ITS Technical Note
For Developing Countries

Technical Note 5

ITS System Architectures For Developing Countries



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Introduction

This *ITS Technical Note* focuses on system architectures for Intelligent Transportation Systems (ITS). As discussed in Section 1, an ITS system architecture is an extremely useful tool for helping to guide the introduction and ongoing development of ITS in a systematic and consistent manner. It provides a basic framework for planning and deploying ITS that helps to ensure sound, flexible design.

Section 2 provides a survey of important ITS system architectures in the developed world, including those of the U.S., Europe, Japan, and the International Organization for Standardization (ISO). Besides providing illustrations of successful system architectures, this information can serve as a starting point for the development of an ITS system architecture in developing countries.

Section 3 provides basic guidance on how developing countries can build their own ITS system architectures using a step-by-step approach. This process is discussed in greater detail in the ITS Toolkit.

1 Why an ITS System Architecture is Important

1.1 What is an ITS System Architecture?

A system architecture for ITS is an "overall framework for ITS" that shows the major ITS components and their interconnections. A very important part of the system architecture is the identification and description of the interfaces between major ITS components. These interfaces allow the major components of an overall intelligent transportation system to communicate with one another and to work together. Many important ITS standards are written to make these interfaces consistent.

An ITS system architecture provides a framework for planning, defining, deploying, and integrating intelligent transportation systems. An architecture defines:

- The user services that ITS systems and applications are expected to perform.
- The entities where these functions exist.
- Information flows and data flows that connect functions and entities

This may sound a little complicated, but informally an ITS system architecture describes what ITS does (the user services), where this happens (entities), and what information moves between these components (flows).

User Services
User services describe the activities that ITS systems and applications perform or support. Typical user services include providing traveler information, managing traffic, electronically collecting tolls, helping drivers perform better (especially in emergency situations), responding to traffic incidents, managing public and private vehicle fleets, etc.

Entities
Entities are physical places like traffic management centers and public transport vehicles where the user services are performed. Entities are also people, like travelers and system administrators who interact with ITS applications, send them information and receive information and services from them. Entities can also be systems, like Electronic Toll Collection (ETC) systems or Parking Ticket Management, which help to perform the ITS user services. Finally, entities can be external sources or destinations of ITS information that are not part of ITS itself. For example, the Global Positioning System (GPS) and the weather forecasting system are not themselves ITS applications or subsystems, but many ITS systems use information from GPS, and ITS systems use weather information and can also help to gather the data used in weather forecasting. A good architecture takes note of all of these kinds of entities.

Information and Data Flows
Information flows and data flows connect the user services and entities into an overall system. For example, ETC includes data flows from a vehicle (physical entity) to a toll collection system (subsystem) and from the toll collection

system to a central accounting system (external destination). Much of the value of ITS applications comes from their ability to gather, analyze, and distribute information about the transportation system. This movement of information is described as "information and data flows." The physical movement of this data is usually handled by wired or wireless communications, although some information still moves using paper and voice communications as well.

1.2 Characteristics of Successful Large Systems

First and foremost, an overall Intelligent Transportation System is a large and complex system. Because of its size and complexity and because it includes a large amount of Information Technology (IT), the successful introduction of ITS needs to be methodical and well controlled. An ITS system architecture can be very helpful in this process.

ITS as a whole is too large and complex to install all at once even in the wealthiest and most technical advanced countries. In most countries, including both developed and developing countries, the right approach is to introduce ITS gradually and in stages, focusing first on the parts of ITS that provide the greatest value in proportion to cost. Therefore, the successful introduction of ITS must include staging, and planning for change, growth, and ongoing integration as new functions are introduced and existing functions evolve.

Large-scale systems that are capable of evolving and expanding successfully have a number of desirable characteristics in common:

- Compatibility
- Expandability
- Interoperability
- Integration
- Standardization

Compatibility
Compatibility means that when software or hardware components in a system are replaced or upgraded the system will still work. Clear, consistent specifications of functionality and of the interfaces between components greatly aids compatibility. A system architecture is an important tool for achieving these clear, consistent specifications.

Expandability
Expandability means that a system can be successfully upgraded to handle greater volumes of work, operate in additional locations, or incorporate new tasks. The issues of expandability and compatibility have many points in common. Taking an ITS example, it should be easy to expand the service area of traffic control signals or enhance their functions by adding additional traffic signals and variable message signs (VMS), adding new types of equipment (e.g., environmental sensors), or upgrading the software controlling the signals. Expandability depends on many factors, including good system design and component compatibility. A system architecture can help to assure that these characteristics exist.

Interoperability
Interoperability means that two separate systems can be linked to work cooperatively and without interfering with one another. Interoperability can be an issue for multiple systems used by a single operator, but it is a much larger challenge when connecting two systems from different operators, regions, or countries. Payment systems using smart cards are an ITS example. Smart cards can be used to pay tolls, train and bus fares, and for parking. If the operators of such services can agree on technology and on administrative and financial processing issues, users will be able to use a single smart card to pay for all the services. If both systems were developed under the same overall system architecture and were developed conforming to the same standards, the likelihood of success in making the systems interoperable is greatly increased.

Integration
One approach to providing interoperability is to integrate applications into a single system. Integration is the mutual connection and harmonization of multiple systems. Integration can be an effective approach, especially when planned in advance. When a single, integrated system is built to provide multiple applications, there can be significant savings in development time, effort, and cost as compared to building each application separately. However, since a single integrated system is more complex, particular care must be taken in its planning and design. Integration of existing applications is much more difficult than building an integrated system from scratch. In either case, a common architecture, especially agreeing on interfaces can make integration much more reliable.

Standards
All of the desirable characteristics of successful large-scale systems listed above are easier to achieve if the developers and deployers make use of good standards. It is through standards that data models, interfaces, and functionality are made consistent. *ITS Technical Note 4* provides an introduction to ITS Standards for Developing Countries.

- Example: Audio/Video Architecture

Audio/video systems illustrate many of the desirable characteristics that are helpful to have in a complex system and the value of an overall system architecture.

The user services of an audio/video system are to:

- Deliver pre-recorded audio/video information and entertainment to end users.
- Deliver broadcast audio/video information and entertainment to end users.
- Amplify and play audio and video from local sources (e.g., home video camera, microphone, electric guitar)
- Locally record audio/video information and entertainment that comes from a variety of sources

The entities are

- Audio/video sources (CD and DVD players, audio and video tape players, microphones, radio and television tuners, electrical musical instruments, etc.)
- Audio/video output devices (speakers, earphones, TV displays, sound and video recorders)
- A central processing device that receives inputs and transforms them into outputs (via amplifiers, mixers, equalizers, filters, etc.)
- Interfaces (cables, plugs, and jacks) to connect the other entities together

The data and information flows are the various audio/video signals that pass through the cables between components.

This architecture has made it relatively easy to create standards for the entities and to create very flexible multimedia audio/video systems. A variety of audio/video sources can be interchangeably plugged into the system and will behave as expected. Most home audio/video systems were ready to accept CD players for music and DVD players for video even if the systems were manufactured and installed long before these players were even invented. Systems do not care about which technology was used to build speakers as long as the connectors are consistent. Similarly, video output can be a traditional TV video tube, a flat panel display, or some not-yet-invented technology, as long as the interface rules for plugs and signal characteristics are observed.

1.3 Benefits of an ITS System Architecture

The previous section described how a system architecture can help promote the inclusion of desirable characteristics in a complex, evolving system like ITS. There are a number of additional benefits which an ITS system architecture can provide. Some of the benefits come from having the system architecture. Other come out of the process of developing the system architecture. These include:

- Helping to create a national or regional vision of ITS
- Identifying and characterizing the major components of a country's planned ITS and, especially important, the interfaces between these components
- Defining a framework into which future development and expansion can be more readily fitted

Vision
One of the principal benefits of developing a national ITS system architecture is that it provides a tangible record of the country's vision for ITS. Especially if kept at a reasonably high level, the system architecture is a convenient reference for all ITS development and a regular reminder of the kind of ITS the country wants to build and maintain.

Identifying and Characterizing
The process of developing a national ITS system architecture is almost as important as the architecture which results. This process requires planners and decision makers to think carefully and systematically about the entities that are to be included in the country's ITS. An effective process includes getting the opinions and requirements of a wide range of transportation stakeholders from all parts of the country. This invariably results in a stronger and more useful architecture (and therefore a stronger and more useful ITS). It also helps to get the buy-in of these stakeholders into the overall process of introducing ITS, providing a greater base of political support and potentially financial support as well.

Framework for the Future
ITS Technical Note 3 and this ITS Technical Note advocate the creation of a "step-by-step" architecture in developing countries. This means that the architecture can be developed incrementally as new requirements become known and new solutions become available. The architecture becomes a mechanism for shaping the future of ITS in the developing country. The architecture needs to stay a few steps ahead of actual deployment, so it is clear where new development fits in. However, as the introduction of ITS proceeds, the expansion of the ITS system architecture can go before it, laying the groundwork for well-controlled, compatible, expandable, interoperable ITS.

2 ITS System Architectures Around the World

The major developed countries of the world have taken the lead in developing ITS system architectures. These include the U.S., the European Union, and Japan. Many other countries, both developed and developing, have created their own national ITS architectures based on these architectures. In addition, the International Organization for Standardization (ISO) includes a working group on ITS architecture (WG1) in its technical committee on ITS (TC204).

2.1 U.S. National ITS Architecture

The U.S. was the first country to develop a national ITS architecture, starting in the early 1990s. Although no mention of a system architecture is made in the original U.S. legislation regarding ITS (part of the Intermodal Surface Transportation Efficiency Act of 1991), ITS America was a strong proponent of a system architecture for ITS and helped to generate federal support for the effort. A large part of the initial development effort was seeking inputs from a wide range of stakeholders. The next version of the ITS legislation (in the Transportation Equity Act for the 21st Century, 1997) put great emphasis on the continuing development and use of the U.S. ITS architecture.

The architecture itself consists of a collection of user services, each with a set of requirements, a logical architecture, and a physical architecture that helps guide the development of standards.

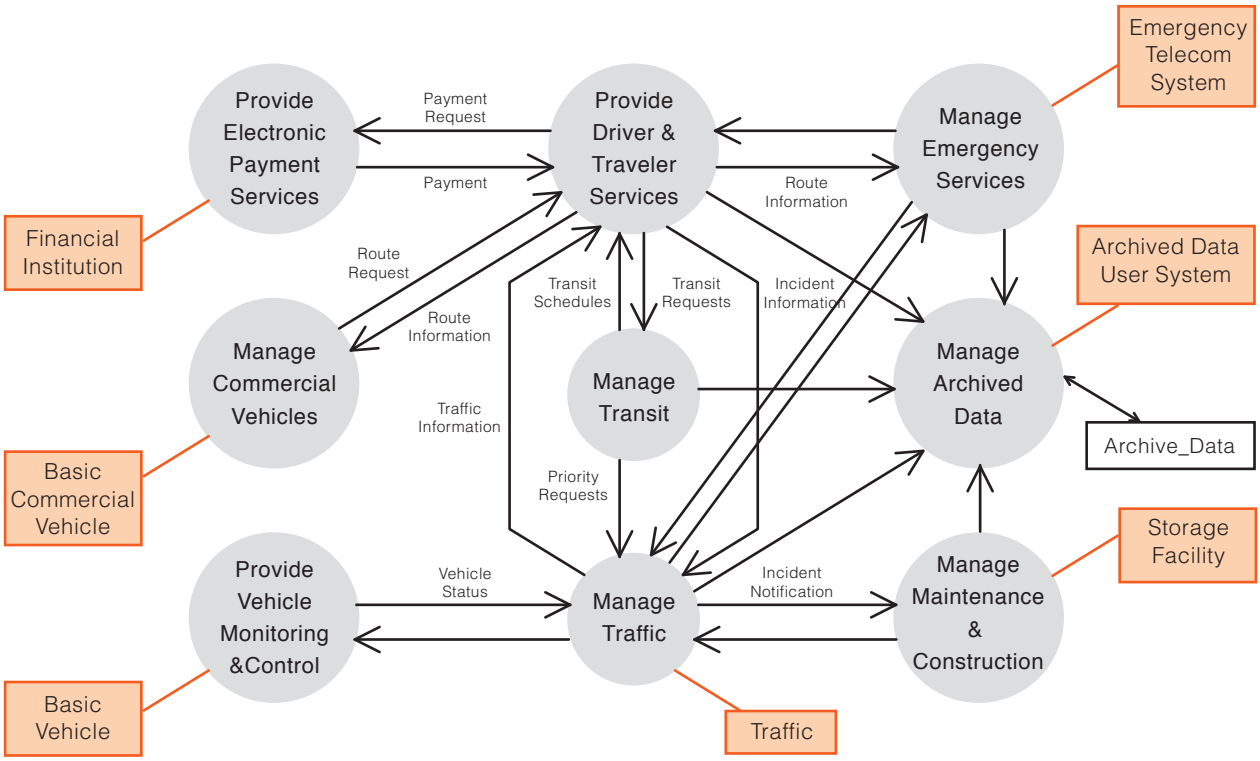
User Services
The U.S. architecture has 33 user services in eight User Service Bundles (see Table 1). There is a strong emphasis on the activities of public agencies and the operation of the infrastructure. One user service bundle relates to vehicle-oriented services. There is a commercial vehicle bundle, but it is focused on the interaction of commercial vehicles with public authorities, rather than such activities as fleet management.

User Service Bundles	User Services
1 Travel and Traffic Management	1.1 Pre-trip Travel Information
	1.2 En-route Driver Information
	1.3 Route Guidance
	1.4 Ride Matching and Reservation
	1.5 Traveler Services Information
	1.6 Traffic Control
	1.7 Incident Management
	1.8 Travel Demand Management
	1.9 Emissions Testing and Mitigation
	1.10 Highway Rail Intersection
2 Public Transportation Management	2.1 Public Transportation Management
	2.2 En-route Transit Information
	2.3 Personalized Public Transit
	2.4 Public Travel Security
3 Electronic Payment	3.1 Electronic Payment Services
4 Commercial Vehicle Operations	4.1 Commercial Vehicle Electronic Clearance
	4.2 Automated Roadside Safety Inspection
	4.3 On-board Safety and Security Monitoring
	4.4 Commercial Vehicle Administrative Processes
	4.5 Hazardous Material Security and Incident Response
	4.6 Freight Mobility
5 Emergency Management	5.1 Emergency Notification and Personal Security
	5.2 Emergency Vehicle Management
	5.3 Disaster Response And Evacuation
6 Advanced Vehicle Safety Systems	6.1 Longitudinal Collision Avoidance
	6.2 Lateral Collision Avoidance
	6.3 Intersection Collision Avoidance
	6.4 Vision Enhancement for Crash Avoidance
	6.5 Safety Readiness
	6.6 Pre-crash Restraint Deployment
	6.7 Automated Vehicle Operation
7 Information Management	7.1 Archived Data Function
8 Maintenance & Construction Management	8.1 Maintenance & Construction Operations

Table 1 U.S. National ITS Architecture User Services

•Logical Architecture

The logical architecture illustrates the ITS system architecture at many levels of detail. The logical architecture aims to explain the configuration of services, without worrying about how it will get done. The logical architecture takes the form of a series of data flow diagrams (DFDs) which depict logical processes (shown as circles), entities (rectangles), data flows (arrows), and data stores (logical data files, shown as a name between parallel lines). Figure 1 shows the very highest level DFD for the U.S. logical architecture. Each of the processes (circles) is then blown up into an entire DFD of its own, with additional lower level detail. This refinement continues for a number of levels.

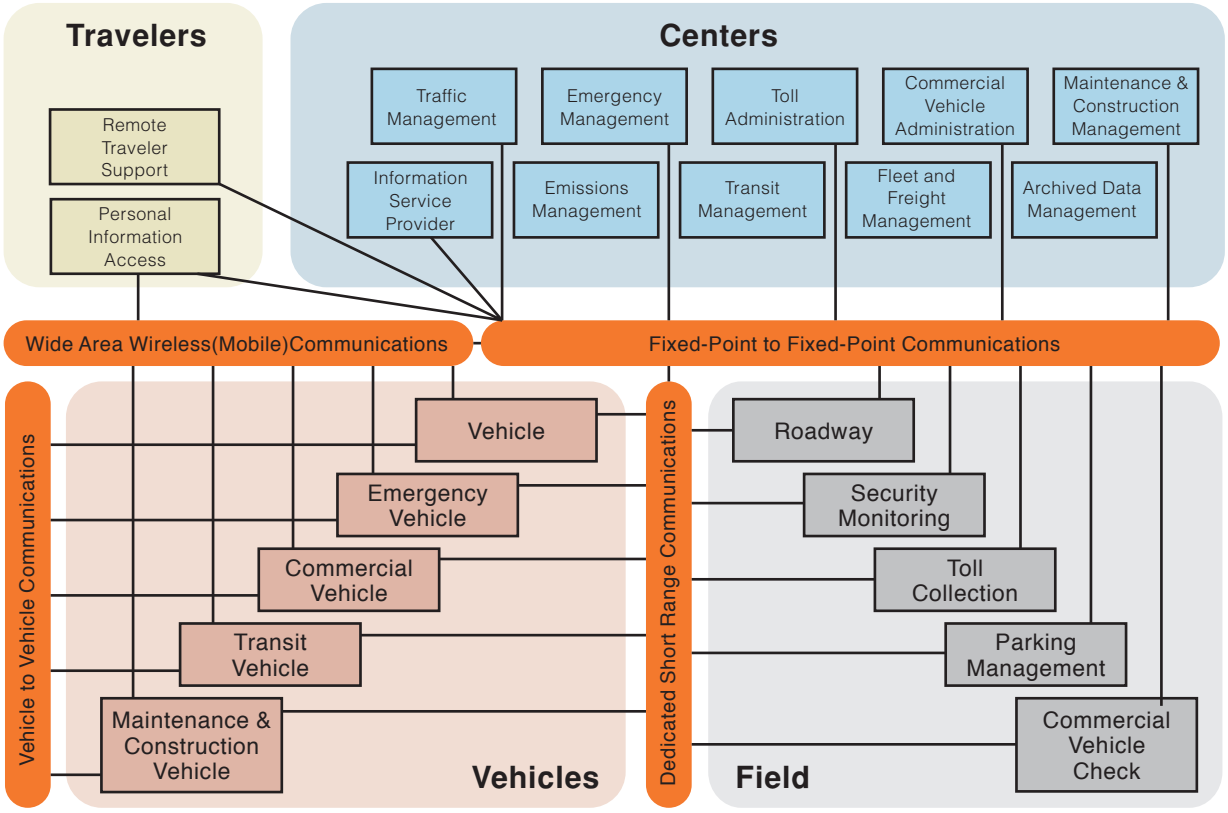


http://www.iteris.com/itsarch/html/glossary/glossary.html entry on “Data Flow Diagrams”

Figure 1 Very High Level Logical Architecture of the U.S. National ITS Architecture

•Physical Architecture

The physical architecture is a physical representation of the important ITS interfaces and major system components. The principal elements in the physical architecture are entities and architecture flows that connect these entities into an overall structure. The physical architecture assigns processes from the logical architecture to subsystems, and groups data flows from the logical architecture into architecture flows. These flows and the corresponding communication requirements define the interfaces which are a main focus of ITS standards development in the U.S. (see Figure 2).



http://www.iteris.com/itsarch/html/entity/paents.html

Figure 2 High Level Physical Architecture of the U.S. National ITS Architecture

•U.S. Regional Architectures

TEA-21, the 1997 law governing surface transportation in the U.S., requires states and metropolitan areas to be in compliance with the National ITS Architecture in order to be eligible to receive federal transportation funds. The U.S. DOT (Department of Transportation) has issued rules stating that compliance means creating and using a regional ITS architecture, based on the National Architecture and adapted to local conditions. Using this regional architecture means that highway and public transport projects supported with federal funds must be developed in conformance with the regional architecture.

2.2 European ITS Framework Architecture

The European ITS Framework Architecture (informally called FRAME) is a project of the EU Directorate on Information Society Technology and is one of the key efforts of the Fifth Framework research program. FRAME, which is still in progress, will deliver a second generation architectural approach, based on the original European ITS Architecture called KAREN (for Keystone Architecture Required for European Networks). KAREN was developed in the late 1990s as one of the projects under the Fourth Framework in the area of Transport Telematics.

FRAME is not, strictly speaking, an architecture. Rather it is a framework or blueprint to help European countries and regions within countries build their own ITS architecture tailored to their particular needs. This is very similar to the experience in the U.S., in which the principal functional use of the U.S. National ITS Architecture has been to guide the development of regional architectures.

FRAME expresses an architecture from a number of viewpoints:

- User Needs to define what the stakeholders want an ITS deployment to provide in terms of services to be delivered.
- Functional Architecture defines the functionality needed by the ITS System to meet the User Needs. The Functional Architecture is composed of Functional Areas, which are further divided into Functions (see Table 2). Each area has Data flow Diagrams to show how the functions relate to each other, to Data Stores, and to the outside world through the Data flows.
- Physical Architecture describes how functions can be grouped into physical locations to form implementable Systems, taking account of any User Needs that have physical as well as functional requirements. It consists of a series of “Example Systems” and provides a methodology for deployment and implementation.
- Communications Architecture describes the

communications links needed to support physical data flows. It provides an analysis of the communications requirements for several of the "Example Systems" from the Physical Architecture, and describes current communication technologies and standards.

- Deployment Study shows how to deploy the Systems derived from the Architecture and describes ways to migrate existing systems to conform with FRAME.
- Cost Benefit Study helps predict the likely costs and benefits that can be expected from deploying the Architecture.
- Framework of Requirements Standards identifies existing standards relating to the European ITS Framework Architecture and identifies future standards needs.

Functional Areas	Functions
1. General	1.1 Architectural Properties 1.2 Data Exchange 1.3 Adaptability 1.4 Constraints 1.5 Continuity 1.6 Cost/Benefit 1.7 Expandability 1.8 Maintainability 1.9 Quality of Data Content 1.10 Robustness 1.11 Safety 1.12 Security 1.13 User Friendliness 1.14 Special Needs
2. Infrastructure Planning and Maintenance	2.1 Transport Planning Support 2.2 Infrastructure Maintenance Management
3. Law Enforcement	3.1 Policing/Enforcing Traffic Regulations
4. Financial Transactions	4.1 Electronic Financial Transactions
5. Emergency Services	5.1 Emergency Notification and Personal Security 5.2 Emergency Vehicle Management 5.3 Hazardous Materials and Incident Notification
6. Travel Information and Guidance	6.1 Pre-trip Information 6.2 On-trip Driver Information 6.3 Personal Information Services 6.4 Route Guidance and Navigation
7. Traffic, Incidents and Demand Management	7.1 Traffic Control 7.2 Incident Management 7.3 Demand Management 7.4 Safety Enhancements for Vulnerable Road Users 7.5 Intelligent Junctions and Links
8. Intelligent Vehicle Systems	8.1 Vision Enhancement 8.2 Automated Vehicle Operation 8.3 Longitudinal Collision Avoidance 8.4 Lateral Collision Avoidance 8.5 Safety Readiness 8.6 Pre-crash Restraint Deployment
9. Freight and Fleet Management	9.1 Commercial Vehicle Pre-Clearance 9.2 Commercial Vehicle Administrative Processes 9.3 Automated Roadside Safety Inspection 9.4 Commercial Vehicle On-Board Safety Monitoring 9.5 Commercial Fleet Management
10. Public Transport Management	10.1 Public Transport Management 10.2 Demand Responsive Public Transport 10.3 Shared Transport Management 10.4 On-Trip Public Transport Information 10.5 Public Travel Security

http://www.frame-online.net/Karen_doc/d22appf.pdf

Table 2 Functional Areas and Functions – European ITS Framework Architecture

2.3 Japanese ITS System Architecture

The Japanese ITS System Architecture was completed in 1999 through the joint efforts of five government ministries involved in ITS, in cooperation with VERTIS (now ITS Japan). The objective of the architecture is to promote:

- Efficient construction of an integrated intelligent transportation system
- A maintainable and expandable intelligent transport system
- The development of domestic and international ITS standards

The development of the Japanese ITS architecture was guided by two principles:

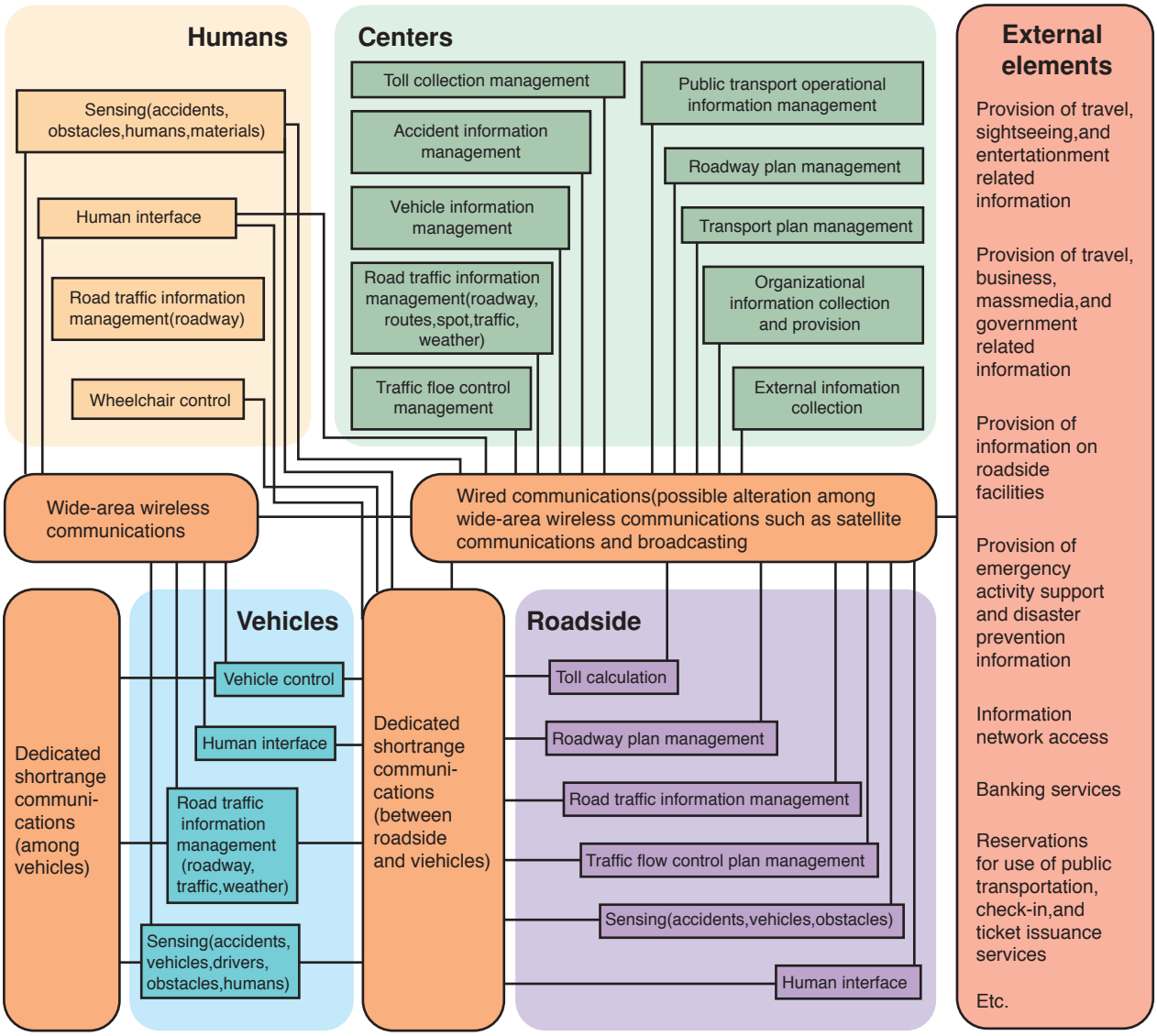
- Assuring that the architecture would be able to flexibly meet changing social needs and evolving technology
- Assuring that the architecture would lead to an ITS that was interoperable and interconnectible with other parts of Japan's advanced information and telecommunications environment

Like other major national system architectures, the Japanese ITS architecture includes an enumeration of user services (see Table 3), a logical architecture, a physical architecture (see Figure 3), and areas for creating ITS standards.

Development Areas	User Services
1. Advances in navigation systems	1. Provision of route guidance traffic information 2. Provision of destination-related information
2. Electronic Toll Collection Systems	3. Electronic toll collection
3. Assistance for safe driving	4. Provision of driving and road conditions information 5. Danger warning\ 6. Assistance for driving 7. Automated highway systems
4. Optimization of traffic management	8. Optimization of traffic flow 9. Provision of traffic restriction information in case of incident
5. Increasing efficiency in road management	10. Improvement of maintenance operations 11. Management of specially permitted commercial vehicles 12. Provision of roadway hazard information
6. Support for public transport	13. Provision for public transport information 14. Assistance for public transport operations and operations management
7. Increasing efficiency in commercial vehicle operations	15. Assistance for commercial vehicle operations management 16. Automated platooning of commercial vehicles
8. Support for pedestrians	17. Pedestrian route guidance 18. Vehicle-pedestrian accident avoidance
9. Support for emergency vehicle operations	19 Automated emergency notification 20. Route guidance for emergency vehicles and support for relief activities
10. General	21. Utilization of information in the advanced information and telecommunications society

http://www.its-jp.org/english/arch_e/doc/summary.pdf

Table 3 Japanese ITS Architecture Development Areas and User Services

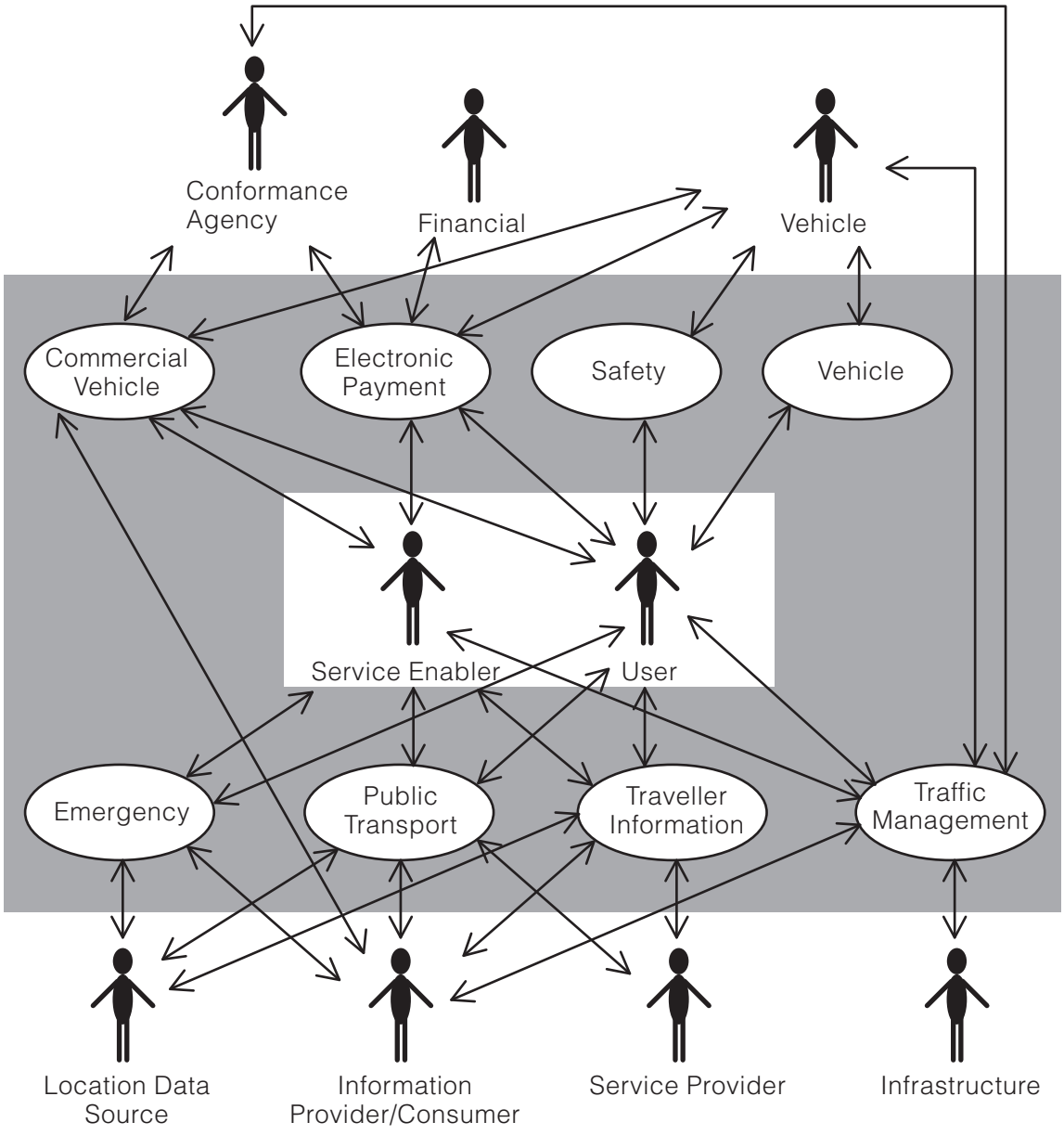


http://www.its-jp.org/english/arch_e/doc/summary.pdf, p20

Figure 3 Subsystem Interconnect Diagram from Japanese Physical ITS Architecture

2.4 ISO ITS Reference Architecture

As indicated in the previous section, one of the primary functions of an ITS architecture is to help define ITS standards, particularly at the interfaces between major ITS components. The ITS technical committee of the International Organization for Standardization (ISO/TC204) has developed an architecture that helps to define its ITS standards activities. Since it is a relatively uncomplicated architecture, it has also served as a base model for the development of other ITS architectures. The principal features of the ISO architecture are a reference model and a collection of user services. The entire architecture is available as an ISO standard, ISO 14813.



ISO/TR 14813-2:1999(E),
Reference Model Architecture — Part 2, p. 10

Figure 4 High-Level Depiction of ISO Core ITS Architecture Reference Model

The reference model is provided as a simple block diagram, as a UML (Unified Modeling Language) diagram, and as a narrative description. The highest level version of the reference architecture is shown as Figure 4.

The user services (Fundamental Services) are currently being revised into a set of Service Domains and Service Groups (see Table 4).

Service domains	Service Groups
1. Traveller Information	1.1 Pre-trip Information 1.2 On-trip Information 1.3 Travel services information 1.4 Route Guidance & navigation-Pre trip 1.5 Route guidance & navigation-On trip 1.6 Trip planning support
2. Traffic management and operations	2.1 Traffic control 2.2 Transport-related incident management 2.3 Demand management 2.4 Transport infrastructure maintenance management
3. Vehicle	3.1 Transport-related vision enhancement 3.2 Automated vehicle operation 3.3 Collision avoidance 3.4 Safety readiness 3.5 Pre-crash restraint deployment
4. Freight transport	4.1 Commercial vehicle pre-clearance 4.2 Commercial vehicle administrative processes 4.3 Automated roadside safety inspection 4.4 Commercial vehicle on-board safety monitoring 4.5 Freight transport fleet management 4.6 Intermodal information management4.7 Management and control of intermodal centres 4.8 Management of dangerous freight
5. Public transport	5.1 Public transport management 5.2 Demand responsive and shared public transport
6. Emergency	6.1 Transport related emergency notification and personal security 6.2 Emergency vehicle management 6.3 Hazardous materials & incident notification
7. Transport-related electronic payment	7.1 Transport-related electronic financial transactions 7.2 Integration of transport related electronic payment services
8. Road transport-related personal safety	8.1 Public travel security 8.2 Safety enhancements for vulnerable road users 8.3 Safety enhancements for disabled road users 8.4 Intelligent junctions and Links
9. Weather and environmental conditions monitoring	9.1 Weather monitoring 9.2 Environmental conditions monitoring
10. Disaster response management and coordination	10.1 Disaster data management10.2 Disaster response management 10.3 Coordination with emergency agencies
11. National security	11.1 Monitoring and control of suspicious vehicles 11.2 Utility or pipeline monitoring

Table 4 ISO ITS Architecture Service Domains and Service Groupings

3 ITS System Architectures for Developing Countries

3.1 Step-by-Step Architecture

Section 1 explained the benefits that can be provided by a good ITS architecture. In brief, an ITS architecture is a valuable tool for describing how ITS will work in a country and for defining its major building blocks. As Section 2 demonstrated, there are many good ITS architectures already in existence. Therefore, it is rarely necessary for a country, especially one with limited resources, to develop its own ITS architecture from scratch. It is generally faster and less expensive to start from an existing architecture and adopt it step by step to the country's requirements.

The Internet contains a great deal of information on ITS architectures, including the entire U.S. National ITS Architecture, one of the most elaborate and comprehensive. Extensive information on both the Japanese and European architectures is also available on the web. ISO TC204's architectural standard is available for purchase from ISO for a modest cost. The governments and ITS promotion organizations of developed countries are usually happy to establish cooperative efforts with developing countries that want to create an architecture of their own. All of these opportunities represent starting points for the step-by-step system architecture approach.

It is not recommended that a developing country simply adopt an existing ITS architecture without careful examination and adaptation. The process of considering the country's particular needs and of adapting the system architecture to suit these needs is a valuable undertaking of its own. It gives planners, decision makers, and developers a much better understanding of the needs for ITS and how ITS can function in their country. The process of thoughtfully adapting an ITS architecture to a country is an important ingredient for the successful introduction of ITS. Criteria for building an ITS architecture from an existing ITS architectures are: 1) Affordability. Can the selected system architecture by affordably established and maintained? 2) Regional compatability and integration. It is clear that ITS can help foster regional interoperability by integrating adjoining transport systems and by allowing technology already developed in an area to be reused. This can help to increase the efficiency of transport within an economic bloc. Using the same ITS architecture throughout the region makes integration easier and also helps to strengthen economic relationships. 3) Geopolitics. An architecture is a key element of IT-enabled transportation, and will have significant economic and social impacts. Consequently, the process for selecting an architecture may need to consider national and regional politics; and 4) Technical aspect. The selection of an architecture should keep in mind the country's technical capabilities, and not include user services that are too expensive or too technical complex for the country to undertake.

A system architecture defines the user services that planners want to deliver and presents an overall structure that can deliver these services effectively. It is a basic design scheme for ITS as a whole. ITS is an enormous program involving multiple systems, multiple stakeholders, multiple procedures for implementation, and wide-ranging effects. Developing countries will find an ITS architecture to be very beneficial, both for the design plan it produces and for the insights that come through the process of developing the architecture.

However, developing countries are likely to find it difficult and potentially too time consuming and expensive to build an ITS architecture that covers all user services of interest at once. Therefore this section focuses on a step-by-step architecture approach, which builds the architecture in stages:

- Define the user services to be provided by the ITS
- Define the processes (activities and functions) required to provide the user services (logical architecture)
- Define the physical entities (subsystems and terminators) that make up an ITS.
- Define the architecture flows that connect the subsystems and terminators (physical architecture)

Developing countries should develop their list of user services by starting from an existing set of user services that are well accepted. Some user services will not be appropriate, in whole or in part, in every country. A reasonable selection can be made by exploring the needs and priorities of the country from the local to the national level. Some considerations are:

- From the users' point of view, what systems could most usefully be introduced?
- What common data should they use?
- What data should be exchanged between systems?
- What common communications standards can be used for data exchange?
- What communications technology is appropriate for each system? What communications infrastructure is already in place?
- Where are standards needed? Of these, which are already available?

3.2 Complementary Activities

There are a number of activities which complement the development of an ITS system architecture and which lay the foundation for the successful introduction of ITS. These are:

- Developing a common data model
- Establishing communications standards.
- Using general purpose communications technology
- Promoting standardization

Developing a Common Data Model

ITS applications depend on the effective availability and use of many kinds of data, including traffic data, road system data, public transport data, weather data, tourism data, etc. This data is often created by multiple organizations and, without careful planning, it is difficult to share across organizations. When data does need to be shared among multiple organizations, a specification is needed to put the

data in a standard, mutually understandable form. It is much easier to plan for data consistency in advance than to make data consistent after individual systems are already deployed. One approach is to adopt existing data, especially elements registered in an ITS data registry like the one being developed by ISO/TC204. Another good practice is to define data models using XML (eXtensible Markup Language).

Establishing Communications Standards

Conventions for data exchange are needed for interoperability when data is collected and managed by two or more different systems. These conventions are communication standards, including data dictionaries, message set specifications, and the protocols which package information for transmission and receipt. Protocols are frequently already standardized by the communications industry, and the organizations that want to introduce ITS can focus on data dictionaries and message sets. Data dictionaries are an organized collection of data elements, which describes the meaning, format, and use of each element. Data dictionaries are very useful to help avoid duplication and misunderstanding. Message sets package the data elements into an agreed upon collection of messages.

Use of General-Purpose Communications Infrastructure

Using existing communication infrastructure reduces the time and cost to introduce ITS and accelerates the convenience and benefit delivered to ITS users. Almost all ITS applications that include wired or wireless communications can use existing communications infrastructure (e.g., Specialized Mobile Radio Services (SMRS), conventional and cellular telephones, the Internet, FM subcarrier, Digital Audio Broadcast (DAB), etc.). Many traffic information services operate through the Internet, and cellular telephone technology is often used to communicate between centers and field equipment. DAB and FM subcarrier have potential for delivering traffic information. The only cases for which ITS-specific communications infrastructure appears to be necessary are ETC, electronic truck clearance, and some emergency services.

Promoting standardization

Many aspects of ITS are being standardized to provide consistency, enlarge markets, promote competition, and enhance interoperability. There are active domestic ITS standards programs in some developed countries and a very active international program of ITS standardization which draws on these domestic programs as well as ideas from other parts of the world. *ITS Technical Note 4* discusses how developing countries can make use of existing standards and participate, in significant ways, in the development of new standards.