

TOWARDS A NATIONAL ITS ARCHITECTURE

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1 WHAT IS ITS?

ITS stands for Intelligent Transportation Systems and it is becoming an increasingly essential tool for the transportation planner seeking to solve the complex transportation issues facing road authorities today. ITS is rapidly developing as a practical means to improve transport efficiencies, reduce accidents, improve safety and security and monitor traffic operations. Hence, Intelligent Transport Systems is synonymous with the concept of providing all forms of transportation smarter, smoother, shorter and safer than is the current situation.

Typical examples of ITS applications are

- the ability to monitor public transport operations either on a route-by-route or on an individual operator basis;
- monitoring traffic operations and improving safety by managing incidents efficiently;
- implementing a tolling strategy without the need to stop the passing vehicles;
- implementing road pricing strategies for private or heavy goods vehicles (including the ability to weigh heavy vehicles whilst the vehicle is in motion);
- enabling law enforcement agencies to monitor traffic flows using real-time information;
- improving the response time of emergency services.

In short, the ability of ITS enables the road authorities to maximise road infrastructure utilisation and optimise management and enforcement services. These services are currently being undertaken by agencies lacking sufficient resources and manpower to effect a sustainable and effective presence on the roads today.

2 WHY ITS?

As the desire for mobility increases, transport operations are becoming more complex. Funds and resources are becoming scarcer, while road user's expectations, in terms of a desire for greater information, less congestion, faster and safer public transport services, are increasing. Through the use of technological developments, ITS offers the ability to more efficiently match user needs with the abilities of road authorities to provide transportation solutions.

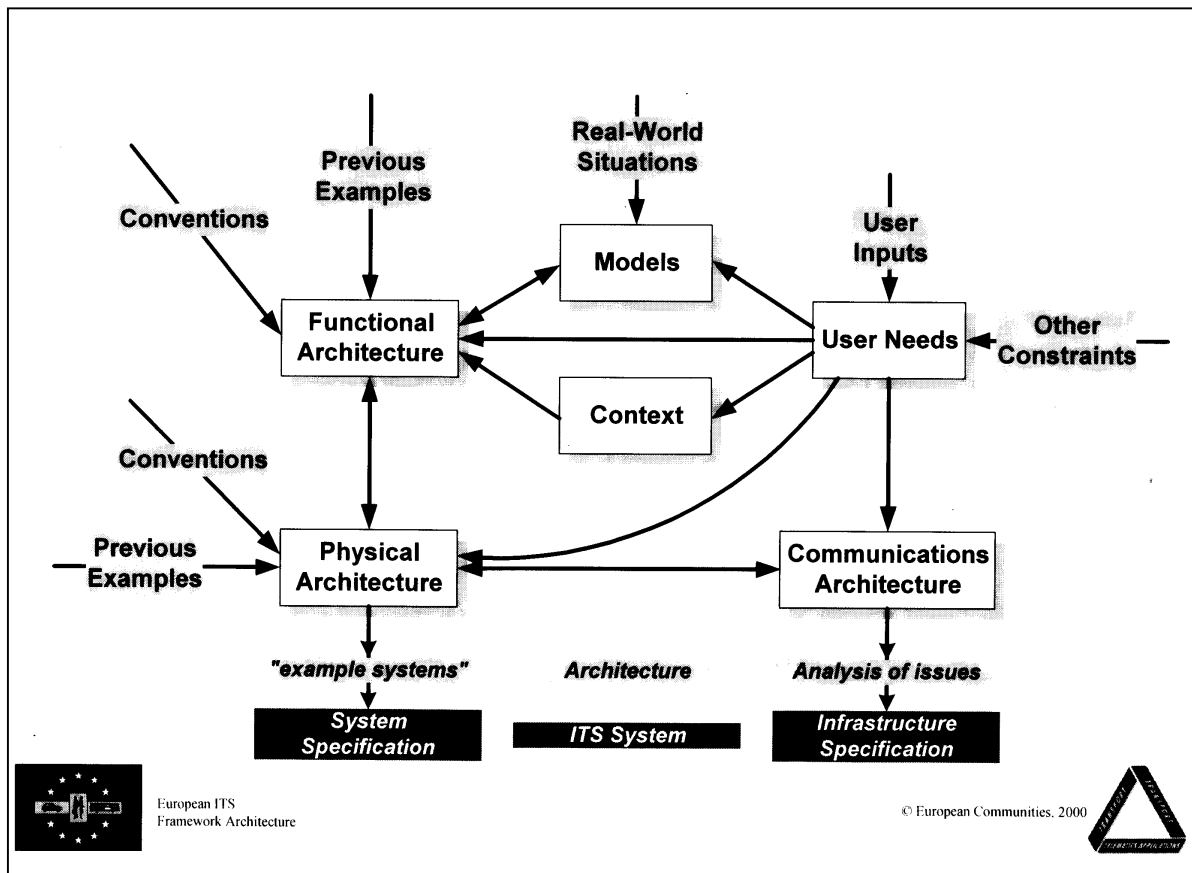
ITS offers the opportunity for road pricing and the implementation of strategies to positively influence travel demand. In the future, if transportation must move towards becoming a self-sustaining industry, ITS offers the ability to generate income and cross-subsidise essential services and infrastructure. Hence, utilising first world technology and the benefits of overseas experience, ITS has the ability to make significant, cost-effective improvements in all areas of transportation, safety and security.

3 WHAT IS AN ITS ARCHITECTURE?

Clearly, ITS can positively enhance the ability of road authorities to achieve these primary objectives, both nationally and on a regional basis. However, the complexity of user needs plus the large diversity of road and transport authorities and operators, dictates the need to co-ordinate efforts across all jurisdictional and functional boundaries, and at all levels e.g. metropolitan, provincial or national.

South Africa cannot afford to implement ad-hoc projects and miss the monetary savings and efficiencies achievable through economies of scale. There is a clear need to co-ordinate ITS initiatives and integrate all road services by fully appreciating all road users' needs and the 'a national architecture' offers a framework for planning a complete system from a strategic perspective. It can be thought of as providing the whole picture but comprising different views of the same system, depending on the needs of the user or service provider. For example, a traffic officer will require access to a different component of the architecture to that of a public transport operator or toll road concessionaire.

Hence, the ITS architecture fulfils the same role as that of a house architecture. The household architecture comprises a detailed systems design for each specific system within the whole house i.e. the electrical network, the plumbing, the lighting etc. Each different household service will require a specific design but all these individual systems must conform to the overall framework if the house is to fulfil its ultimate function. In the same way, the ITS architecture offers a complete framework to all the different users who might only require a small part of the whole. Figure 1 shows a diagram from European literature, KAREN, describing this process. KAREN will be referred to throughout this paper as it offers a sound basis from which to construct the South African architecture, without 're-inventing the wheel'.



3.1 ARCHITECTURE LEVELS

Before developing an architecture, it is important to clearly define the nature of the architecture i.e. the 'what' that is being designed. Hence, an architecture consists of the following different levels:

- Functional Architecture – the processes of the system and how the data flows between each system, or the functionality needed by the system to fulfil the User Needs.
- Physical Architecture – the actual infrastructure that performs the processes described in the functional architecture, to meet the User Needs.
- Communication Architecture – how each link between the applications in the physical architecture communicate with the applications in the outside world.
- Information Architecture – the structure of the information used by the system.
- Organisational Architecture – the respective responsibilities of the management system.

By defining all these different aspects, it is clear that the overall architecture can become a complex entity. Such diversity can lead to wasted expenditure and confusion so it is the role of the Architecture Manager to co-ordinate all activities and maintain the ultimate goal of the initiative, in much the same way a house architect supervises and maintains the overall aim of his design with the various sub-contractors.

Hence, an Architecture Framework offers:-

Compatibility and consistency of information and equipment for all users.

An open market for services and equipment so vendors may compete equally and with confidence.

Economies of scale to permit efficiencies and ease investment decisions.

A National Architecture permits road authorities to produce a master plan to facilitate ITS deployment enabling full co-operation across geographical borders and jurisdictional and functional boundaries.

4 HOW TO DEVELOP A NATIONAL ARCHITECTURE

An architecture must therefore be:

- Structured
- Technology independent, permitting evolution
- Not product, nor vendor constrained
- Based on modular input from providers/manufacturers
- Migratable from legacy systems i.e. be able to expand from existing systems.

4.1 USER NEEDS

For an architecture to be appropriate, and remain appropriate, it must be user-needs driven. Hence, the first goal is to determine USER NEEDS. There are various classes of User:

Operators want ITS to diminish congestion and improve traffic problems e.g. metro planning authorities, public transport operators, freight and fleet operators.

Commercial vendors who make ITS e.g. vehicle, software, hardware, and component manufacturers telecommunications service providers.

Users (primary and secondary) use ITS e.g. commuters (private and public), businesses, tourists, emergency services, traffic management agencies.

Agencies/Authorities rule ITS e.g. government departments, road authorities plus legal and financial administrators or agencies.

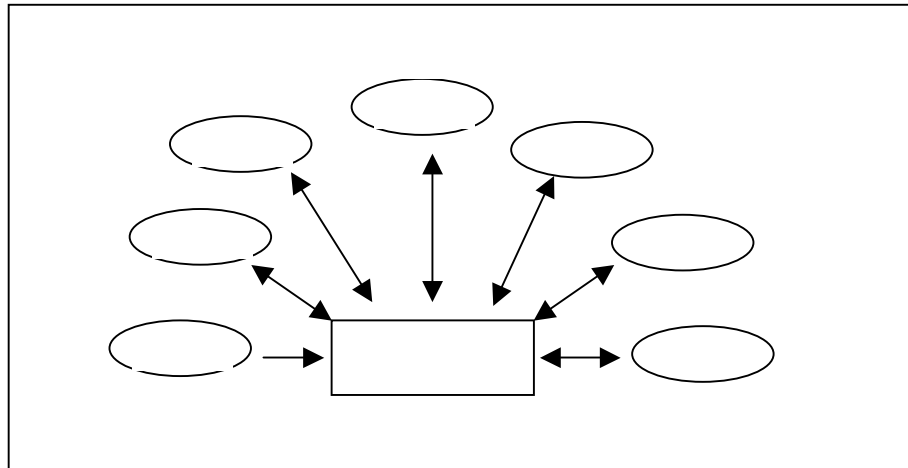
All these potential users must be approached and their needs elicited in a structured manner. However, due to the 'newness' of ITS in South Africa, there are many users with little or no knowledge of the opportunities presented by ITS for all transport users, agencies and authorities alike. Hence, this procedure of determining User Needs, must include an education and capacity building element, in order that future users can understand their needs, plus those of others, better. This procedure has been performed in great detail in Europe and America and there are a number of aids available. For example, user needs have been compiled into a number of main "User Groups" which, by definition, relate directly to the function provided by ITS, and not any design aspect of ITS. These groups, as defined by the European KAREN project, are shown below to illustrate how such needs are grouped.

1. **General** – affecting the framework architecture, performance, quality control and any constraints of role payers or systems.
2. **Infrastructure Planning and Maintenance** – long-term planning, modelling and reporting.
3. **Law Enforcement** – enforcing laws, regulations and collecting evidence.
4. **Financial Transactions** – payment for traffic and travel services, the transaction, enforcement and revenue sharing.
5. **Emergency Services** – prioritisation of vehicles, incident management, security and stolen vehicle management and the movement of hazardous goods.
6. **Travel Information** – management of pre-trip, on-trip, modal choice and route guidance.
7. **Traffic, Incidents and Demand Management** – includes traffic control, monitoring and enforcement, speed management, road pricing, access control, incident and demand management.
8. **Intelligent vehicle Systems** – on-board systems.
9. **Freight and Fleet Management** – statutory data collection, operations management, vehicle and cargo security.
10. **Public Transport Management** – on-trip information, safety and security, inter-modal commuting, public transport priority and performance management.

Clearly, a number of these are more, or less, relevant to the South African perspective. Each area will need to be developed using overseas experiences but in full cognisance of SA conditions and realities. Many of these groups have over-lapping functions and needs. Hence, it will be vital for the **Architecture Manager** to oversee this development of user needs in a precise and structured manner.

4.2 SYSTEM CONTEXT

The next stage in the architecture development process is to determine the System Context. This is the relationship between the outside world and the various systems within the architecture. Such a relationship defines what the outside world must give to the system and what the system must feed back to the outside world. This interface is defined by the use of 'Terminators' which themselves are shown in the 'Context Diagram'. A Terminator is a rigorous definition of the functionality that the outside world is expected to provide, in order that the System can deliver services and facilities required by the Users. The Context Diagram simply shows the part of the outside world with which the System must interface. An example of this is shown in a very simple format below in Figure 2.



4.3 FUNCTIONAL ARCHITECTURE

4.3.1 Defining Functions

At its highest level, the Function Architecture consists of eight Functional Areas whose purpose and activities are related. These area definitions are expressions of the area of responsibility filled by the functionality in the Area. Thus a Functional Area called “Manage Public Transport Operations” contains all the functionality for that purpose. According to KAREN, the functionality in each Functional Area is divided into high and low level functions:-

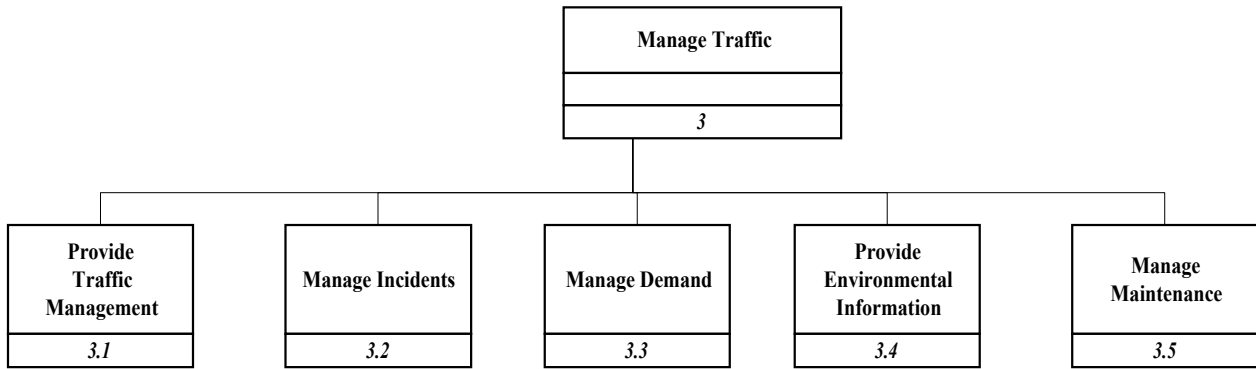
- (1) High Level Functions: The High Level Function descriptions consist of an Overview plus a list of constituent Functions. Because the Overviews can be used elsewhere, e.g. in the Physical Architecture. The High Level Functions rarely fulfil User Needs by themselves but always fulfil those covered by their constituent Low Level Functions.
- (2) Low Level Functions: These are Functions whose functionality can be described without the need for sub-division into lower level Functions. They therefore represent the lowest level of functionality in each Area. Their descriptions consist of an Overview, lists of input and output Data Flows and detailed Functional Requirements, providing details of what the Functions actually do.

KAREN describes the eight functional areas:

1. Provide Electronic Payment Facilities
2. Provide Security and Emergency Facilities
3. Manage Traffic
4. Manage Public Transport Operations
5. Provide Advanced Driver Assistance Systems
6. Provide Traveller Journey Support
7. Provide Support for Law Enforcement
8. Manage Freight and Fleet Operations

Taking functional area 3 as an example to demonstrate how the functional architecture might look, KAREN splits this into five high level functions, which are described using KAREN in Figure 3.

FIGURE 3: AN EXAMPLE OF FUNCTIONAL ARCHITECTURE



4.3.2 Components of a Functional Architecture

KAREN suggests that this High Level Function shall provide facilities for the management of traffic using the road network. It shall include functionality for managing both the urban and inter-urban parts of the network. Facilities shall be provided that enable data to be collected about the use of the road network and to provide priority for selected vehicles e.g.

Component Functions:

3.1.1 Provide Urban Traffic Management

3.1.2 Provide Inter-urban Traffic Management

To achieve these functions, User Needs are described extensively in Karen e.g.

“The system shall be able to implement identified control strategies that conform with specified policy.”

“The system shall manage road traffic in such a way that levels of environmental (i.e. atmospheric and noise) pollution may be reduced.”

“The system shall ensure that traveller information service providers are aware of the traffic management strategy, so that they can provide information that conforms to it.”

“The system shall be able to manage the urban/inter-urban interface.”

The following defines part of the **Hierarchy Diagram** for the “Provide Traffic Management” Function. It contains User Needs and Functional requirements in what is only a small component to the overall complex architecture.

4.3.3 Trace Tables

KAREN provides “Trace Tables” to assist in the complex task of linking Functions with User Needs, and an example is shown below.

Table 1 User Needs and the Functions that serve them (KAREN D3.6 A1)

User Need		Function	
Number	Description	Number	Name
2.1.1.1	The system shall be able to produce information for travellers on the traffic and travel conditions of all transport modes relevant to the geographical area covered.	3.1.1.4	Manage Urban Traffic Data
		3.1.2.4	Manage Inter-urban Traffic Data
		3.3.2	Implement Demand Management Strategy
2.1.1.3	The system shall be able to collect traffic data for road network use analysis and prediction calculations.	3.1.1.1	Collect Urban Traffic Data
		3.1.1.2	Monitor Urban Car Park Occupation
2.1.1.3	The system shall be able to collect traffic data for road network use analysis and prediction calculations.	3.1.1.4	Manage Urban Traffic Data
		3.1.2.1	Collect Inter-urban Traffic Data
		3.1.2.2	Monitor Service Area Vehicle Occupation
2.1.2.1	The system shall be able to model the road network for strategic planning calculations.	3.1.1.3	Provide Urban Traffic Forecasts and Strategies
		3.1.2.3	Provide Inter-urban Traffic Forecasts and Strategies
2.1.2.2	The system shall be able to develop and implement traffic environmental management strategies based on current and predicted traffic conditions.	3.1.1.5.1	Provide Urban Traffic Management
		3.1.2.5.1	Provide Inter-urban Traffic Management
2.1.2.3	The system shall be able to assist in the planning of (inter-modal) routes.	3.1.1.3	Provide Urban Traffic Forecasts and Strategies
		3.1.1.4	Manage Urban Traffic Data
		3.1.2.3	Provide Inter-urban Traffic Forecasts and Strategies
		3.1.2.4	Manage Inter-urban Traffic Data

This table highlights the complexity and interaction of User Needs with Functionality of the system and shows the importance of using a rigorous numbering system when preparing the functional architecture.

4.4 PHYSICAL ARCHITECTURE

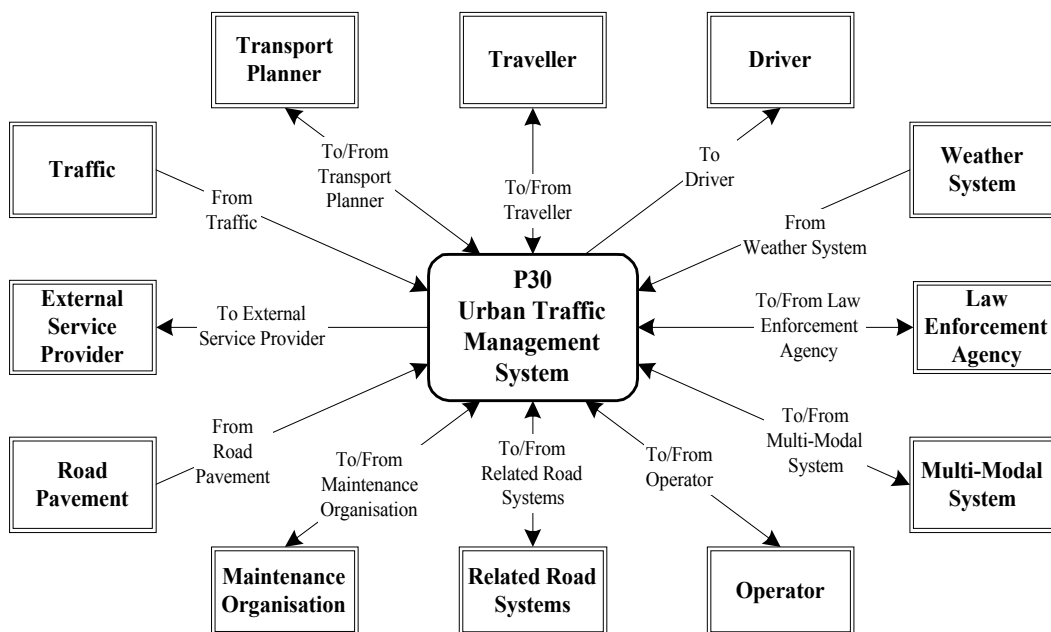
The next step in the development of an architecture is to create the Physical Architecture. This process builds on the functionality described above and groups similar functions into sub-systems. A sub-system should be unique to each physical location within the System e.g. roadside, vehicle, personal device, freight device, central and kiosk. The physical architecture must take into account any User Needs that might have physical, as opposed to functional, requirements.

4.4.1 Physical Architecture System and Sub-systems

Hence, the Physical Architecture is designed to act as a starting point for the creation of the lower level architectures and physical systems. To assist the users through the complex task of building the physical system, or sub-systems, it will be useful to describe real world examples or models.

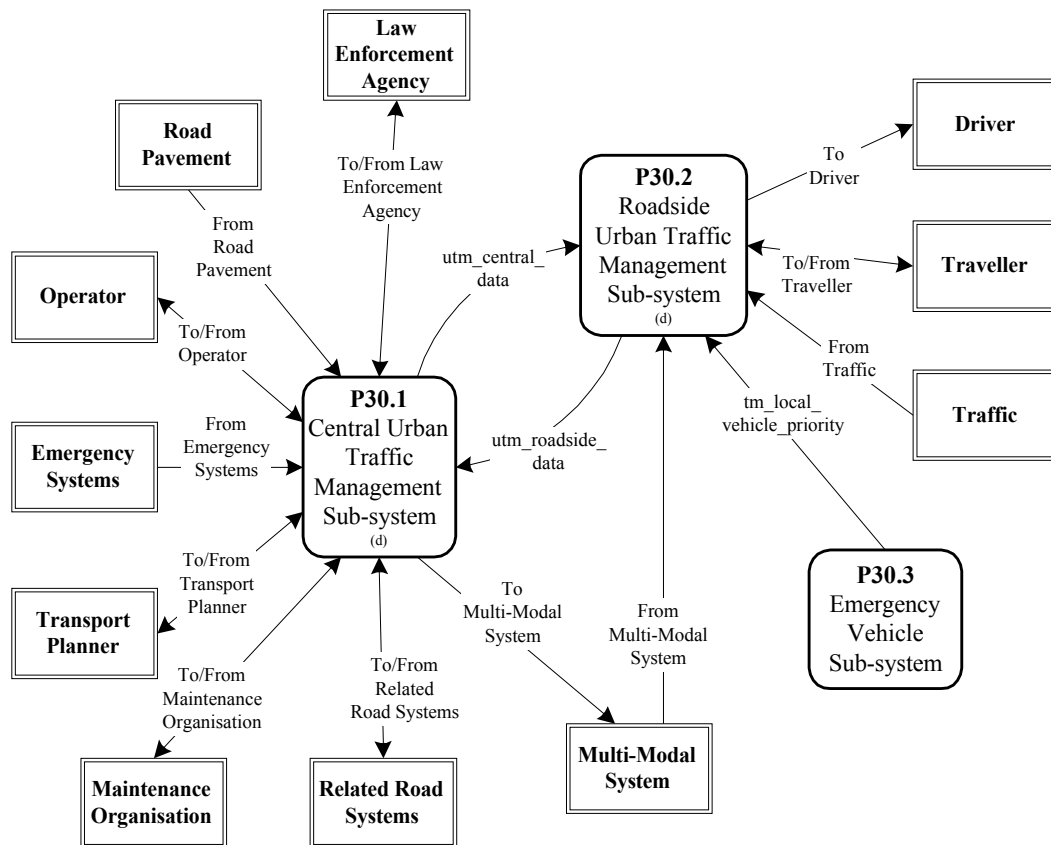
One example of a high level system is shown below in Figure 5, the context diagram.

Figure 5 P30 Urban Traffic Management System - Context Diagram (KAREN D3.2 A1)



While a sub-system make look like the following:

Figure 6: P 30 Urban Traffic Management System - Sub-systems (KAREN D3.2 A1)



4.4.2 Data Storage for Physical Systems

With these example sub-systems, it is now possible to list all of the respective low-level functions, together with their specific user needs. Thus it becomes possible to list all the required data flow between various components and where such data should be physically stored e.g. in ‘data stores’. ‘Data Flow Diagrams (DFD’s) are used in KAREN to describe this flow of information, and this naturally leads into the design of the communication architecture. An example of a data store is as follows for the function of “**Manage Traffic**”.

- D 3.1: Urban Traffic Data Store
- D 3.2: Inter-urban Traffic Data Store
- D 3.3: Environmental Data Store
- D 3.4: Incident Data Store
- D 3.5: Demand Data Store
- D 3.6: Maintenance Data Store
- D 3.7: Urban Road Static Data Store
- D 3.8: Inter-urban Road Static Data Store

Each Data Store appears in the DFD of the High Level Function in which it is used. Each DFD also shows the Data Flows that link each Data Store to the Functions.

A typical Data Store could contain traffic flow data for the urban road network and car park data. The data in the Store is divided into two parts, one for data from the actual urban road network and the other for car park data. Each part may have up to three sets of data, comprising, historic, current and predicted data.

The actual data in the urban road network part of the Store may comprise but not be limited to the following items:

- date/time: (numbers);
- location: (characters);
- flow: (numbers);
- speed: (numbers);
- headway: (numbers);
- occupancy: (numbers);
- queue: (digit - indicating yes/no);
- count: (numbers).

There will be one set of the above data for each location in the urban road network where some or all of the data is obtained. Within each set there will be both current and historic data. Predicted data may use a different set of locations and contain a smaller sub-set of the above data.

The second part of the Data Store will contain data for car parks located in the urban road network. For each car park, the data may be divided into three parts comprising, historic, current and predicted data. The actual data in this part of the Store may comprise but not be limited to the following items:

- date/time: (numbers);
- car park location: (characters);
- count: (numbers);
- occupancy status: (digit - shows increasing or decreasing).

There will be one set of data for each car park in the urban road network. Within each set there will be both current and historic. The count may be either the number of vehicles in the car park, or the number of spaces. Which ever is used, it will be consistent across all car parks served by a particular System. Predicted data may not contain a value for the increasing/decreasing indicator.

5 CONCLUSION

This document has described the process of building an ITS Architecture. This process is complex, with numerous questions and “what ifs” to be answered. In South Africa today, the concept of ITS needs to be promoted if it is to achieve the benefits that have been observed internationally. If an architecture development methodology is followed rigorously, then road authorities have an opportunity to not only improve the cost-effectiveness of transportation provision but also to provide a management tool for organisations which offers improved co-operation within the various road authorities and across jurisdictional boundaries. Hence, the potential seamless benefits that ITS offer the road user should be extended to the provision of services by road authorities and enforcement agencies. In this way, it will be possible to provide smart services across the spectrum of transportation to the benefit of all.

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Johann Andersen is a director in the Transportation Division at Africon, a multidisciplinary civil engineering consultancy. He is responsible for ITS and Transport Planning Services in Africon. He has an undergraduate degree in Civil Engineering from the University of Stellenbosch, a Masters degree in Transportation from the University of Texas at Austin and a PhD from the University of Stellenbosch. He is a member of SAICE and serves on the National Committee of the Transportation Division of SAICE.

He is involved in a large number of projects, both locally and internationally. His field of expertise and interest is in the areas of Transportation Planning, Modelling, Traffic Engineering and Traffic Law Enforcement: specifically linking transportation solutions with IT Systems and appropriate technology. He has also published extensively in this field.

He has been involved in the ITS initiative from the outset, with inter alia the following:

- Technical support to the ITS National Committee (Co-architecture manager)
- Responsible for the technical programme at the first SASITS Awareness Symposium
- Marketing ITS to industry and various official organizations
- Various papers and presentations at conferences
- Representing ITS South Africa in Miami, December 2000 at an ITS America conference
- Member of Interim Management Committee, SASITS

Johann is married and has three sons (12 years, 7 years and 6 months).