort is clarification of the system and problems being addressed. If this initial "scoping" is not carried out, it is likely that the alternatives examined and the potential applications that result may be too narrow to solve the problem or the issues and boundaries of the system included in the analysis may expand beyond the point that they can be addressed. Consequently, in order to help bound the Phase II development of an e-transit reference enterprise architecture and understand the focus of the overall TCRP J-09 e-Transit Program in general, additional clarification of the definition of e-transit is provided below.

As stated in the introduction, the effort will derive its definition of e-transit from the broad roles of e-government and e-business as "The use of digital technologies to transform government operations in order to improve effectiveness, efficiency, and service delivery."[22]

However, if a liberal interpretation of this definition is made, e-transit can quickly expand to include all ITS, IT, advanced communications, and other technology activities within a transit agency. This broad definition is not the intent or focus of the e-transit program or Phase II effort. For example, upgrading existing autonomous applications and systems that do not change or add either functionality or new channels of communication should not be considered part of e-transit. The definition of e-transit that will be used should therefore be refined to include applications and services that deliver a service to someone externally or internally[23] and

- Provide additional functionality, integration, or interactions to expand the responsiveness or access of the enterprise and/or
- Use new channels of communication and information flow provided by advancing digital technologies.

For example, implementing a stand-alone spatial database or geographic information system (GIS) within an application (e.g., a scheduling/run-cutting system) is not e-transit, while integrating all spatial database needs and applications within an enterprise GIS that is accessed through the agency's computer network and intranet is.

e-Transit is also much more than just e-commerce or the establishment of a transit agency website or intranet. e-Transit includes applications and functions for providing the following transactions:

- Government (i.e., transit agency) to consumer (both existing and potential transit passengers),
- Government (i.e., transit agency) to citizen,
- Government (i.e., transit agency) to business,
- Government (i.e., transit agency) to employee,

[22]Mark Forman, OMB Associate Director for IT and *e*Government, September 2001.

[23]"Service delivery is the key for e-government. Without delivery of service to someone, internally or externally, the process cannot be considered e-government" ("What is e-Government? Gartner's Definitions," C. Baum, A. Di Maio, F. Caldwell, Gartner-Group Tutorials, TU-11-6474, Research Note 11 August 2000).

- Government (i.e., transit agency) to government,
- Business to business (in support of transit activities), and
- Business to consumer (in support of transit activities).

Figure 3-4 shows the existing and potential near-term e-transit applications that resulted from a scan of the past TCRP J-09 e-transit reports and the literature and activities of the transit industry and e-government in general. These applications will be used as the initial potential e-transit applications for assessment in the Phase II effort. However, since the IT is rapidly changing, additional information will also be collected from transit agencies, the literature, and other industries as one of the Phase II tasks in order to ensure that all potential applications are considered.

Figure 3-4 also illustrates another important point concerning the channels of communication that are part of e-transit. e-Transit is not just limited to applications developed for the Internet or intranets, but includes all channels of communication provided by digital technologies (e.g., commercial mobile services, mobile phones, personal digital assistants (PDAs), and integrated voice response systems). This expanded view of e-transit and e-government in general is important because new technologies and ways to communicate continue to emerge.

It is also important to note that none of a transit agency's business functions and activities are, or are not, intrinsically e-transit. One of the fundamental characteristics of the existing and emerging e-transit applications is that they have the potential to remove existing constraints on where, how, when, and by whom activities are performed. The increasing speed and channels of communications, computing power, and distributed processing capabilities allow many functions that must be carried out by transit agency staff on location during business hours to be outsourced to application service providers or others. These functions can be performed in remote locations and carried out 24 hours a day, 7 days a week. Likewise, e-transit applications increase the ability to provide up-to-date and continuous information on system and transaction status that was previously not possible. As stated in the introduction, this structural transformation,

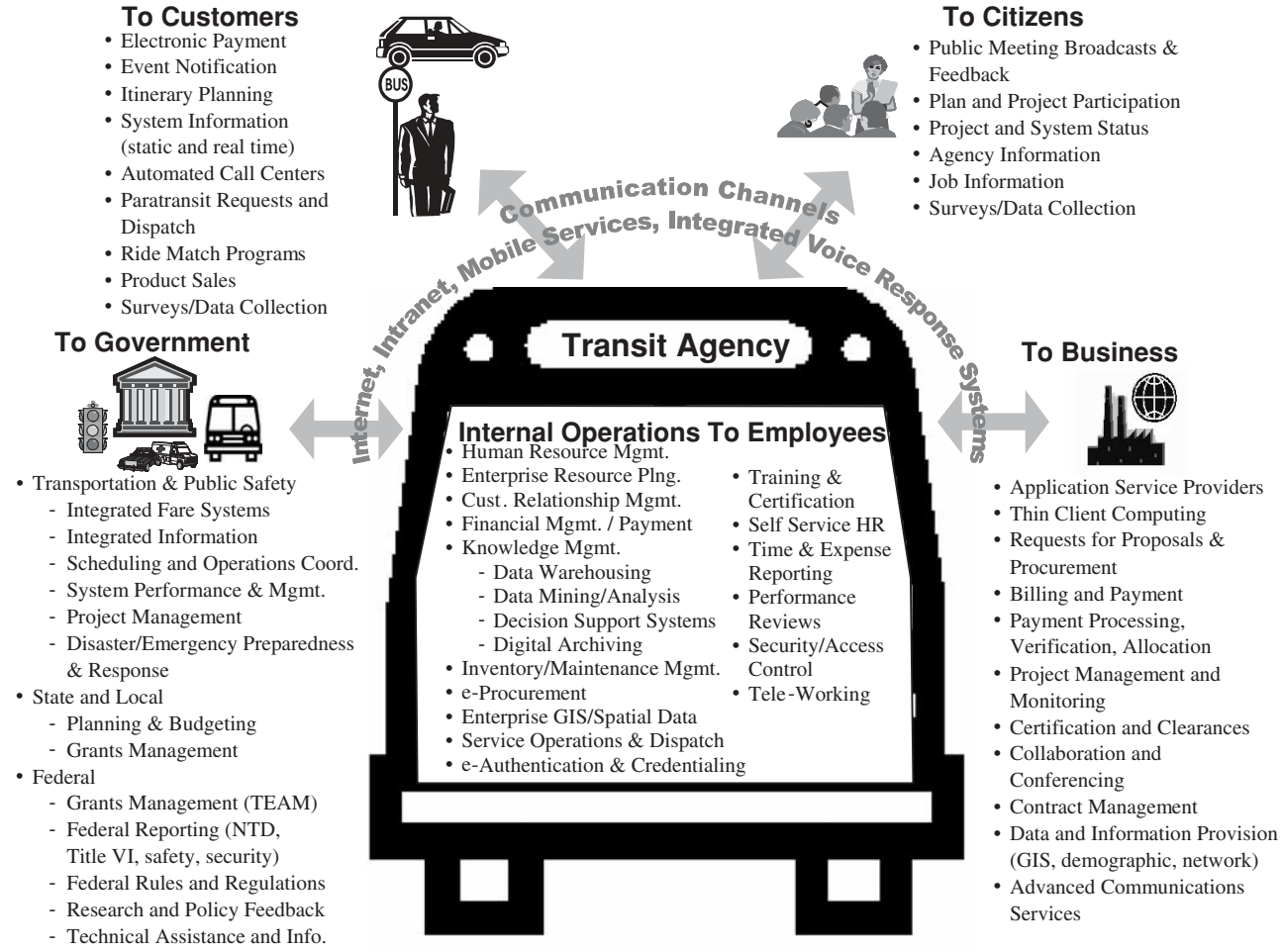

Figure 3-4. e-Transit services and applications.

process re-engineering, and provision of new opportunities, and not just technology, is the true focus of what e-transit is all about.

3.1.3 As Is "Transit Today" Scenario

The As Is "Transit Today" scenario provides a basis for assessment of potential e-transit applications. From this scenario, the To Be "Transit of the Future" scenario will evolve. The As Is scenario should be defined so that

- Typical variations in conditions, situation, and operations experienced by transit agencies across the country are addressed; and
- Transit agencies can evolve toward implementing integrated ITS, advanced information technologies, e-transit applications, and a new customer-oriented transit paradigm of mobility management.[24]

The scenario captures the base-case transit agency operating environment, business objectives and functions, staff roles and organization, processes, and technologies.

The following assumptions define the type of agency and its operating environment:

- The large multijurisdictional metropolitan urban area is supported by an active metropolitan planning organization (MPO).
- The large multimodal transit agency is governed by an independent transit board of directors that operates as the following separate business units:
  - Fixed-route bus system,
  - Rail system,
  - Paratransit system, and
  - Ride match program.
- Other local transit agencies, county and city traffic operations and centers, and commuter rail agencies are operating within the transit agency's service area.
- There is daily fixed-route bus and rail transit service.
- There is daily paratransit service that serves elderly passengers and passengers with disabilities and requires scheduling trips 24 hours in advance.
- The bus, rail, and paratransit operating departments each have separate operating policies and procedures for unusual events that can disrupt normal operations, including inclement weather, special events, or major road or freeway closures.
- While each transit agency within the region has a website that provides schedule information and the rail system provides an itinerary planner and has just introduced a new fare card, there are currently no shared transportation information or integrated payment systems.
- An agencywide emergency and disaster operations and management plan is coordinated with the regional emergency operations and management center. This plan provides for centralized communications and operations of all the region's transportation agencies in the event of a terrorist act, natural disaster, or other emergency.
- There is heavy congestion during the weekday peaks in both the morning and afternoon.
- Periodic severe inclement weather conditions of both snow and severe rain can disrupt transit operations.

One of the key steps in developing any enterprise architecture is the determination of the enterprise's business objectives and functions. The As Is "Transit Today" scenario will presume that the regional transit agency is still operating under the "public" transit ownership and operation paradigm that evolved in the 1950s and 1960s that treated transit as a public utility. Characteristics of this perspective of transit's purpose and business functions include the following:[25]

- Agency-owned and -operated transit services based upon Industrial Age values and practices, such as
  - Effective and efficient transit services,
  - Focus on a small piece of transportation services that are within mandate,
  - Autonomous and adversarial relationship with other modes,
  - Command and control of operations and services, and
  - Management assets (e.g., machines, buildings, and materials).
- Efficient transit performance, including
  - Fixed-route services;
  - Focus on current passengers and major markets;
  - Subsidy-dependent public service with "locked" revenues;
  - Provision of physical infrastructure and services;
  - Control of costs and operational orientation;
  - Hierarchical, rigid, autonomous organization structure; and
  - Separation of labor and management.

While it is recognized that many pioneering transit agencies already have shifted, or are in the process of shifting, away from this business perspective, others have not. Consequently, we will use it as a starting point in order to reflect the full range of points in the evolution to the To Be scenario.

The functions that support the above objectives and values can be separated into "value-added" functions that contribute directly to the agency's primary mission of providing and

[24] See Section 3.1.4.

[25] *TCRP Research Results Digest 24: Creating a New Future for Public Transportation: TCRP's Strategic Road Map,* Richard Daft, Robert Lingual, Glenn Perdue, April 1998.

operating transit services and "support" functions that provide agencywide support or contribute to more than one of the value-added functions.[26] The initial value-added and support business functions assumed for the As Is "Transit Today" scenario are shown in Figure 3-5. The value-added chain of functions that move from potential ridership analysis to providing on-street transit services is shown by the block arrows in the top of the figure. These high-level functions will be further refined, and the sub-functions, processes, staff roles and responsibilities, and technologies to carry them out will be identified as part of the Phase II e-transit enterprise reference architecture development. Another important set of assumptions within the As Is scenario is the level of ITS, advanced information technologies, and e-transit solutions included. As shown in Table 3-1, Gartner, Inc., defines four phases of e-government, and consequently e-transit, as follows:

1. Presence: agency website and basic information.
2. Interaction: e-mail, interactive information access and searching, and public feedback.
3. Transaction: self-service applications, interactive forms, verification, personal business transactions and payments, privacy, and authentication.
4. Transformation: new services and ways of doing business, new applications, and potentially new enterprise-wide identity and business objectives.

Transit agencies across the country are in various stages of making the transition from presence to transformation. The Bay Area Rapid Transit District is in the process of implementing a complete business analysis planning effort that includes a cross-cutting assessment of business functions and practices, implementation of enterprise resource planning and other advanced applications, and new ways of offering e-transit services and applications to both the public and employees (e.g., transfer of schedules and maps to PDAs). Table 3-2, derived from the FTA's 2002 TransitWeb directory of transit agency websites, indicates where the transit industry is today as a whole. Most agencies, however, can now be considered to be at the presence, or interaction, phases of e-transit implementation. Of the 477 websites from transit agencies within urban areas, all have "presence" with basic information, or they would not be in the database. Seventy-four percent provide for e-mail contact, but only 6% have trip planners (18% in the largest agencies) (i.e., interaction). The implementation of services that require transactions, or transformation of the business mission and functions, is only beginning to be seen (7% include online purchase of fare media, though this increases to 16% for the largest agencies;

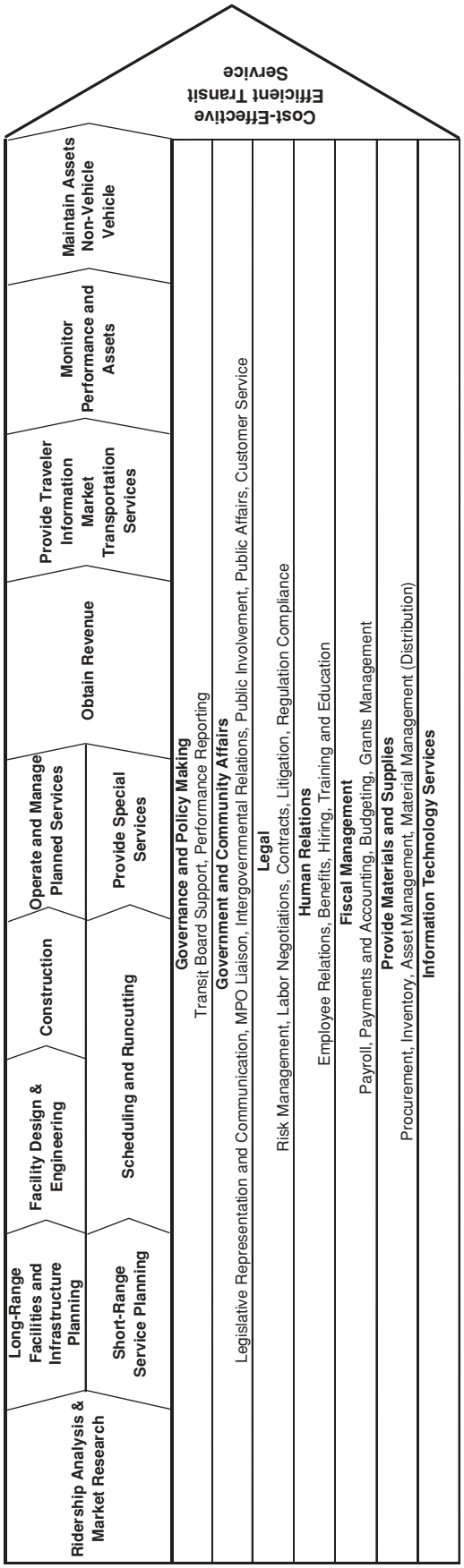

Figure 3-5. Transit agency business value-added chain.

[26] "Enterprise Architecture Planning: Developing a Blueprint for Data, Applications and Technology," Spewak, John Wiley and Sons, New York, 1992, and "Competitive Advantage: Creating and Sustaining Superior Performance," Michael E. Porter, The Free Press, 1985.

TABLE 3-1 Four phases of e-government[27]

Phase	Phase 1 Presence	Phase 2 Interaction	Phase 3 Transaction	Phase 4 Transformation
Strategy /Policy	Public Approval Visibility	Information Access and Search Public Feedback E-mail	Competition Confidentiality/Privacy Fees for Transaction e-Authentication	Funding Stream Allocation Agency Identity & Roles Virtual Agencies Integrated Functions & Services
People	Existing	Content Mgmt. Increased Support Staff Governance	Self-Services Skill Set Changes Portfolio Mgmt. Outsourcing Increased Business Staff	Job Structures & Roles Relocation /Telecommuting Organization Performance Measures Multiple Programs/Skills Privacy Reductions
Process	Streamline Processes	Knowledge Mgmt. E-mail Best Practices Content Mgmt. Meta Data Synch.	Business Process Re-engineering Relationship Mgmt. Online Interfaces Channel Mgmt.	Integrated Services Changed Value Chain New Processes/Services Changed Relationships Seamless Integration with Other Agencies
Technology	Website Markup	Search Engine E-mail	Legacy System Links Security Information Access 24/7 Infrastructure Outsourcing	New Applications New Data Structures Enterprise Integrated Applications

4% provide real-time information; and 2% have e-mail alert registration).

However, the transit industry is moving further into the electronic age. Transit-focused e-commerce efforts have been initiated by APTA (e.g., Transportmax) and the private sector (e.g., Ibus and Irail). Significant advances in incorporating e-commerce and e-transit into the country's transit operations have also been made, as reported by the APTA IT surveys:

- Internet technologies are becoming transaction oriented (31% of agencies offer services, from online purchasing of passes for customers to online purchasing of office supplies for employees).
- Emerging communications technologies are being used (54% use mobile computing such as PDAs and laptops, and 26% use teleconferencing).
- Transit ITS is being adopted. (From 1999 to 2002, the following increases took place: computer-aided dispatch, 36% to 55%; automated vehicle location, 22% to 51%; automated passenger counters, 18% to 34%; passenger information systems, 18% to 29%; and fare payment systems, 16% to 20%). Many of these systems also can be considered e-transit.
- Use of client/server and Internet applications, COTS, and ERP applications is increasing (e.g., PeopleSoft, SAP, and Oracle).

[27]The Gartner Group, "Four Phases of e-Government Model" Research Note 21, November 2000.

The As Is scenario will therefore assume the web "presence" of the regional transit agency with some interactive and transaction features. However, significant e-procurement and enterprise management applications (e.g., enterprise resource planning, human resource management, self-service intranets, and knowledge mining) will not be assumed as part of this base scenario.

3.1.4 To Be "Transit of Tomorrow" Scenario

The To Be "Transit of Tomorrow" scenario represents the desired future state of the transit agency and its business objectives and functions, staff roles and responsibilities, processes, technologies, and applications. It will use the same overall environmental and system factor assumptions incorporated into the As Is scenario (e.g., large multimodal transit agency within large urban area, multiple jurisdictions and other transportation agencies, strong MPO, and congestion and inclement weather events). By definition, the evolution of the To Be scenario is the result of the Phase II systems engineering and enterprise architecture efforts and analysis. However, basic assumptions that describe the scenario's concept of operations—including changes in business objectives and goals, external constraints and trends, and advances in technology—can be defined and are discussed.

Public transit in the United States is in the midst of reinventing itself, as documented by the recently completed

TABLE 3-2 ITS transit website characteristics by size of urban area[28]

Population	0 140,000	140,001 250,000	250,001 600,000	600,001 1,000,000	1,000,001 2,500,000	2,500,001 Plus	Total
Number of Sites	48	63	96	50	79	141	477
Feature Description	% of Sites with This Feature						
Route-Choosing Content							
System map	40%	48%	60%	38%	58%	60%	54%
shows transfer points	23%	32%	46%	28%	43%	49%	40%
point and click for detail	10%	11%	23%	10%	20%	30%	20%
"you are here" feature	2%	5%	2%	4%	8%	4%	4%
Trip Planner	0%	0%	2%	0%	4%	18%	6%
Route-Specific Detail							
Route maps	31%	57%	70%	54%	70%	57%	59%
Schedules	81%	86%	93%	76%	86%	87%	86%
Download to PDA	0%	0%	2%	0%	3%	2%	1%
Fares							
General fare information	88%	90%	94%	88%	90%	93%	91%
Online purchase of fare media	0%	2%	4%	0%	8%	16%	7%
Information on where to purchase fare media	38%	40%	50%	52%	56%	60%	52%
Multimodal Information Available on Site							
Traffic (multimodal) info.	0%	0%	0%	2%	0%	1%	0%
Park and ride lot info.	8%	10%	14%	24%	32%	25%	20%
Bicycles on/with transit info.	20%	26%	27%	20%	32%	38%	30%
Link to a car sharing site	0%	0%	0%	0%	1%	1%	0%
Outreach to Potential Users							
Rules and tips for using the system	48%	35%	53%	38%	41%	40%	43%
Includes information useful to lead tourists	8%	10%	16%	4%	13%	23%	14%
Language choice	0%	2%	6%	4%	5%	6%	4%
Links to Other Traveler Information Sites							
To other transit sites in region	32%	41%	26%	34%	41%	69%	44%
To traffic information sites in region	4%	6%	5%	6%	9%	19%	10%
To intercity transportation sites	9%	24%	15%	24%	23%	29%	22%
To transit-related goverment sites	34%	22%	20%	12%	34%	47%	31%
Current or Real-Time Information							
Current info. (reroutings, etc.)	4%	6%	13%	16%	22%	24%	16%
Real-time info. (NextBus, etc.)	0%	2%	3%	0%	3%	9%	4%
E-mail alerts sign-up	0%	0%	0%	0%	3%	6%	2%
Contact Information							
E-mail contact	69%	63%	77%	64%	87%	76%	74%
Phone contact	90%	94%	90%	94%	95%	92%	92%

TCRP J-08 New Paradigms for Public Transportation[29] project. Initiated in 1998, the New Paradigms project documented the factors and ongoing trends in demographics, technology, and public expectations that are creating a "crisis" in public transportation and the need for a new business paradigm. The research identified key factors from other industries and international experiences that, when combined, create a new vision for transit operations in the United States. The research identified and documented transit agencies around the country that are already reinventing themselves. The To Be "Transit of the Future" scenario will incorporate into its assumptions and business objectives the results of the New Paradigms project summarized below.

The new paradigm that was described in the J-08 project includes a fundamental shift in how transit agencies view their mission and the functions that they perform from that of owning and operating the transit services and facilities that they are mandated to provide and focusing on their systems effectiveness and performance to that of "mobility managers" focused on meeting the customer's door-to-door

[28]From the TransitWeb 2002 FTA Transit Agency Website Directory maintained by the Volpe Transportation Systems Center (http://transitweb.volpe.dot.gov).

[29]*TCRP Report 97: Emerging New Paradigms—A Guide to Fundamental Change in Local Public Transportation Organizations,* Robert G. Stanley et al., Transportation Research Board, Washington D.C. 2003.

TABLE 3-3 Three-tiered organizational model for the new transit paradigm

Tier	Key Attributes	Key Actions
Strategic	Interfaces with customers and understands their "full trip" needs and requirements.	Monitors performance. Brokers end-to-end trip from operators and service providers.
Tactical	Integrated systems of routing, dispatching, and tracking.	Applies Information Technology.
Operational	Niche markets and modal services by those that do them best.	Involves many suppliers in providing modal capacity and support services and responding flexibly and rapidly to service requests.

TABLE 3-4 Six dimensions of fundamental change leading to a new paradigm[30]

1. Mission Shift	Core mission shift from simply providing a form of capacity with assets you own to a broader responsibility for *managing mobility*, managing a wide range of assets…
2. "Obsession" for the Customer	Measures of success and performance are increasingly focused on the *quality of the customer experience*…
3. Collaboration	Collaboration across modes, organizations, and jurisdictions has become a fundamental strategy…
4. Integration	Integration of assets, services, and business functions is a common feature of emerging business models…
5. Information Technology	Effective links to customers and partners are dependent on deployment of state-of-the-art information technologies like universal fare systems; real-time, on-street customer information; and unified scheduling and dispatching systems…
6. Organizational Structure Change	New business units, functions, skills, and business processes are inevitable with change in these other dimensions…

needs for travel. The shift in perspective can be summarized as follows:

> The strategic interest lies in creating an organization whose principal responsibility is to provide the customer with knowledge of, and ease of access to, a range of services that can serve individual traveler needs and that has the capacity to continuously monitor, evaluate, and ensure the quality of the travel experience.[31]

A three-tiered organizational model is presented that is made up of a top strategic tier, a middle tactical tier, and a bottom operational tier. Table 3-3 summarizes concepts behind this new organizational approach. The middle tier is built around the use of integrated information technologies and communications, or e-transit. It incorporates many of the fundamental ideas and principles of e-transit and e-business in general, including

- Customer orientation,
- Separation of ownership and delivery of functions, and
- A flexible and responsive process to meet customers' shifting requirements.

The dimensions of fundamental change necessary for transit agencies to evolve toward the new paradigm are also described. These are summarized in Table 3-4.

Consequently, the To Be scenario will explore the shift from autonomous operation of the transit agency's fixed-route, paratransit, and rail systems to integrated management and operation of overall transit service across the region. This shift may require new e-transit connections and applications both within the agency and between agencies. Likewise, shifts to integrated passenger information, fare systems, transfers, and other services will all be investigated.

In addition, the To Be scenario will assume that current trends in technology development and applications continue

[30]Ibid.
[31]Ibid.

and promising e-transit options become a reality. Some of these trends and options include

- Continued implementation of existing e-transit applications and enterprisewide systems for enterprise resource planning, knowledge management, decision support, and other applications;
- Further investigation of the virtual transit enterprise being tested in South Carolina;
- Use of virtual private networks and the "Internet cloud" to increase opportunities for outsourcing and pooled applications among transit providers; and
- Continued evolution of "smart enterprise suites," web services, and e-authentication and security to enable new applications.

Each of these developments will be monitored and considered in the assessment of the final To Be scenario.

3.1.5 Coordination with the National ITS Architecture, Security, and Other Related Efforts

One potential concern that has been raised is the coordination of the development of the e-transit reference enterprise architecture with the National ITS Architecture and applicable standards, the U.S. DOT enterprise architecture, the Transportation Security Administration Transportation Worker ID Card and Card System Architecture, and federal e-government and architecture activities. A basic principle of the Phase II effort will be to coordinate and interface with these other efforts. Special care will be taken to use naming conventions, functional requirements, information flows, and so forth that have already been created by these overlapping efforts. Because of the significant overlap between e-transit and ITS, the coordination with the National ITS Architecture is explored more fully below.

The U.S. DOT initiated the creation of the National ITS Architecture to reduce the burden and assist in managing the development and implementation of ITS across the United States. The National ITS Architecture provides the logical and physical architectures for the development of the ITS user services, which capture from a user's perspective what we would like the ITS in the United States to do. The National ITS Program Plan first established 29 ITS user services in 1995. New user services have been added since then to address changing needs, increasing the total to 33 (as of July 2004). The Version 5.0 update incorporating security concerns arising from September 11, 2001, was released on a CD-ROM in November of 2003. It is also accessible via the Internet at http://www.its.dot.gov/arch/arch.htm.

The building blocks that the National ITS Architecture uses to provide assistance in implementing the user services at different levels and configurations are the National ITS Architecture market packages. Each of the market packages describes the subsystems, interfaces, and conceptual equipment packages needed to implement a key function used by the user services. A transit agency may be responsible for applications that implement any number of the ITS user services, from electronic fare collection, to passenger information, to archived ITS data. The market packages and applications that implement these user services are also often potential e-transit opportunities. Table 3-5 lists the user services and market packages from Version 5.0 of the National ITS Architecture that may be e-transit and implemented by a transit agency.

The National ITS Architecture also provides a general framework for implementing the user services and integrating ITS strategies within and across agencies, modes, and jurisdictional boundaries. Figure 3-6 represents the physical architecture subsystems and the communications between them.

In developing and implementing their ITS transit systems, transit agencies may be responsible for the following sub-systems:

- Centers
  - Transit Management
  - Information Service Provider
  - Emergency Management
  - Maintenance and Construction Management
  - Archived Data Management
- Travelers
  - Remote Traveler Support
  - Personal Information Access
- Vehicles
  - Transit Vehicle
  - Maintenance and Construction Vehicle
- Field
  - Roadway
  - Security Monitoring
  - Parking Management

When applications impacting the above sub-systems or the potential user services and market packages from Table 3-5 are considered in the e-transit reference enterprise architecture, the information available from the National ITS Architecture will be used. Again, the National ITS Architecture provides the market packages, functional requirements, and information flows between sub-systems and terminators required to implement the ITS user services. The National ITS Architecture does not address where, how, or by whom each function is performed within the transit agency or the additional functions, information flows, and activities that must be carried out to support the ITS user services that do not directly relate to its provision. Nor does the National ITS Architecture address how each ITS component relates to the overall business objectives and value-added chains of functions of the transit agency. This information will be developed and added as part of the Phase II effort.

TABLE 3-5 ITS user services and market packages with potential e-transit intersections

User Service	User Service Name	Market Package	Market Package Name
1 Travel and Traffic Management		**Traveler Information**	
1.1	Pre-Trip Travel Information	ATIS7	Yellow Pages and Reservation
1.4	Ride Matching and Reservation	ATIS8	Dynamic Ridesharing
1.5	Traveler Services Information	**Traffic Management**	
1.7	Incident Management	ATMS01	Network Surveillance
1.8	Travel Demand Management	ATMS02	Probe Surveillance
1.10	Highway Rail Intersection	ATMS05	HOV Lane Management
1.10	Highway Rail Intersection	ATMS09	Traffic Forecast and Demand Management
		ATMS13	Standard Railroad Grade Crossing
		ATMS14	Advanced Railroad Grade Crossing
		ATMS15	Railroad Operations Coordination
		ATMS16	Parking Facility Management
		ATMS17	Regional Parking Management
		ATMS18	Reversible Lane Management
		ATMS19	Speed Monitoring
2 Public Transportation Management		**Public Transportation**	
2.1	Public Transportation Management	APTS1	Transit Vehicle Tracking
2.2	En-Route Transit Information	APTS2	Transit Fixed-Route Operations
2.3	Personalized Public Transit	APTS3	Demand Response Transit Operations
2.4	Public Travel Security	APTS4	Transit Passenger and Fare Management
		APTS5	Transit Security
		APTS6	Transit Maintenance
		APTS7	Multimodal Coordination
		APTS8	Transit Traveler Information
3 Electronic Payment			
3.1	Electronic Payment Services	APTS4	Transit Passenger and Fare Management
4 Commercial Vehicle Operations		**Commercial Vehicle Operations**	
5 Emergency Management		**Emergency Management**	
5.1	Emergency Notification and Personal Security	EM01	Emergency Call-Taking and Dispatch
5.2	Emergency Vehicle Management	EM02	Emergency Routing
5.3	Disaster Response and Evacuation	EM03	Mayday Support
		EM04	Roadway Service Patrols
		EM05	Transportation Infrastructure Protection
		EM08	Disaster Response and Recovery
		EM09	Evacuation and Reentry Management
		EM10	Disaster Traveler Information
6 Advanced Vehicle Safety Systems		**Vehicle Safety**	
7 Information Management		**Archived Data Management**	
7.1	Archived Data Function	AD1	ITS Data Mart
		AD2	ITS Data Warehouse
		AD3	ITS Virtual Data Warehouse
8 Maintenance and Construction Management		**Maintenance & Construction**	
8.1	Maintenance and Construction Operations	MC01	Maintenance and Construction Vehicle & Equip. Tracking
		MC02	Maintenance and Construction Vehicle Maintenance
		MC03	Road Weather Data Collection
		MC04	Weather Information Processing and Distribution
		MC05	Roadway Automated Treatment
		MC06	Winter Maintenance
		MC07	Roadway Maintenance and Construction
		MC08	Work Zone Management
		MC09	Work Zone Safety Monitoring
		MC10	Maintenance and Construction Activity Coordination

As an example, Figure 3-7 provides the information flows to and from the transit management and information service provider centers from Version 5.0 of the National ITS Architecture. The figure shows information flows for route, schedule, and fare information to and from the transit management center and the information service provider center. The detailed performance specifications also provided by the National ITS Architecture for the pre-trip traveler information user service and transit traveler information market package describe what needs to be transmitted between the two centers. However, the specifications do not address who is responsible for developing and maintaining the information for

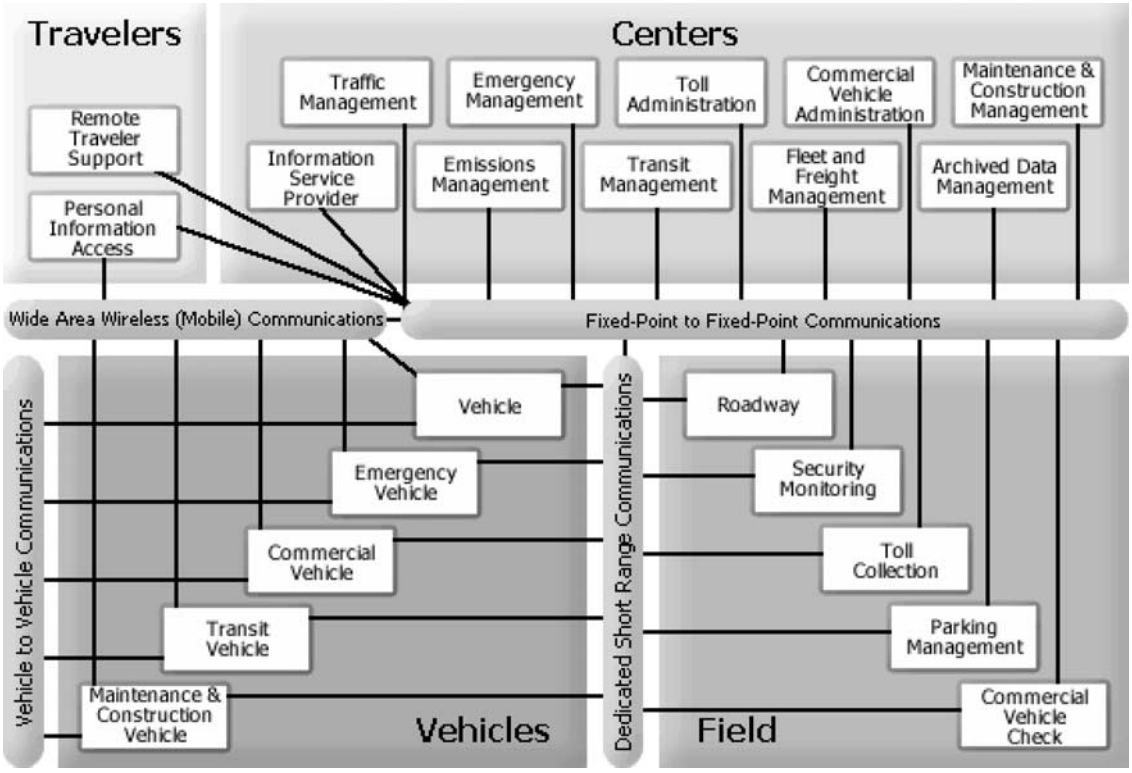

Figure 3-6. National ITS Architecture 5.0 sub-systems and connections.[32]

each center, how the information is developed, how and where it is stored, how often it is updated, how it is validated and checked, what channels of communication are used, or how the information is displayed. This additional information would have to be developed and incorporated into the e-transit reference architecture as part of assessing potential e-transit applications for data integration, website interaction and interfaces, or mobile services.

3.2 POTENTIAL INPUTS AND RESOURCES FOR DEVELOPING THE REFERENCE ENTERPRISE ARCHITECTURE

Critical to both successfully applying the systems engineering process and building the reference enterprise architecture is the identification and involvement of key stakeholders and system users who are being examined. It will also be important in Phase II to capture the advances made by pioneers in IT practices and e-commerce/e-government in transit- and transportation-related and other industries. This step will be accomplished by doing the following:

1. Carry out a review and assessment of existing literature and ongoing efforts.
2. Collect information from transit agencies on current and planned business goals and needs, organization, processes, technologies, and e-transit applications through email queries and online surveys, telephone interviews, and/or site visits.
3. Establish an advisory group of members both within and outside of the transit community to provide information and feedback throughout the life of the project. An online forum will be used to share information and facilitate discussion with this group. In addition, working group and/or focus group meetings and conference calls may be held on specific topics.

A number of related efforts by professional organizations and the federal government have already been identified. Consequently, during the project special attention will be given to initiating and maintaining the coordination and participation of these groups, including the following:

- The Transportation Research Board (TRB) committees and ongoing research from the Transit Cooperative Research Program (TCRP) and the National Cooperative Highway Research Program (NCHRP);
- The American Public Transportation Association (APTA; through its IT committee and e-visioning task force, APTA maintains an e-commerce initiative and portal: TransportMax);

[32]The National ITS Architecture Version 5.0, U.S. DOT, November 2003.

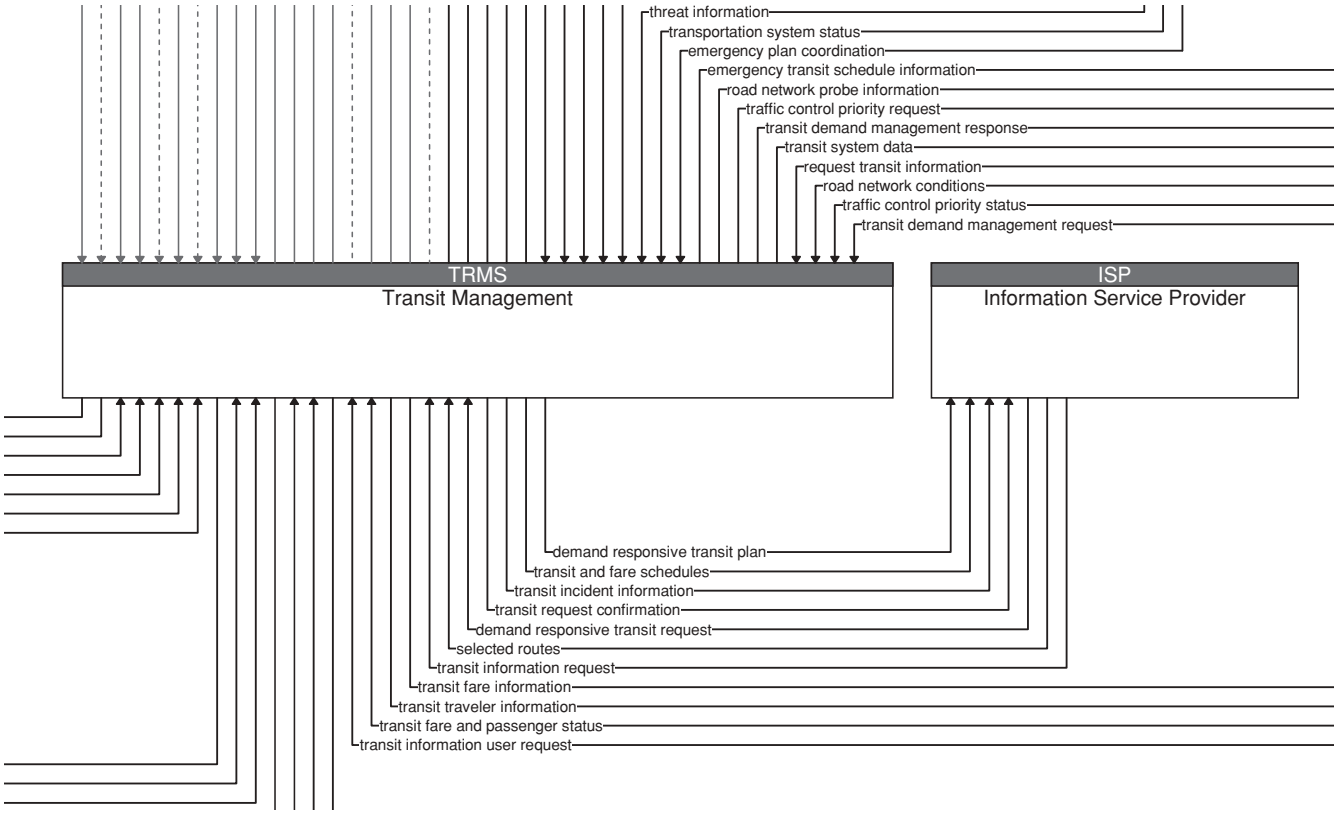

Figure 3-7. National ITS Architecture 5.0 transit management to information service provider information flows.

- ITS America forums (e.g., on public transportation, transportation operations, and planning);
- The National ITS Program efforts and products, including the ITS Transit Program (e.g., electronic payment, passenger information, transit signal priority, transit operations decision support, advanced communications, and intelligent vehicle initiative) and the National ITS Architecture and standards development efforts;
- The U.S. DOT e-government enterprise architecture managed by the DOT's chief information officer (http://cio.ost.dot.gov/index.html); and
- Homeland security activities now part of the Transportation Security Administration.

A number of transportation research results reports and sources of information directly related to the Phase II efforts have already been identified. Additional scans and literature reviews will take place early in the Phase II effort. Significant sources of information and past works that will be incorporated into the review are shown below:

- TCRP Report 84: e-Transit: Electronic Business Strategies for Public Transportation (Project J-09 report)
  - Volume 1, Supply Chain: Parts and Inventory Management (Mitretek Systems and TransTech Management, Inc., 2002)
  - Volume 2, Application Service Provider Implementation Guidelines (Mitretek Systems, 2002)
  - Volume 3, Using the Internet for Transit Training and Certification (Multisystems, Inc., with Brattle Systems, Inc., 2003)
  - Volume 4, Advanced Features of Transit Websites (Multisystems, Inc., and Matthew Coogan, 2003)
- TCRP J-08: New Paradigms for Public Transit Results
  - TCRP Report 97: Emerging New Paradigms, A Guide to Fundamental Change in Local Public Transportation Organizations (Robert Stanley et al., 2003)
  - TCRP Research Results Digest 55: Support for Fundamental Change in Public Transportation (Robert Stanley, 2002)
  - TCRP Report 58: New Paradigms for Local Public Transportation Organizations Task 5 Report: Opening the Door to Fundamental Change (Cambridge Systematics, Inc., et al., 2000)
  - TCRP Report 53: New Paradigms for Local Public Transportation Organizations Task 1 Report: Forces

and Factors That Require Consideration of New Paradigms (Cambridge Systematics, Inc., 1999)
  - TCRP Research Results Digest 24: Creating a New Future for Public Transportation: TCRP's Strategic Road Map (Richard Daft et al., 1998)
- TCRP and NCHRP IT syntheses
  - TCRP Synthesis 35: Information Technology Update for Transit (Roger Boldt, 2000)
  - TCRP Synthesis 5: Management Information Systems (Roger Boldt, 1994)
  - NCHRP Syntheses 296: Impact of New Information and Communication Technologies on Transportation Agencies (Carol A. Zimmerman et al., 2001)
- APTA products
  - IT surveys for 1999, 2002, and 2004 (pending)
  - TransportMax transit industry procurement portal (http://www.transportmax.com)
  - Annual TransITech Conference presentations and papers (2001–2004)
- Other transit industry e-business portals
  - IRail eProcurement Market Place (http://www.irail.com/pre/default.asp)
  - IBusXChange eProcurement Market Place (http://www.ibusxchange.com/pre/default.asp)
- ITS-related resources and literature
  - U.S. DOT ITS Joint Program Office Electronic Document Library for ITS-related reports and documents (http://www.its.dot.gov/itsweb/welcome.htm)
  - The National ITS Architecture Version 5.0
  - U.S. DOT ITS standards development activities for Transit Communications Interface Protocols (TCIP), and National Transportation Communications for ITS Protocol (NTCIP) for center-to-center and center-to-field ITS standards (http://www.standards.its.dot.gov/standards.htm)
- European Commission's Voyager Project. Its mission is to create a vision and make recommendations for the implementation of attractive, clean, safe, accessible, effective, efficient, and affordable European local and regional public transport systems for the year 2020 (http://www.voyager-network.org).

It will also be important to identify, collect information from, and garner participation of public agencies with recent or pioneering experience in e-transit, organizational transformation and process re-engineering, enterprise IT plans, or enterprise architectures. The APTA IT and ITS Joint Program Office annual deployment surveys will be used as sources to agencies for surveys and interviews. In addition, a preliminary list of potential candidates that have already been identified with either noteworthy e-transit applications or recent comprehensive re-engineering, IT strategic planning, or enterprise architecture efforts is as follows:

- Ann Arbor Transportation Authority (AATA; Ann Arbor, Michigan)
- Bay Area Rapid Transit District (BART; San Francisco, California)
- Central Ohio Transit Authority (Columbus, Ohio)
- Dallas Area Rapid Transit (Dallas, Texas)
- Go Transit (Toronto, Ontario)
- Hampton Roads Transit (Norfolk, Virginia)
- King County Transportation and Pierce Transit of the Puget Sound Region (Seattle, Washington)
- Los Angeles County Metropolitan Transit Authority (Los Angeles, California)
- Metropolitan Transit Authority of Harris County (Houston, Texas)
- New York City Metropolitan Transit Authority (New York City, New York)
- Portland Tri-Met (Portland, Oregon)
- Road Island Public Transportation Authority (RIPTA)
- Utah Transit Authority (Salt Lake City, Utah)
- San Diego Metropolitan Transit Development Board and the North County Transit District (San Diego, California)
- South Carolina Department of Transportation (South Carolina)
- Washington Area Metropolitan Transit Authority (WMATA; Washington, D.C.)

All have recently undergone strategic business planning and assessments or have implemented pioneering e-transit applications. For example, BART completed the first-phase tactical planning of its Business Advancement Plan (BAP) in 2002 and has requested proposals for the BAP implementation (deadline 4 January 2004). The BAP was a comprehensive assessment of transforming BART's mission, business objectives, structure, and processes to meet the demands of this century. BART has also implemented many e-transit applications for customer service, maintenance, and procurement. WMATA is also currently engaged in a comprehensive IT strategic planning initiative that is reshaping the agency's organization and functions. WMATA is also a pioneer in implementing electronic payment systems (currently moving to a multi-agency, multi-application system) and passenger information over the Internet. Also, WMATA's rail passenger e-mail major delay notification system sends out e-mail notices to subscribers based upon their origin and destination when significant delays are expected. AATA was one of the first transit authorities in the country to implement an integrated set of ITS transit services and change the way it does business to account for the new capabilities that these services enable.

New e-transit concepts are also being developed. For example, The South Carolina Department of Transportation, with the support of the Federal Transit Authority, is in the process of developing and testing a "virtual transit enterprise"

that pools the use of many applications that support the business functions of transit across traditional agency boundaries and organizations.

Last, experiences and expertise from other industries will be identified and analyzed in order to explore new opportunities for transit. Potential candidates and resources are the following:

- e-government resources
  - The e-Government Act of 2002 (www.whitehouse.gov/omb/egov/index2.html)
  - Implementation guidance for the e-Government Act of 2002 (http://www.whitehouse.gov/omb/memoranda/m03-18.pdf)
  - e-Government Journal (http://www.egovjournal.com)
  - National Science Foundation Digital Government Research Program (http://www.digitalgovernment.org/)
  - The Gartner Group e-government tracking and reports (by subscription only)
- Enterprise architecture resources
  - The Federal Enterprise Architecture Program Management Office (http://feapmo.gov/)
  - The U.S. DOT enterprise architecture development and products (http://cio.ost.dot.gov/architecture/index.html)
  - The Zachman Institute for Framework Advancement (http://www.zifa.com/)
  - The Enterprise Architecture Community (http://www.eacommunity.com/)

3.3 PROPOSED PHASE II PRODUCTS

The three major proposed Phase II products were briefly mentioned in the Chapter 1 introduction:

1. An e-transit reference enterprise architecture and model documentation;
2. Guidance on use of the reference enterprise architecture, including examples of typical applications; and
3. An online forum and e-mail exchange for identifying and discussing emerging e-transit opportunities.

Technical memorandum and summary reports will also be created to capture specific tasks and milestones as these products are created. A more detailed explanation of all of the proposed products and how they might be used is provided below.

3.3.1 e-Transit Reference Enterprise Architecture

The e-transit reference enterprise architecture will provide the context to evaluate how potential e-transit applications may affect transit's overall business and operations. The enterprise architecture provides a repository for information and relationships for business requirements, people, processes, and technologies within the organization and includes the following:

- *Business Model* (Row 1, "Planner, Conceptual," perspective of the Zachman Framework).
- *Information Architecture* (Column 1, "What, Data," Rows 1 and 2, of the Zachman Framework).
- *Applications Architecture* (Column 2, "How, Functions," Row 2, "Owner, Conceptual," of the Zachman Framework).
- *Technology Architecture* (Column 3, "Where, Network," Row 2, "Owner, Conceptual," of the Zachman Framework).

The enterprise architecture will include

- The As Is "Transit Today" base case business requirements and operations of a typical large transit agency serving a major metropolitan area,
- The To Be "Transit of the Future" vision based upon the TCRP J-08 new paradigms project results and the implementation of integrated e-transit applications, and
- A typical sequence of actions and their impacts for making the transition from the today to the future vision.

Because the enterprise architecture captures all of the information and relationships required to meet the business needs and objectives of a typical transit agency (versus focusing on one functional area or department such as IT, operations, service planning, or maintenance), it can be used to trace the cascading impacts of a new e-transit application throughout the organization and also to unveil new ways enabled by the application of meeting the business objectives and needs of the organization. For example, past system deployments have not properly accounted for the cost and effort associated with maintaining accurate schedule and route information (including detours and other modifications) and reliable customer access for Internet-based passenger information systems. The functions required to provide these services (i.e., the online information maintenance) were previously not continuous and therefore were overlooked or simply did not exist. An online passenger information system may also drastically alter the information requests, functions, daily activities, and processes of a transit agency's customer service department and call center.

The To Be "Transit of The Future" scenario will focus on the identification and incorporation of potential e-transit applications to meet the existing and proposed business objectives and requirements described in the concept of operations (e.g., recommendations of the TCRP J-08 new transit paradigms project). Evolution requirements and evaluation criteria will be developed based upon inputs from transit agencies, domain experts, and the new paradigms project. These requirements and criteria will then be used to analyze alternative e-transit applications for the To Be scenario, ways in

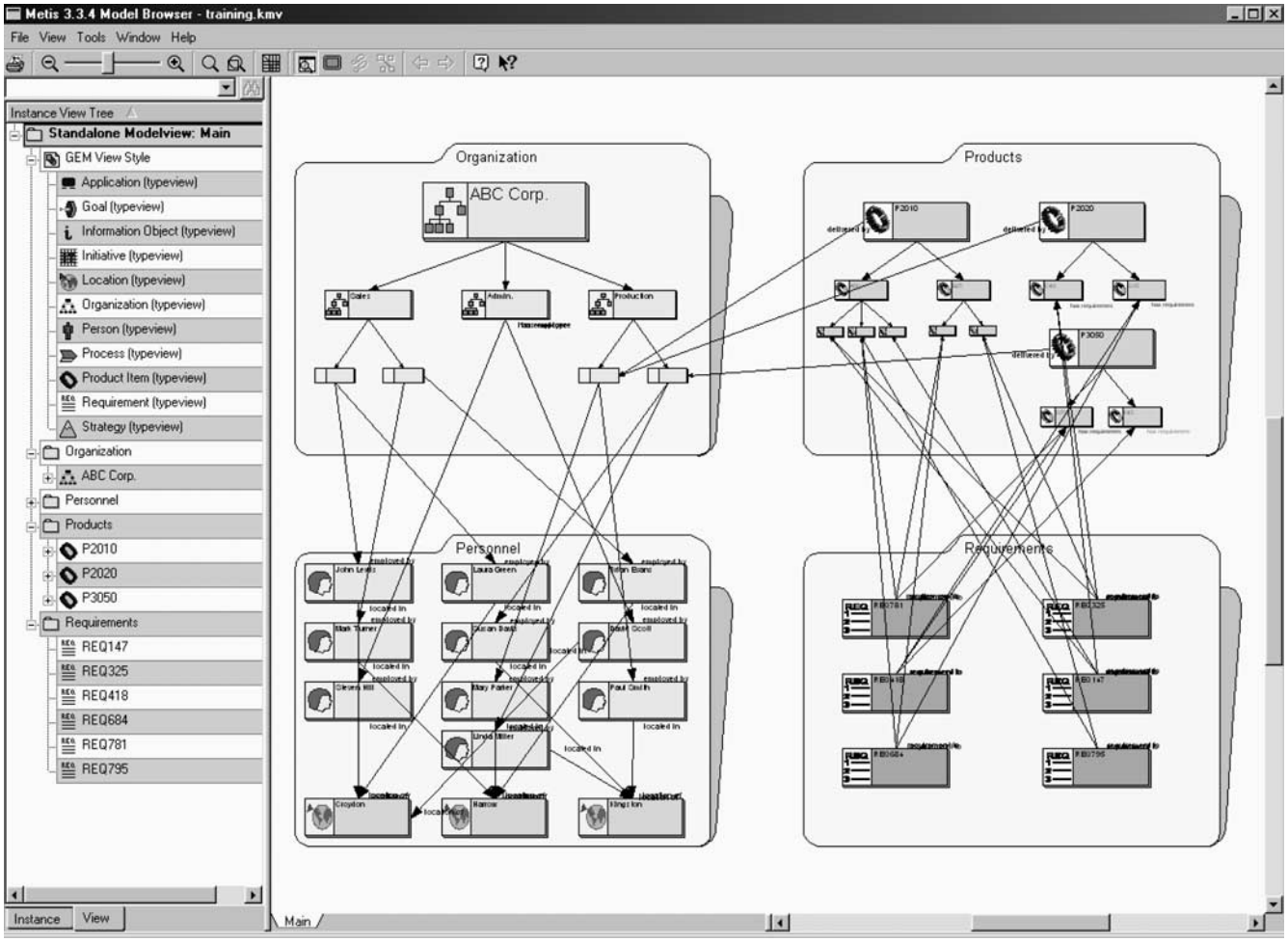

Figure 3-8. User interface and navigation bars of a commercial enterprise architecture tool.[33]

which they should be integrated with each other and the existing systems and processes, and ways in which they should be implemented. Again, implementation will include organization and process changes, as well as simply the new technologies and applications.

The e-transit reference enterprise architecture should be captured and provided using an automated tool. Figure 3-8 shows an example screen shot. The relationships between the business functions, people, processes, and technologies within the As Is and the To Be scenarios and the transition are very complex and very difficult to present in a manner that is understandable and traceable in a paper or static format. Software tools provide the ability to easily drill down to different layers of the architecture, trace relationships and their evolution between scenarios, and display the information from different perspectives.

Technical memoranda and summary reports will also be provided documenting task milestones during the development of the e-transit reference enterprise architecture. These include descriptions of e-transit state of the practices and emerging opportunities, the As Is and To Be scenarios and their concepts of operations, and an overview of the reference architecture itself.

3.3.2 e-Transit Reference Enterprise Architecture User's Guide

The e-transit reference enterprise architecture is a template-like tool that is meant to be used to identify topics in need of additional research, assess e-transit applications, plan their transition to the future, and develop their situation-specific enterprise architectures. Consequently, a user's guide that includes directions and examples for typical applications of the reference enterprise architecture is an additional major Phase II product.

The user's guide will include an introduction to enterprise architecture concepts; an overview of what is considered e-transit and how it relates to ITS, security, IT, advanced

[33]Metis by Computas.

communications, and other specialty areas; and the concepts of operation for the As Is and To Be scenarios. The guide will also provide a general process and criteria for evaluating e-transit options and their impacts using the e-transit reference enterprise architecture, describe how the architecture can be used to assess whether emerging e-concepts and applications are worth pursuing by transit as a whole, and identify topics for additional research.

It is likely that independent transit agencies will simultaneously embark upon capturing their current enterprise architecture. Guidance toward coordinated, compatible e-transit architectures will promote synergy by facilitating sharing of the best e-transit practices and reuse of e-transit applications. Figure 3-9 shows this guided evolution of a transit system's enterprise architecture.

Therefore, another key product of this effort will be guidance on how the e-transit reference enterprise architecture can be referenced or used as a starting point by a typical transit agency. The guidance will encompass both the assessment of current conditions and architecture and the development of a target enterprise architecture. The guidance will describe how to use the e-transit evaluation criteria and systems engineering processes to develop the target architecture. The target architecture will facilitate achieving the vision (and business requirements) of a transit agency through the elimination of duplication while increasing interoperability, communication, coordination, and synergy and improving value to customers. Implementing the target e-transit enterprise architecture will support integration of cost-effective technology to provide timely, high-quality transit information and services to customers, suppliers, and stakeholders. We expect to develop, in collaboration with domain experts, guidance for each step toward implementation of a transit agency's target, e-transit enterprise architecture. Representing the transition between the two and sequence of changes in bridging elements for the near term can be the core of the typical transition plan that will be provided as part of the guidance.

Supporting technical memoranda will also be provided for review and feedback by the TCRP J-09 Project Panel during the development of the user's guide. These memoranda will include draft guidance on using the e-transit reference enterprise architecture to identify national research needs and emerging e-transit opportunities and to apply the architecture to develop an agency-specific enterprise architecture for e-transit planning and assessment.

3.3.3 Online Forum and E-Mail Exchange

Because it is anticipated that e-transit opportunities, communications and information technologies, and other changes will continue to occur at a rapid rate during the life of this project, a third product will be the creation of an online forum and e-mail exchange. This product will be used to identify emerging issues and to make recommendations to the e-transit panel for additional investigation under the J-09 e-Transit Program. It will also be used to provide collaboration between the project team and the members of advisory panels from the transit and other industries participating in the project. Figure 3-10 provides an example of an online forum that was successfully used for the Federal Transit Administration and ITS Joint Program Office project on developing core functional requirements for Transit Operations Decision Support Systems (TODSS) that had very similar ongoing collaboration and feedback needs (http://www.mitretek.org/ITSTransitForums).

The forum will have the ability to control access to discussions and documents and actions (e.g., view, download, post new topics, provide feedback, and upload) based upon a user's membership and access rights. Options for hosting the online board include TRB's WebBoard (which already has an access-controlled e-transit forum), APTA's transit forums, Yahoo groups, or a contractor-provided application.

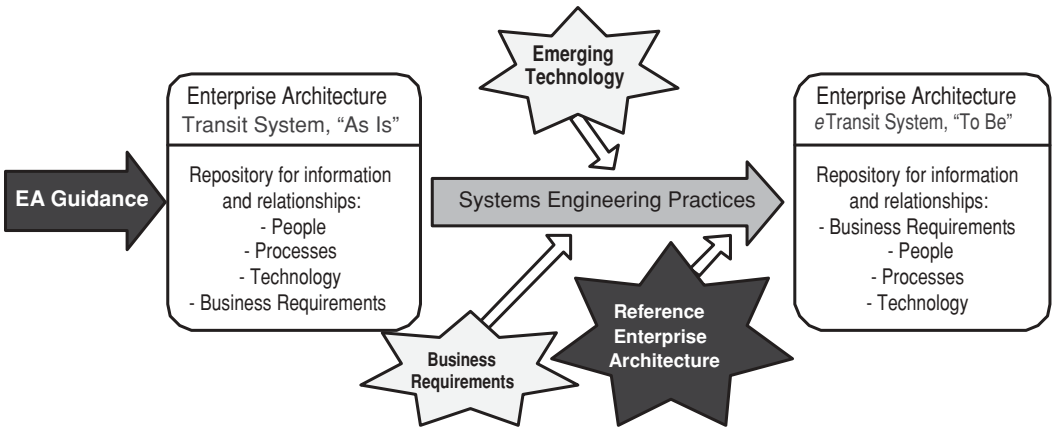

Figure 3-9. Reference enterprise architecture will guide evolution to e-transit.

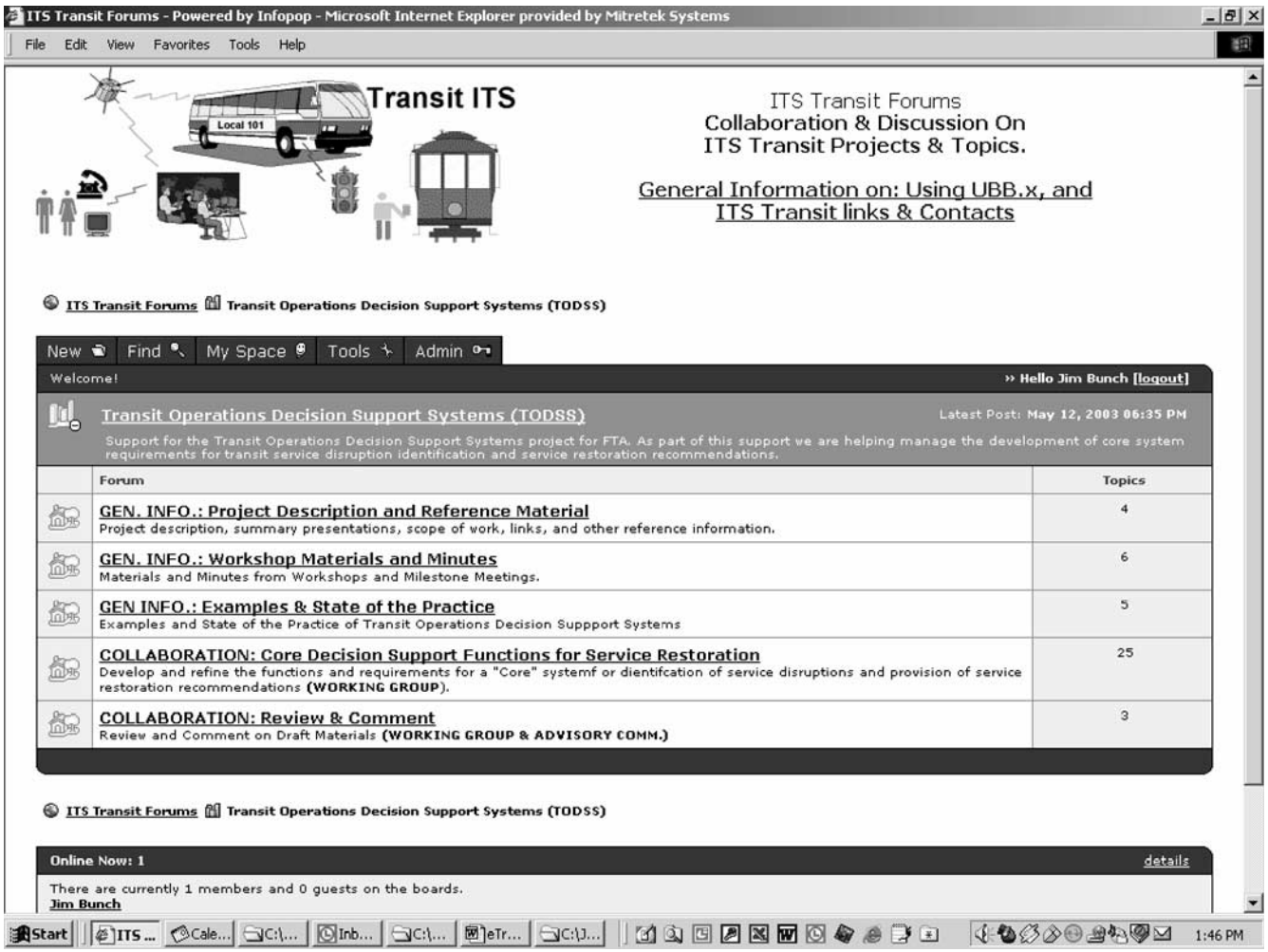

Figure 3-10. Transportation operations decision support systems online forum.

CHAPTER 4

PHASE II RESEARCH PLAN

A draft of the Phase II research plan for the development of an e-transit reference enterprise architecture is provided below. The tasks are based upon the discussion of the systems engineering process and enterprise architecture in Chapter 3. These tasks are the minimum tasks that result in a usable e-transit reference enterprise architecture.

4.1 TASK 1: PROJECT MANAGEMENT AND DETAILED RESEARCH PLAN

This task provides for all project refinement, management, and monitoring activities during the Phase II effort, including project initiation; the development of the detailed Phase II research plan, schedule, and budget; any required contract actions as called for during the project; continued monitoring of project performance; and preparation of progress reports.

The contractor will facilitate an initial kickoff meeting or conference call with the TCRP staff officer and project panel to discuss the project goals and expectations. Managers and key staff assigned to the project will participate in the kickoff meeting. The contractor will take notes and prepare a summary of the key points discussed.

The detailed research plan will provide the specific approach, methods, and deliverables for each task and provide an overall staffing plan, budget, and schedule for the Phase II effort. It will also

- Identify potential experts from transit and other industries that are candidates for participation in working groups and/or focus groups;
- Identify methods for information collection (e.g., using interviews, site visits, and survey strategies by phone, Internet, or in person); and
- Describe the approach for ongoing interaction and collaboration with the TCRP J-08 e-Transit Project Panel.

Progress reports will be prepared and delivered in a manner consistent with the TCRP procedures as modified by the overall TCRP contract for this work.

Task 1 deliverables include

- Technical Memorandum: Kickoff Meeting Summary;
- Detailed Phase II Research Plan, Costing, and Schedule; and
- Progress Reports.

4.2 TASK 2: TCRP RESEARCH DIGEST SUMMARY OF CONCEPT PAPER (OPTIONAL)

This is an optional task to be carried out at the request of the project panel and the TCRP staff officer.

The final concept paper may be useful and have merit to the transit community in and of itself. Consequently, a summary version of the final concept paper may be developed that is suitable for publication as a TRB research digest. This will also allow for timely release of the principles and concepts prior to the completion of overall effort in Phase II.

Task 2 deliverables include

- TCRP Research Digest: Concept for Development of a Reference e-Transit Enterprise Architecture Using Systems Engineering.

4.3 TASK 3: COLLABORATION FORUM AND PARTICIPANTS

As discussed in Chapter 3, a key component of this project is the participation of experts from transit, IT, and other industries. This task will therefore finalize the approaches and methods to be used for collaboration throughout the project and the online collaboration, working group, and/or focus group members who have agreed to participate in the effort. The final recommendations and participant lists will be provided as a technical memorandum.

Mitretek will establish and monitor an online collaboration forum for the project. The forum will be used to share project documents and materials, provide feedback and discussion on draft products, and discuss emerging e-transit concerns and issues. Potential options include TRB's WebBoard forums, the APTA online forums, a member-only Yahoo group, or similar tools.

Task 3 deliverables include

- Technical Memorandum: Collaboration Approach and Participants and
- Online Collaboration Forum.

4.4 TASK 4: TRANSIT INDUSTRY INFORMATION COLLECTION

This task provides for the collection and analysis of information from the transit industry. It includes

- Review of literature and ongoing parallel efforts from the transit industry,
- Final refinement of the data collection plan,
- Development of survey instruments and other collection tools,
- Collection of transit industry information, and
- Compilation and analysis of the information.

The contractor will perform a literature review that will cover the sources of information (as discussed in Chapter 3), including past TCRP reports and syntheses; the APTA IT surveys; the annual ITS deployment tracking surveys; the APTA e-business activities; papers and presentations from the annual APTA TransITech conferences; the National ITS Architecture and related standards activities; the Transportation Security Administration and FTA transit security programs; and ITS transit and e-transit activities reported in professional journals, conferences, and trade publications. Mitretek will deliver the results of the literature review in a technical memorandum that documents the e-transit state of the practice and emerging potential applications.

The contractor will update and refine the data collection plan and schedule as part of the Task 2 detailed research plan using information from the literature and parallel research review and survey instruments or other data collection tools developed. The updated plan and schedule will be provided for review in a technical memorandum. It is anticipated that the data collection may include the following:

- E-mail query/online survey (transit agencies; online forums; APTA, the Community Transit Association of America, and TRB committee members; and industry representatives);
- Transit agency phone interviews (15 to 20);
- Transit agency site visits (3 to 5); and
- Collaboration working and focus group sessions (as called for).

The e-mail query/online survey will be used to identify high-level business functions, e-transit applications, integrated services, and interactions with transit customers and the general public, other state and local agencies, the private sector, or the federal government that are part of current or planned transit operations across the country. The phone interviews, site visits, and working group/focus sessions will collect more detailed information on how the transit agency's activities are carried out.

The data collected will identify the current business functions, processes, and organizational structures found in transit agencies across the country and how they may differ by agency size, modes operated, or other characteristics. The information collection will also identify the e-transit applications being used, or planned for, by both typical and pioneering transit agencies. In addition, unique e-transit applications, examples of business process re-engineering efforts, business-oriented IT strategic planning, and/or enterprise architectures for transit agencies will be identified and captured in the analysis.

Data collection and analysis will continue as needed throughout the development of Task 6 and Task 7.

Task 4 deliverables include

- Technical Memorandum: Final Data Collection Plan, Survey Instrument(s), and Schedule and
- Technical Memorandum: e-Transit State of the Practice and Emerging Transit Applications.

4.5 TASK 5: EMERGING e-CONCEPTS

The contractor will identify existing and emerging e-business and e-government applications from other industries and evaluate their potential adaptation and use by transit to meet one of the goals of the overall J-09 e-transit project. The contractor will perform a scan and review of other industries to identify emerging e-concepts to incorporate into the To Be "Transit of the Future" scenario within the e-transit reference enterprise architecture. Special attention will be given to the industries and applications most closely related to transit, including

- Related transportation industries (e.g., air, trucking, rail, and overnight delivery services),
- Fleet management and maintenance,
- Road and bridge asset management and maintenance,
- European experiences in reinventing transit,
- Construction and project management, and
- Military logistics.

However, there are also a number of other areas where e-concepts with potential application to transit are also being developed. Examples include

- e-Government and enterprise architecture developments by other local, state, and federal agencies, especially the U.S. DOT and Transportation Security Administration enterprise architectures and e-government services;
- The medical and health insurance industries (e.g., mobile data entry, online customer services, and distance-based diagnostics);
- Trends and advances in IT and mobile computing in general; and
- The entertainment and online gaming communities (e.g., interactive collaborative applications and simulations).

The contractor will first conduct Internet searches, scans of trade publications, and a literature review. This will include reviewing material from e-government, IT, and industry-tracking online communities and e-zines, as well as searches of Gartner and other industry-tracking services. It will also include the more traditional review of reference databases, journals, and conference proceedings.

Following the literature review, the contractor will facilitate one or more focus group sessions and/or working group meetings to further explore potential concepts. These brainstorming efforts will attempt to bring experts from both transit and other industries together in a synergistic way to evaluate the concepts that have been identified and to identify new concepts.

The contractor will summarize the results of this task in a technical memorandum. A report that merges and summarizes the results from both Tasks 4 and 5 will also be produced.

Task 5 deliverables include

- Technical Memorandum: Emerging e-Concepts from Other Industries with Potential Transit Applications and
- Summary Report: e-Transit State of the Practice and Emerging Potential Applications.

4.6 TASK 6: e-TRANSIT CONCEPT OF OPERATIONS

A concept of operations is used to describe the system being developed, what the users want it to do, and how it is expected to operate. It typically includes

- Description of the system and its operating environment (e.g., boundaries),
- User needs describing what the users of the system want it to do,
- Operating policies and constraints,
- Modes of operation (e.g., normal and emergency), and
- Operational scenarios that illustrate how the system will operate.

The concept of operations, therefore, provides the highest layer, or scope and context, of the enterprise architecture.

The contractor will develop the concept of operations details that will be used as a basis for creating the e-transit reference enterprise architecture. The concept of operations refines the overview provided in Chapter 3 and includes the following:

- Definition of e-transit (finalize).
- Final description of the As Is "Transit Today" scenario. This scenario captures the business purposes, functions, and operations of a typical regional transit agency of today operating in a large urban area. The scenario may include multiple transit modes (e.g., rail, bus, and para-transit) and also have other transit agencies operating in its region.
- Final description of the To Be "Transit of the Future" scenario. The To Be "Transit of the Future" scenario implements the new operating concepts that have emerged from the TCRP J-08 new transit paradigms research that includes an integrated set of potential e-transit applications.

The contractor will provide each of the above to the project panel as technical memoranda for review and comment. Once comments have been received and incorporated, the contractor will prepare and deliver a summary report documenting the overall concept of operations.

Task 6 deliverables include

- Technical Memorandum: Overview of e-Transit Concepts and Applications,
- Technical Memorandum: e-Transit Concept of Operations for the As Is "Transit Today" Scenario,
- Technical Memorandum: e-Transit Concept of Operations for the To Be "Transit of the Future" Scenario, and
- Summary Report: e-Transit Concept of Operations.

4.7 TASK 7: e-TRANSIT REFERENCE ENTERPRISE ARCHITECTURE

This task determines the business functions and requirements, processes, information needs and transformations, interactions, interfaces, and so forth that are needed to implement the Task 6 concept of operations and represents these ideas within the e-transit reference enterprise architecture. The enterprise architecture provides a repository for information and relationships for

- Business requirements,
- People,
- Processes, and
- Technologies.

The enterprise architecture will capture the As Is "Transit Today" architecture and the sequence and impacts on the organization of making the transition to the To Be "Transit of the Future" architecture. As discussed in Section 3.1, the enterprise architecture will include a

- Business model,
- Information architecture,
- Applications architecture, and
- Technology architecture.

The contractor will

- Develop the As Is "Transit Today" business model, information architecture, applications architecture, and

technology architecture and represent them in Metis or another chosen enterprise architecture tool;
- Carry out system engineering to define the evolution requirements from the As Is "Transit Today" to the future and evaluate different system configurations and e-transit applications to get there; and
- Add the resultant To Be "Transit of the Future" business model, current systems and technologies, information architecture, applications architecture, and technology architecture to the enterprise architecture.

The resultant e-transit enterprise architecture tool will be provided to the project panel for review after the creation of the As Is "Transit Today" architecture and again when it is completed and includes the To Be "Transit of the Future" architecture. The contractor will also incorporate a sequence of steps that effect the transition. This sequence will be accompanied by model documentation describing the entities, structure, and definitions within the reference enterprise architecture. Last, the contractor will produce a summary report providing an overview of the architectures for each scenario and their concepts of operations and the reference enterprise architecture as a whole.

Task 7 deliverables include

- e-Transit Reference Enterprise Architecture captured using Metis by Computas, Systems Architect by Popkin, or an equivalent tool;
- e-Transit Reference Enterprise Architecture Model Documentation; and
- Summary Report: Overview of the e-Transit Reference Enterprise Architecture.

4.8 TASK 8: GUIDANCE ON USING THE REFERENCE e-TRANSIT ENTERPRISE ARCHITECTURE

The e-transit reference enterprise architecture is meant to be a tool, and it needs guidance and examples to be properly used. This task provides for the development of guidance in using the e-transit enterprise architecture. This includes the preparation of examples to illustrate the use of the architecture in typical applications.

The contractor will perform the following activities for this task:

1. Prepare criteria and recommendations on how to capture potential e-transit applications within the reference enterprise architecture framework.
2. Develop a typical transition strategy for implementation of the To Be "Transit of the Future" architecture that includes phasing and dependency analysis.
3. Develop draft guidance to the TCRP J-08 e-Transit Project Panel for identifying research needs and emerging opportunities. This guidance will be provided to the project panel for review as a technical memorandum.
4. Develop draft guidance for transit agency enterprise architecture development, e-transit planning, and implementation. This guidance will be provided to the project panel for review as a technical memorandum.

The end product will be an e-transit reference architecture user's guide and example applications. The user's guide shall include an introduction to enterprise architecture concepts, an overview of the definition of e-transit, the concepts of operation for the As Is and To Be scenarios captured within the e-transit reference architecture, and how to use the reference architecture for different purposes.

Task 8 deliverables include

- Technical Memorandum: Using the e-Transit Reference Enterprise Architecture to Identify Research Needs and Emerging Opportunities (Draft Guidance to TCRP Panel);
- Technical Memorandum: Using the e-Transit Reference Enterprise Architecture to develop a Transit Agency Enterprise Architecture for e-Transit Planning and Implementation (Draft Guidance to Transit Agencies); and
- e-Transit Reference Enterprise Architecture User's Guide and Example Applications.

4.9 TASK 9: RECOMMENDATIONS FOR UPDATE AND MAINTENANCE OF THE e-TRANSIT REFERENCE ARCHITECTURE

Given the rapid advances in e-transit technologies and services, the ever changing business and IT environments, and the ongoing adoption of e-transit by transit agencies, it is essential that the e-transit reference architecture be updated and maintained to ensure its continued usefulness. TCRP projects, however, are developed around fixed time frames and deliverables. If the information is to remain current, a permanent home and adoptive "parent" must be found for the project. Promising options include continued support by TCRP under the J-08 e-transit project, or as part of the J-06 Quick Response for Special Needs efforts, and APTA's IT committee. Another option is to provide for maintenance and upkeep of the reference architecture as part of a federally funded support contract or research center, such as the ITS support that contractors provide to the FHWA's ITS Joint Program Office, the Volpe Transportation Systems Center, or the University of South Florida's National Transit Institute. Each option has different advantages and disadvantages. All would require that continued funding be identified and obtained.

The contractor will identify and analyze potential options for continued maintenance and upkeep of the e-transit reference architecture. The contractor will take into consideration

potential funding opportunities, availability of knowledgeable staff and resources, organizational concerns, and other characteristics suggested by the project panel in order to rank the options and make a recommendation to TCRP. The contractor will provide summary options, analysis, and recommendations in a technical memorandum.

Task 9 deliverables include

- Technical Memorandum: Recommendations for Update and Maintenance of the e-Transit Reference Architecture.

4.10 TASK 10: FINAL PROJECT REPORT

The final project report will document the key results from all the research tasks and provide a summary of each of the major project products. Recommendations and major conclusions will also be highlighted in an executive summary of the project. An outline and draft of the final project report will be prepared and submitted in electronic format during the preparation of the final document. If requested, a briefing and/or conference call will also be provided to discuss comments of the outline and draft reports and agree upon the final report content and structure. In order to minimize the response time in preparation of the final report, a 2-week review and comment period is requested with comments being provided electronically directly to the project team. This will be modified as necessary to meet the project panel's needs and to conform to the TCRP policies and practices.

The final project report will incorporate all comments and recommendations received from the project panel. The number of copies and format will conform to the overall J-09 contract and TCRP reporting requirements as described in the TCRP "Procedural Manual for Agencies Conducting Research in the Transit Cooperative Research Program."

Task 10 deliverables include

- Final Report Project Outline,
- Draft Project Report, and
- Final Project Report.

APPENDIX

OVERVIEW OF POTENTIAL ENTERPRISE ARCHITECTURE APPLICATION TOOLS AND RECOMMENDATIONS

TOOLS TO SUPPORT e-TRANSIT REFERENCE ENTERPRISE ARCHITECTURE

Tools to support the e-transit reference enterprise architecture can be evaluated for planning and performance. Under the planning factor are sub-factors for the underlying technology of the tool, market share and third-party opinions of the tool, the relative stability of the tool as it evolves, outside investments, and functional modules or third-party add-ons. Under the performance factor are sub-factors for the tool's and other module's packaging, pricing, ease of setup, training, use, and maintenance by both systems architects and others who need to interface with the tool. Performance sub-factors include service, support, and management by the tool developer and by third-party manufacturers.

TOOL REQUIREMENTS

The requirements for tools for the development of e-transit reference enterprise architecture include the following:

- Support architecture development at the multi-enterprise level, since e-transit will involve federal, state, and local governments as well as commercial enterprises.
- Support the Office of Management and Budget concepts for architecture described in OMB 96-17. This requires the ability to represent and interrelate organizations, functions, systems, data, and infrastructure at high levels.
- Be able to drill down from higher levels to lower levels.
- Be able to depict evolution of the architecture.
- Focus on strategy and planning rather than custom software implementation.
- Support simultaneous development of the architecture by a team, which may be distributed geographically.
- Provide results that can be shared across a wide audience, either by direct access via a client or by publishing it as web pages or documents.
- Display architectural information understandable by non-technical users.
- Provide reasonably priced options for users to access, display, and view the architecture using client software, viewers, web publishing, or some other means.
- Be able to scale up and support a large, complex architecture with good performance and reliability.
- Be widely used, either within the transportation domain or by other government agencies. This provides some guarantee that the tools will continue to be supported by a vendor.

CHARACTERIZATION OF EXISTING TOOLS

There are basically three types of tools that are potential candidates: enterprise architecture tools, computer-assisted software engineering tools (CASE), and generic tools.

Enterprise Architecture Tools

Some of these tools evolved from enterprise modeling tools used for business process re-engineering; the rest are newer tools developed to directly support federal architecture efforts related to Clinger-Cohen and OMB 96-17. These tools are often oriented toward the Zachman Framework (a widely used enterprise architecture model) and may provide support for generation of OMB Exhibit 300s. They may include an IT inventory capability. These tools are based on a database that captures information about all architectural elements and their interrelationships.

In an ideal situation, the enterprise architecture is a high-level blueprint (i.e., of people, processes, technology, and their relationships) for transforming how an entity, or function that cuts across entities, operates. Coordinated enterprise architectures provide a vital means to a desired end—successful delivery of information and service to customers.

The disadvantage of these tools is that because of their heritage, they tend to be strongest on organizational and process modeling and weaker on technology modeling. They may be limited to the analysis as a single enterprise. They are often costly and require significant training and ongoing consulting help from the vendor.

Computer-Assisted Software Engineering Tools

Many existing CASE tools are being remarketed as "architecture" tools. The capabilities of these tools generally have not been expanded in any serious way to address enterprise architecture modeling. As originally designed and sold, these tools are oriented toward capturing the requirements and design for software systems. With some difficulty, they can be used to capture requirements and design of enterprises or larger systems. The intended audience for these tools is software developers, and the diagrams and output from the tools are generally less understandable to non-technical users than the products of enterprise architecture tools. These tools may be "object oriented," based on network and process analysis, or based on project management. Object-oriented tools tend to provide flexibility and scalability; however, users may be required to understand object-oriented design

concepts. Several of the object-oriented CASE tools were identified and included in the assessment for use in developing the e-transit reference enterprise architecture. Others, such as CORE by Vitech, were not part of the detailed assessment because of time and budget constraints. These tools are based on a database that captures information about requirements and design "objects" and their interrelationships.

Because a competent enterprise architecture is a high-level blueprint (i.e., of people, processes, technology, and relationships) for transforming how an entity operates, a CASE tool that manages a very detailed model of a small portion of an entity may not be appropriate to aid in the transformation of an entity. Transformation of an entity's operations requires understandable communications and coordination throughout the entity and across interfaces to related entities.

Generic Tools

Generic tools are designed to support the visual representation of process models, data models, and other diagrams. Tools like Visio are very flexible and can be used to create any sort of diagram, allowing users to create their own custom representation formats. More specific tools like BPWin for process modeling and ERWin for data modeling could be used to represent one or more aspects of the architecture.

These tools are inexpensive and widely used. Models developed in them could be easily maintained by the government. Training needs are minimal. However, these tools do not support an underlying database of architectural objects and do not provide reporting or analysis. They are not multiuser and do not support team efforts explicitly. Their flexibility and minimal training is a hidden liability. A drawing style, a modeling style, and a methodology must be imposed at the outset to effectively use the output of these tools to assemble an enterprise architecture. This is necessary so the independently created results will mesh when they are collected and presented as components of an enterprise architecture.

In assessing available tools, the contractor will focus on those that are most commonly selected for use in recent years, with special focus on the enterprise modeling tools, since they appear to provide a better fit. Tools selected for assessment against the architectural requirements include Framework by Ptech, Adaptive, Metis by Computas, Systems Architect by Popkin, Rational Rose, and Visio. Table A-1 identifies current products in each of these categories and summarizes their characteristics.

TOOLS IN USE IN THE TRANSPORTATION DOMAIN

In assessing candidates, it is worth reviewing the tools that have been developed by the U.S. DOT ITS Joint Program Office for reference and use by state and local agencies.

National ITS Architecture

The National ITS Architecture is a reference architecture for implanting the ITS user services included in the National ITS Program Plan. The current National ITS Architecture was built using the CASE tool, Teamwork (which is no longer available). It uses ITS market packages as building blocks that can be chosen to implement the ITS user services in an integrated fashion. The artifacts produced, data flow diagrams, p-specs, and entity-relationship diagrams in the case of the ITS help users understand what information flows must take place, what each stakeholder must do, and how components may be integrated for successful deployment and operation of the overall system. However, the National ITS Architecture does not address how the ITS system relates to the business objectives of an agency or the roles and

TABLE A-1 Characterization of enterprise modeling tools

Category	Enterprise Architecture	CASE	Generic Tools
Examples	- Framework by Ptech * ~ 100K - Adaptive by Adaptive, Inc. - Metis by Computas * ~ 20K - Systems Architect by Popkin * ~ 20K	- Rational Rose by IBM - Enterprise Architect by Sparx Systems - Corporate Modeler 8e by Casewise - Visible Advantage by Visible Systems	- Visio by Microsoft - BPWin by Computer Associates - ERWin by Computer Associates
Focus	Organization-level model of business, including IT as an element	Requirements and design of custom software	Visual representation of complex information
Cost Range*	$10,000 - 100,000	$1,000 - $25,000	$250 - $1,000

* Total cost is highly dependent on features, supplemental modules, training needs, staff training needs, and ongoing consultant support (sometimes onsite for days or weeks).

processes required to provide the information flows and interfaces required. As discussed in Chapter 3, the National ITS Architecture will therefore be used as a source of information for the development of the e-transit reference enterprise architecture, but is not a tool per se.

Turbo Architecture

Turbo Architecture is a tool developed under the ITS Joint Program Office Architecture Program to assist state and local entities in developing regional ITS architectures that are based upon the National ITS Architecture and that are tailored to the specific ITS user services that the entities plan to implement in their regions and their supporting concept of operations. The tool comes with a predefined set of questions designed to help identify the user services, the market packages that will be used to implement them, and the integration and information interfaces that are necessary for operations. Since Turbo Architecture was developed and tailored to specifically address the scope of the National ITS Architecture, it has limited utility and application for other uses and limited capability for extension into other layers of interaction (non-ITS processes, roles, and responsibilities) or requirements. It is also a single-user tool with limited ability to produce custom views or drill-down analyses.

TOOL COMPARISON

Table A-2 compares the above tools that meet the minimum requirements and are therefore potential candidates for use in this project. The table excludes Turbo Architecture and others that did not pass the initial screening. The degree of support for the requirement is measured on a 0–5 scale, with 5 being complete support for the requirement and 0 being no support. In some cases, the tool does not provide explicit support of the requirement, but can be used easily in a way that would be consistent with the requirement. In these cases, an asterisk is included.

TOOL SELECTION

Based upon the analysis, the use of Metis by Computas (see Figure A-1) is recommended for development of the e-transit architecture. Metis is a family of client and server

TABLE A-2 Rating of selected tools against requirements

Requirement	Framework	Adaptive	Metis	Systems Architect	Rose	Visio
Supports multi-enterprise architecture	2	5	5	5	3*	3*
Consistent with OMB 96-17	5	2	5	5	4	3*
Can drill drown from higher to lower levels	5	5	5	5	5	0
Supports depiction of evolution	1	5	5	4	1	3*
Focuses on strategy and planning	5	5	5	5	0	0
Supports simultaneous development	0	5	5	5	5	0
Produces results that can be “published”	3	5	5	5	3	5
Has information that is understandable by non-technical users	4	4	4	4	2	3*
Has a reasonable price	1	3	3	3	2	5
Is scalable	5	5	5	5	5	2
Is widely used	2	1	4	4	5	5
Unweighted sum	33	40	46	45	36	29

* The tool does not provide explicit support of the requirement, but can be used easily in a way that would be consistent with the requirement.

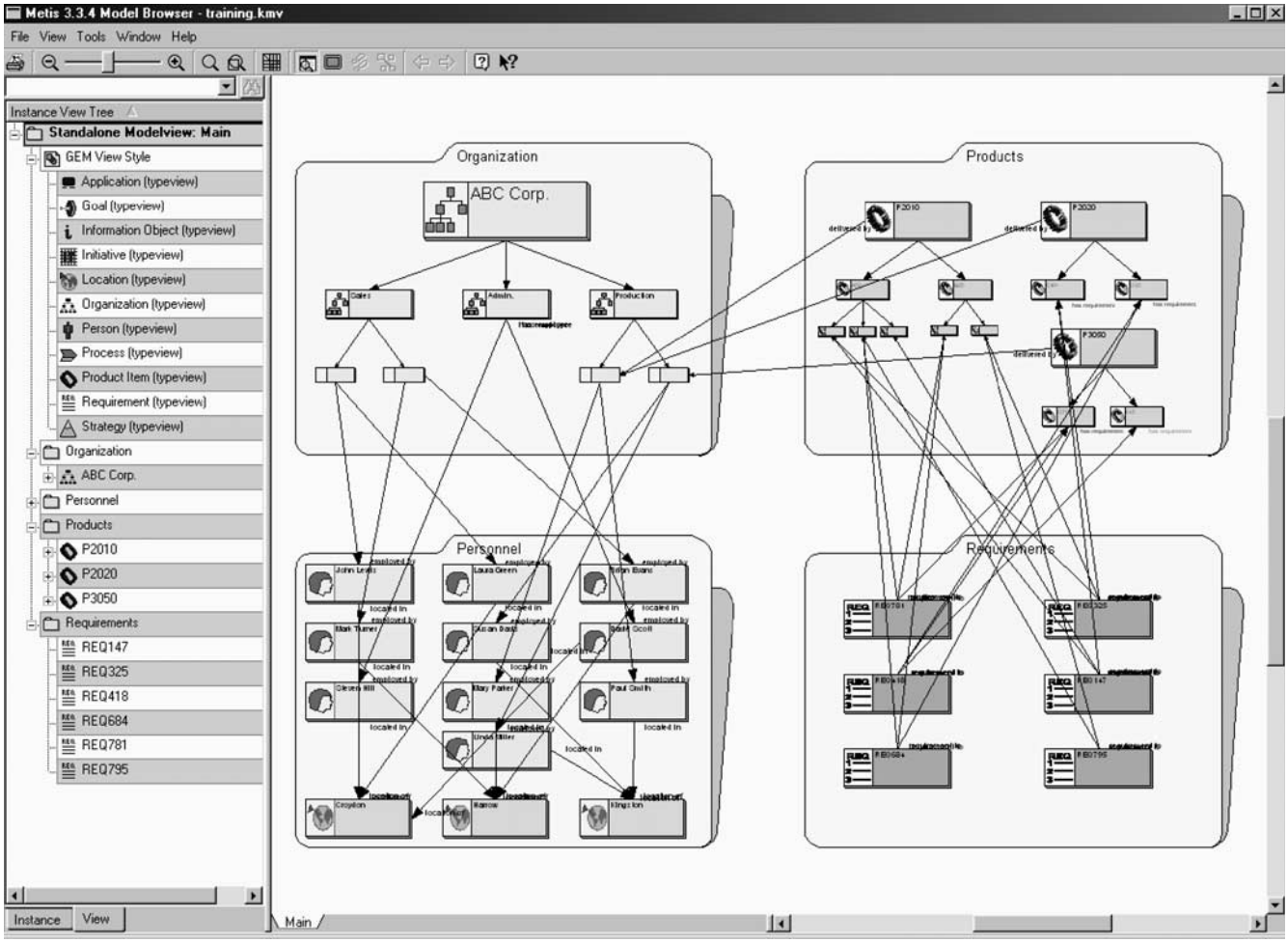

Figure A-1. Metis's model development interface with navigation tool tree on left.

products for creating, visualizing, changing, sharing, and managing visual enterprise models and comes the closest to meeting task requirements. It also has the ability to support the evolution from today to the future vision, which is an important requirement for this effort. Popkin's System Architect is also a viable candidate and has many desirable features. It, however, is very closely tied to the Zachman Framework and may be slightly less flexible than Metis. Additional tools that best meet the needs of specific tasks may also be needed for some specific parts of the research. However, regardless of how the initial research is carried out, it is recommended that Metis be used as a repository for the final results.

The following aspects of Metis make it a good choice:

- *Supports Multi-Enterprise Architectures.* Metis has a very flexible concept of organizations that supports different stakeholder groups. Its very flexible drill-down capability makes it good for capturing complex multi-enterprise architectures. For example, Metis is currently used by the Department of Commerce to maintain an architecture that spans all of the department's diverse organizational components.
- *Can Drill Down from Higher to Lower Level:* Metis supports a user-friendly drill-down capability that lets users hide details or expose them at the individual object level.
- *Supports Depiction of Evolution.* Metis has powerful support for capturing and depicting architecture evolution. Each element of the architecture can be marked as planned, operational, or in development. Designers can specify a date range when each element is valid. Viewers and designers can then filter the architecture to show only elements that are valid at a given point in time. This capability allows designers to develop an architecture that captures years of planning in a single diagram and then filter views to show what it will look like at any given point in time (e.g., in 1 or 2 years).
- *Supports Simultaneous Development.* Metis is based on a client/server architecture. The designer and editor tools access a centralized database that contains the

architecture models. Many developers can work on the architecture models simultaneously.

- *Produces Results That Can Be Published.* Metis diagrams can be printed or plotted. In addition, for $42 a set, a reviewer capability can be purchased that supports full viewing of the architecture and provides a comment capability. The viewer can be downloaded free as a trial for short-term use. Reviewers access a server-based copy that allows them to see the latest version at all times and view each other's comments.
- *Is Widely Used.* In recent years, Metis has frequently been selected over other enterprise architecture tools by federal agencies. Metis is used by the following government agencies for representation and management of enterprise architecture:
  - Environmental Protection Agency;
  - The National Oceanic and Atmospheric Administration;
  - Bureau of Engraving and Printing;
  - U.S. Department of Defense;
  - Bureau of Alcohol, Tobacco, and Firearms;
  - U.S. Mint;
  - U.S. Census Bureau;
  - Inspector General for Tax Administration; and
  - National Institute of Standards and Technology.

Metis was competitive in price with other tools—around $8,000 a set for developers and $42 a set for reviewers. This is a bigger investment than using tools like Visio or Turbo Architecture. However, the tool is likely to pay for itself in reduced development costs.

Metis does not have the weaknesses that many other enterprise architecture tools exhibit. It supports technology architecture just as well as process architecture. It appears to have been designed to support activities like e-transit.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation