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Development of the Regional ITS Architecture for the San Juan Metropolitan Area

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Abstract
Several regions around the U.S. and Puerto Rico have been facing increasingly complex problems related to their transportation systems. In many cases, the use of advanced technology and strategies collectively known as Intelligent Transportation Systems (ITS) has helped to substantially improve their transportation systems. The integration of all the ITS components in a framework is called the ITS system architecture and has usually been an important part of the success.

This paper presents the methodology followed to develop the regional ITS architecture for the San Juan Metropolitan Area. Initially, the region is described including the stakeholders group and identified needs. A description of user services, operational concepts and functional requirements is then presented. These steps lead to the presentation of the system architecture based upon the National ITS architecture. At the end, the implications of the architecture in terms of planning and project development are discussed.

Keywords
ITS, Stakeholders, Market Packages

1. Introduction

Since the Sixties, the Puerto Rico Department of Transportation and Public Works have been actively looking for and implementing innovative solutions to the ever increasing problem of congestion on the highway system in the San Juan Metropolitan Area. Today, many of these solutions are widely recognized as basic elements of Intelligent Transportation Systems.

The San Juan Metropolitan Area (SJMA), as defined by the 2000 Census, consists of 30 municipalities. Of these municipalities, only six municipalities were chosen for the development of this Regional ITS Architecture on the basis of population and land area. These represent the geographic scope of the architecture. These municipalities are Bayamón, Caguas, Carolina, Guaynabo, San Juan and Toa Baja.

The combined population of these cities is 1,181,088 people and the combined area is 247.3 square miles. This represents 31 percent of the population of Puerto Rico and 7.22 percent of its area. The services to be included in the regional ITS architecture are mostly related to incident management and traffic management.

1.1 Transportation Problems in the SJMA

An assessment of average daily traffic volumes and levels of service on the major roadways was performed using the 1992 Highway Performance Monitoring System (HPMS). This indicates that numerous roadway segments are opening at, or above, capacity. Of the 90 roadway segments in the SJMA for which data are available, 36 segments are operating above capacity throughout the day, 7 segments are operating at 80 percent of capacity or more, and another 19 segments are operating between 60 and 80 percent of capacity. Only 28 segments are operating at below 60 percent of their capacity.

Given that these capacity statistics reflect average daily traffic volumes, it can be expected for the congestion to increase during peak periods when most roadway segments operate at or above capacity. The acute levels of congestion result from the following conditions:

- Concentrated population and employment densities and centralized development patterns.
- High and increasing travel demand.
- Limited capacity of the network of highways and arterial streets in the SJMA.
- Inadequate public transportation service.
- Lack of inter modal connections.
- Constrained mobility for low–income families.

The congestion and delays that characterize much of the region's transportation system have also intensified other social and environmental problems such as productivity losses, wasted energy, degraded air quality, and increased vehicular accidents.

1.2 The need for ITS in the SJMA

San Juan's transportation systems are facing significant challenges. The 1.4 million SJMA residents generate 3.4 million trips per day. These daily trips are expected to increase to 4.6 million by 2010, which represents an increase of 35 percent. This will happen as a result of a 10 percent growth in population and employment and a 10 percent increase in per capita trip making.

To meet these challenges, San Juan has recognized the need to find innovative solutions to save travelers time through enhanced traffic management, traveler information and transit services. Lives will also be saved with improved safety measures. Moreover an impact on the economic side is expected by reducing operating expenses and leveraging limited transportation funds. Advanced information and communications technologies, also known as Intelligent Transportation Systems (ITS) are among the tools necessary to meet San Juan's transportation challenges.

2. Regional Stakeholders

The process of the ITS architecture development is, to a large degree, a process of consensus building. The participation and agreement of a diverse set of local stakeholders, is critical to the success of the SJMA Regional ITS Architecture. A group of agencies were identified, because of their transportation related management or vested interest in the SJMA, as stakeholders for the development of this regional architecture.

2.1 Stakeholders Description

Puerto Rico Highway and Transportation Authority (PRHTA)

The PRHTA, under the Puerto Rico Department of Transportation and Public Works has a very complex organizational structure of its own. The PRHTA is mainly responsible for the construction and maintenance of the highway system and the Tren Urbano (metro system) in Puerto Rico. The PRHTA is also the key stakeholder in the development of the Regional ITS Architecture for the SJMA.

Metropolitan Bus Authority (MBA)

The MBA, under the Puerto Rico Department of Transportation and Public Works supervises, maintains and provides public transportation services for the SJMA.

Municipalities

The municipalities included in this project are Bayamon, Caguas, Carolina, Guaynabo, San Juan and Toa Baja. Although each municipality has its own organizational structure, their role in the development of the system is the same. These municipalities have as a short time goal the development of surveillance centers outfitted with video equipment. The main objective of these centers is to enhance public safety. At the same time these centers could contribute in incident management.

Local Emergency / Security Agencies

The Local Emergency / Security Agencies include the Fire Department, Emergency Medical Services, 911 and the Police Department. Within this group, the Police Department is probably the most important. The Police Department has the faculty by law to redirect traffic, implement strategies of traffic displacement, etc. Also it will have permanent presence in the PRHTA TMC.

Research Groups

Within this group are included all agencies public and private with some access to the data archives collected by the PRHTA TMC. An example of these groups is the University of Puerto Rico.

3. ITS Inventory

The process of gathering information about the ITS inventory for the SJMA consisted of distributing questionnaires, exchanging phone calls, conducting meetings and workshops, and reviewing documents to establish existing ITS elements in the region. The questionnaires were based on the National ITS Architecture TurboArchitecture ^{TM} software package. The following topics were addressed:

- Archived Data Management
- Emergency Management
- Electronic Tolling
- Freeway Management
- Maintenance and Construction Operations
- Public Transportation
- Regional Traveler Information
- Traffic Management

From this effort the following elements were determined to be relevant to the SJMA ITS Architecture. The subsystems and related elements pertaining to the SJMA ITS Architecture are presented in Table 3-1.

Table 3-1. SJMA ITS Architecture Subsystems and Related Elements

Subsystem	Elements
Travelers	
Remote Traveler Support	• Remote Traveler Support
Personal Information Access	• PRHTA TMC • User Personal Computing Devices
Centers	
Archive Data Management	• PRHTA TMC
Traffic Management	• PRHTA TMC
Emergency Management	• Emergency Management System (Local Emergency / Security Agencies) • Surveillance Center
Toll Administration	• Toll Roads
Maintenance and Construction Management	• Toll Roads
Information Service Provider	• PRHTA TMC • Media (private and public agencies)
Transit Management	• Transit Management System
Vehicles	
Transit Vehicle	• Vehicles
Emergency Vehicle	• Vehicles
Maintenance and Construction Vehicle	• Vehicles
Vehicle	• Vehicles (including probe vehicles, maintenance and construction vehicles, and service patrol)
Field	
Roadway	• PRHTA TMC • Roadside Equipment
Security Monitoring	• Security Monitoring Field Equipment
Toll Collection	• Toll Roads

4. User Needs and Services

The identification of needs provides the essential framework for architectural development at the highest level. As established before, the San Juan Metropolitan Area has recognized the need to find solutions to save travelers time through enhanced traffic management, traveler information and transit services. This analysis helped to identify the gaps between existing systems and future needs. The needs were identified through interviews, meetings and knowledge from the project's team. To help with organized project development, the needs were categorized by ITS User Services. The National ITS Architecture Version 5.0 grouped the ITS User Services into eight User Services Bundles for convenience. Some of these bundles and some of the needs associated with each bundle follow.

Service Bundle: *Travel and Traffic Management*

Related Needs:

- Specialized maintenance for DMS, CCTV and communication media such as fiber optics and central software system
- Provide system wide arterial management strategies
- Develop access management plans/strategies (signal spacing)
- Improve traffic flow monitoring
- Provide more widespread centralized computer control
- Improve or implement ability to remotely modify signal timing
- Reduce emergency vehicle delays at signals
- Improve inter-jurisdictional continuity
- Upgrade signal hardware
- Implement or improve signal coordination
- Better management periods of high traffic demand in poor roadway conditions
- Provide quality real time congestion related information
- Communicate with adjacent cities
- EVP/ITS and AVL/ITS interconnect

Service Bundle: *Public Transportation Management*

Related Needs:

- Improve regional trip planning
- Improve patron safety (in-vehicle and at stations)
- Provide transit priority at signals
- Enable dissemination/display of bus arrival times

Service Bundle: *Electronic Payment*

Related Needs:

- Capability for vehicle operators to pay tolls without stopping their vehicles
- Provide confirmation of the toll collection transaction to each customer
- Identify those vehicles and/or operators that violate the toll collection process

Service Bundle: *Emergency Management*

Related Needs:

- Automatic notification of declines in traffic flow
- Provide alternate route plans
- Increase broad understanding of existing incident management procedures
- Improve incidents response coordination between agencies
- Improve incidents detection
- Provide quality real time congestion information
- Improve traveler information during incidents
- Involve in decision process regarding potential diversion of traffic on or off the toll roads
- Notify public if tolls are waived/resumed
- Notify if completed or under-construction projects can be affected
- Real time info to review closures, congestion, incidents

Service Bundle: *Information Management*

Related Needs:

- Provide a Historical Data Archive system for ITS data
- Include a function to ensure integrity of operational data as received from field equipment or data collection devices
- Import ITS operational data from ITS Operational Repositories
- Import ITS Freeway Operations data including traffic flow surveillance data, visual and video surveillance data, freeway flow metrics, electronic toll collection data, etc.

Service Bundle: *Maintenance and Construction Operations*

Related Needs:

- Provide AVL for MCO vehicles
- Improve work zone TTC
- Improve detection and removal of dangerous trash barrier on roadways
- Improve coordination of constructions notification and information distribution
- Improve fleet information and management
- Coordinate traffic control plans between jurisdictions
- Increase use of portable control devices
- Provide real time congestion information
- Improve traveler information
- Need to both receive and disseminate advanced notice of construction and maintenance projects, closures and other issues that affect drivers
- Need to monitor weather and construction progress
- Ability to track maintenance vehicles
- Up to date (via web site) information to review closures, congestion, incidents, etc.

Service Bundle: *Regional Traveler Information*

Related Needs:

- Provide real time congestion information
- Expand traveler information delivery methods
- Use public cable TV to disseminate traffic information
- Improve procedure to obtain information
- Provide information to private information service providers
- Better road construction information
- Provide en-route traveler information
- Provide traveler information through Internet

5. Operational Concept

The operational concept documents the current and future roles of the stakeholders. Moreover, it defines their responsibilities in the implementation and operation of the regional system.

Once the User Services have been defined, market packages can be assigned to address the needs defined previously. Within these market packages the roles and responsibilities of the stakeholders and/or the operational concept is defined.

5.1 Market Packages

The market packages provide an accessible, service-oriented perspective to the Regional ITS Architecture. They are tailored to fit, separately or in combination, real world transportation problems and needs that have previously been identified. Market packages collect together one or more equipment packages that must work together to deliver a given transportation service and the architecture flows that connect them and other important external systems. In other words, they identify the pieces of the physical architecture that are required to implement a particular transportation service. Table 5-1 represents a listing of selected market packages from the National Architecture Version 5.0 as they apply to the SJMA Regional ITS Architecture.

Table 6-1: Market Packages Summary

Archived Data Management	
AD1	ITS Data Mart
AD2	ITS Data Warehouse
Transit Services	
APTS1	Transit Vehicle Tracking
APTS4	Transit Passenger and Fare Management
APTS5	Transit Security
APTS6	Transit Maintenance
APTS7	Multi-modal Coordination
APTS8	Transit Traveler Information
Traveler Information	
ATIS1	Broadcast Traveler Information
Freeway Management	
ATMS01	Network Surveillance
ATMS02	Probe Surveillance
ATMS06	Traffic Information Dissemination
ATMS07	Regional Traffic Control
ATMS18	Reversible Lane Management
ATMS19	Speed Monitoring
ATMS21	Roadway Closure Management
Surface Street Management	
ATMS01	Network Surveillance
ATMS03	Surface Street Control
ATMS06	Traffic Information Dissemination
ATMS07	Regional Traffic Control
Incident Management	
ATMS08	Traffic Incident Management System
ATMS09	Traffic Forecast and Demand Management
Electronic Toll Collection	
ATMS10	Electronic Toll Collection
Emergency Management	
EMS01	Emergency Call-Taking and Dispatch
EMS02	Emergency Routing
EMS03	Mayday Support
EMS04	Roadway Service Patrols
EMS05	Transportation Infrastructure Protection
EMS08	Disaster Response and Security
EMS10	Disaster Traveler Information
Maintenance and Construction Management	
MC01	Maintenance and Construction Vehicle and Equipment Tracking

MC02	Maintenance and Construction Vehicle Maintenance
MC07	Roadway Maintenance and Construction
MC08	Work Zone Management
MC10	Maintenance and Construction Activity Coordination

6. Functional Requirements

The needs, services and market packages and the roles of the agencies have been identified in continuing to develop the Regional ITS Architecture for the SJMA. The next step of the process is to identify the activities that are performed by the systems themselves. This can be either the existing systems or those that are planned.

7. ITS Interconnects and Architecture Flows

In this step of the process it is possible to see the outline of a framework for integrating systems to finally gather the benefits of sharing data. The framework for integration is identified and the potential flows are examined. A high level conceptual diagram, usually called a "sausage diagram", depicts the physical systems that can be interconnected in a region. Figure 7-1 shows the "sausage diagram" for the SJMA ITS Architecture. The Figure shows the potential for connectivity among different subsystems.

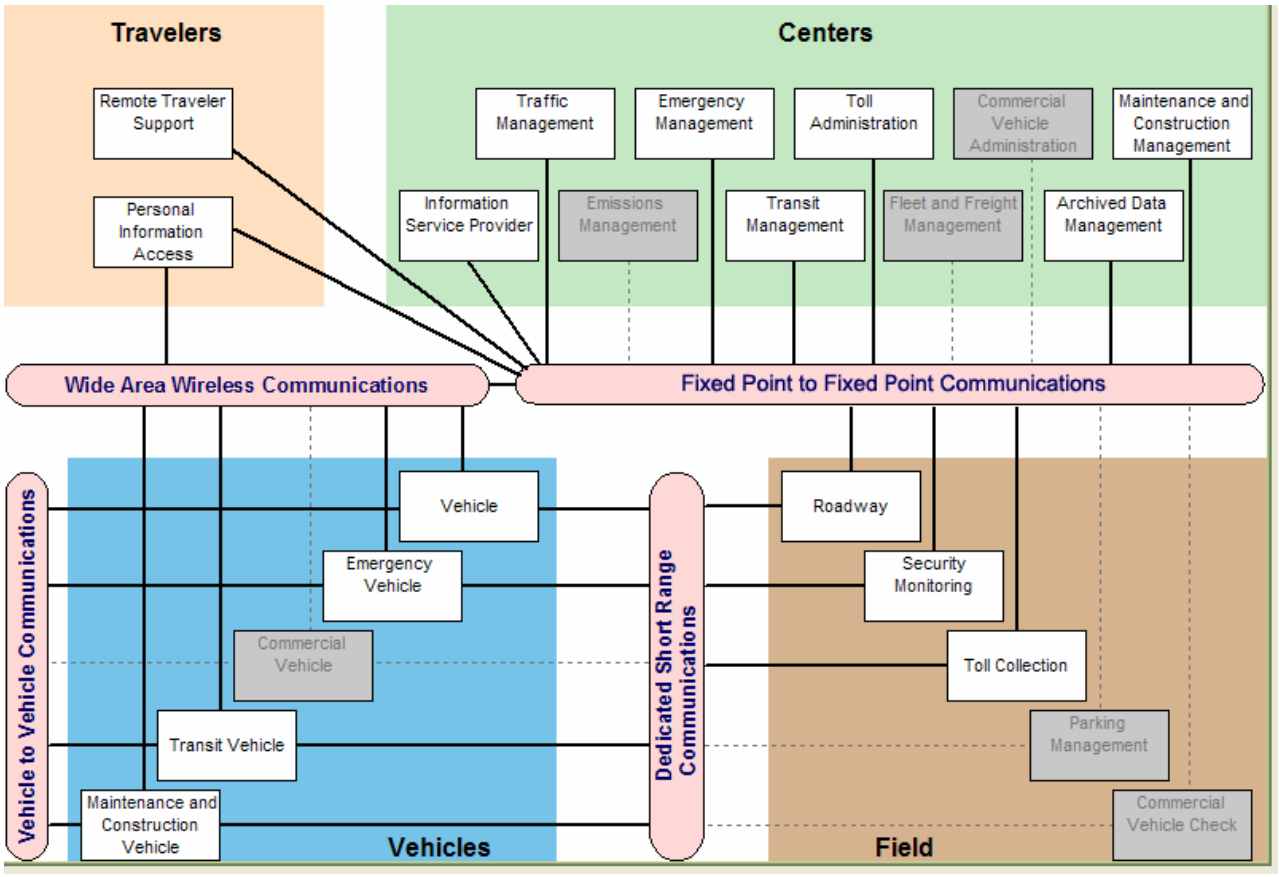

Figure 7-1 : Metropolitan ITS Architecture Subsystems

8. Project Sequencing

In this step of the regional ITS architecture development, a sequence of ITS projects that will contribute to the regional transportation system is identified. These individual ITS projects will be implemented over the years. An ITS project is defined by the FHWA as "Any project that in whole or in part funds the acquisition of technologies or systems of technologies that provide or significantly contribute to the provision of one or more ITS user services as defined in the National Architecture." Furthermore, project sequencing, according to the FHWA Regional ITS Guidance Document, represents consensus building about setting priorities that show how ITS projects can build one another.

Table 8-1 presents the listing of projects by title, stakeholder, description and expected timing of implementation. All projects are listed irrespective of whether or not they will be funded through federal sources.

9. Conclusion

The San Juan Metropolitan Area Regional ITS Architecture will serve as a cornerstone for interagency ITS coordination within the San Juan Metropolitan Area. It is intended that stakeholders will use this architecture as a resource to identify planned and existing regional ITS projects, and to see how various projects are dependent upon one another. Therefore, the Regional ITS architecture will be used to support both the planning process and the project implementation process.

10. Recommendations

The San Juan Metropolitan Area Regional ITS Architecture presented in this work, considers only six of the thirty cities in the Metropolitan Area as defined by the 2000 Census. At this time this is enough since the projects being considered for deployment in the near future are well represented within this architecture. Still as conditions in the region change and projects are considered it is recommended that this version of the architecture is revised and expanded according to the maintenance plan describe previously.

11. References

U.S. Department of Transportation, Federal Highway Administration, Federal Transit Administration. 2001. Regional ITS Architecture Guidance.

U.S. Department of Transportation, Federal Highway Administration, Federal Transit Administration. 2001. FHWA's Final Rule and FTA's Policy.

U.S. Department of Transportation, Federal Highway Administration, National ITS Architecture Team. 2004. Regional ITS Architecture Maintenance White Paper.

U.S. Department of Transportation, Federal Highway Administration. 2004 Developing and Using a Concept of Operations in Transportation Management Systems

U.S. Department of Transportation. Intelligent Transportation Systems. http://www.its.dot.gov/ Active May 2005.

Intelligent Transportation Society of America. http://www.itsa.org/ Active May 2005

Southern California Association of Governors, Southern California Regional ITS Architecture Final Version 6.0 http://www.scag.ca.gov/its/

Table 8.1 Project Sequencing

Project Title	Stakeholder	Description	Timing
Digital Map of Puerto Rico	911	Develop a map with all the possible geographical information and physical information.	S
PRHTA TMC - Highway Advisory Radio (HAR) - Dynamic Message Signs (DMS) - Camera Surveillance - Loop Detectors	PRHTA	These systems are part of Phase I on the PR-22.	S S S S
Control Aided Dispatch	Municipality of San Juan	Emergency Center Dispatch.	S
Mapping System		Accurate maps of the municipality of San Juan	S
Camera Surveillance of the Old San Juan		A Network surveillance of the old San Juan connected with the Control Aid Dispatch	S
Surveillance Center	Municipality of Bayamón	Outfitted with video equipment to enhance public safety in the Downtown Bayamón.	S
Surveillance Center	Municipality of Caguas	Outfitted with video equipment to enhance public safety in Downtown Caguas.	S
Surveillance Center	Municipality of Carolina	Outfitted with video equipment to enhance public safety in Downtown Carolina.	S
Surveillance Center	Municipality of Guaynabo	Outfitted with video equipment to enhance public safety in Downtown Guaynabo.	S
Surveillance Center	Municipality of Toa Baja	Outfitted with video equipment to enhance public safety in Downtown Toa Baja.	S
Automatic Bus Scheduling and Maintenance	MBA	Use of data available from the AVL system to develop automatic scheduling for busses and maintenance	M
Advanced Bus Information System	MBA	Display AVL and arrival info along the bus routes.	M
Tren Urbano Extensions to Caguas, Carolina, Minillas, Old San Juan, and Airport	Tren Urbano	According to the Master plan for Tren Urbano, various extensions of the system are planned using advanced technologies.	M/L

S = short term (0-5 years) M = medium term (6-10 years) L = long term (11-20 years)