A CONCEPTUAL ARCHITECTURE FOR INTELLIGENT TRANSPORT SYSTEMS AT THE REGIONAL LEVEL

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1. Background

The institutional issues surrounding Intelligent Transport Systems [ITS] are evolving at a rapid pace in South Africa. ITS structures are currently being formalized and a government endorsed institutional structure has been formed.

As a result of the dynamics of the situation, this paper explores only the broader principles of ITS architecture relating to national and regional strata, without expanding on details. The actual presentation will provide more information regarding the current status of regional and national developments.

1.1 ITS deployment

A group of technologies, collectively known as Intelligent Transport Systems, are currently being developed and deployed worldwide to improve transportation system efficiency and effectiveness.

ITS integrates a number of technologies, including computers, communications and control, with transport systems to improve safety, reduce congestion and maximize the capability of these transport systems without negatively effecting the environment.

By and large ITS, offers an alternative or supplement to traditional measures for addressing transportation problems and needs. ITS can also complement existing traditional transportation systems by improving safety and efficiency as well as offering higher levels of service provision.

1.2 Overview of ITS structures in South Africa

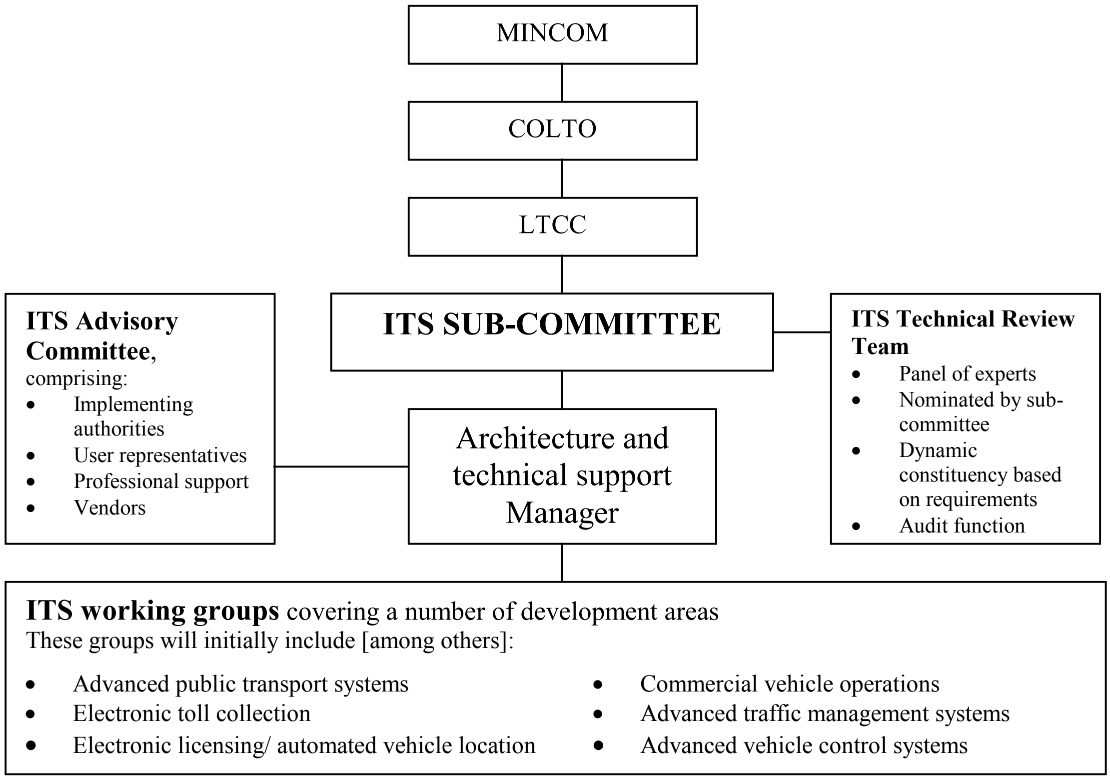
The ITS institutional structures in South Africa form part of the MINCOM/ COLTO hierarchy, with an ITS sub-committee reporting to the LTCC [Land Transport Coordinating Committee]. The ITS sub-committee will be supported by an ITS advisory committee, a technical review team and an architecture and technical support manager.

A number of ITS working groups will report to the sub-committee, the activities of these groups will be co-ordinated by the architecture and technical support manager.

The structure provides the opportunity to develop a national ITS architecture and deployment strategy that incorporates user, technical, institutional, political and private sector inputs.

Figure 1, below, provides an overview of the ITS structure approved by COLTO.

Figure 1: National ITS institutional Structure in South Africa



1.3 National Architecture and standards

A national ITS architecture will traditionally provide a common structure for the design, deployment and operation of these systems. The national architecture should define the framework for the tailored local and regional deployment initiatives. The benefits of a defined framework include:

- Interoperability on a national level,
- Increased competition through the use of open standards,
- Future flexibility by allowing the merging of existing legacy systems with new systems,
- Lower costs in the long term as economies of scale evolve and through the availability of multiple vendors for open systems,
- Promoting the development of public/ private partnerships to the eventual benefit of transport system users,
- Enhanced deployment and operational strategies through national cooperation, and
- Increased integration of transportation systems within, and across, regions.

Although the ideal would be for a unique ITS architecture and related standards to be developed exclusively for South African requirements, this is unlikely to be affordable, nor desirable as a result of the evolution of a global economy where major vendors react to global markets.

It is probable that the national architecture will evolve from architectures and standards developed elsewhere, with adaptations to suite our local requirements. Some of these standards are quite well developed.

Countries like Japan, the USA and Europe, in particular the UK, have developed [and are further developing] ITS architecture models. The European ITS architecture initiative, KAREN, is nearing completion with the specification of user needs and the functional architecture released in draft form. The following sections briefly describe some elements of ITS related architecture from two of these countries, the USA and the UK. The purpose of the description is to illustrate the scope and extent of the development of the ITS architecture but does not provide an in-depth comparison of the two models.

Of the two architecture concepts, the USA model is the more extensive is scope. The UK model, while quite limited, has strong ties to the South African situation as a result of the local use of some UK developed ITS applications.

1.3.1 USA developments

The USA has arguably produced the most comprehensively documented ITS architecture. Large elements of the architecture are of direct relevance to South African conditions and requirements. The total cost of the development of the USA national architecture is difficult to estimate, due to the voluntary contributions, but is likely to be in excess of R100 million.

The USA national ITS architecture provides a structure for the design of ITS. The architecture defines the functions that must be performed by components or subsystems, where these functions reside (e.g. roadside, traffic management center, or in-vehicle), the interfaces and information flows between subsystems, and the communications requirements for the information flows (e.g., wireline or wireless) in order to address the underlying user service requirements.

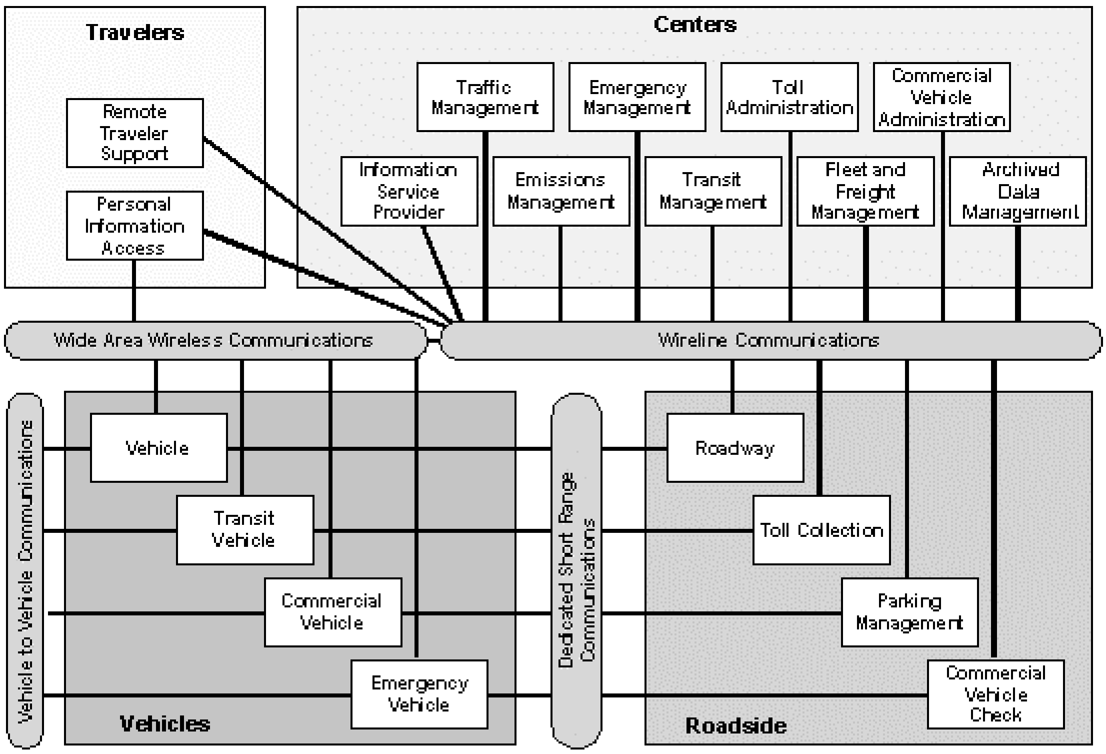
The USA architecture helps identify typical user requirements [in bundles] and relates these requirements to logical and physical component frameworks. The diagram, shown overleaf in Figure 2, [from the National ITS Architecture] indicates the 19 transportation subsystems in the USA architecture.

The four general communication links (ovals) used to exchange information between subsystems are also depicted.

This Figure represents the highest level view of the transportation and communications layers of the physical architecture. The subsystems roughly correspond to physical elements of transportation management systems and are grouped into four classes, namely:

- Centers,
- Roadside,
- Vehicles, and
- Travelers.

Figure 2: US National ITS architecture



Source: USA National ITS Architecture

In turn these physical and logical frameworks also point at equipment and market packages. The market packages identify typical systems required for specific transport related tasks and functions. The architecture consequently provides a clear path for identifying and assembling building blocks for the development of ITS according to particular user requirements.

Since the USA national ITS architecture is also the foundation for much of the ongoing ITS standards work, consideration of the interface and information exchange requirements established by the architecture, as it stands today, will likely facilitate or ease the transition to incorporating standards-compliant interfaces in the future (as and when approved standards are made available).

1.3.2 UK Developments

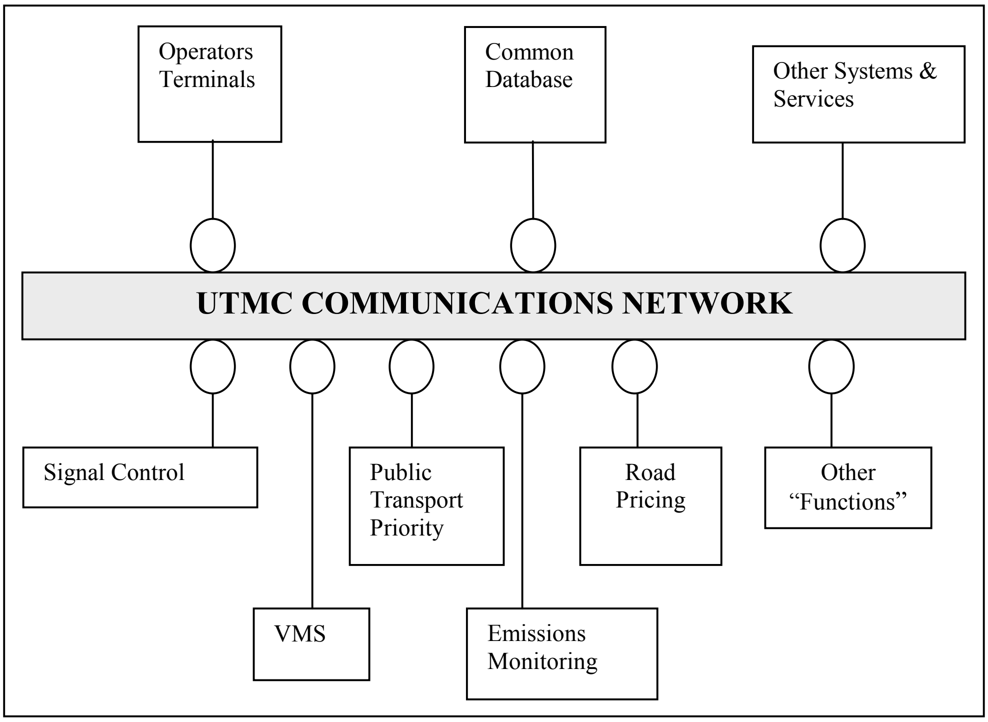
To provide the tools to support efficient and effective network management and to facilitate competition in the supply of transport services, the UK Department of the Environment, Transport and the Regions [DETR] developed the Urban Traffic Management and Control [UTMC] concept. The UTMC concept is the UK framework for the development and deployment of ITS in urban areas. It does not define policy requirements but supports the chosen policy and provides the means to develop systems that can make best use of local opportunities.

The aim of this five-year, R50 million initiative, is to bring to the market an open, modular systems that will support, in a cost-effective way, the management of transport into the 21st century in the UK and overseas.

To this end the UTMC concepts and associated standards have been developed to be internationally relevant and flexible enough to accommodate the rapid changes in markets, standards and technologies that characterize today's computing, communications and telematics industries. The approach embodied in the UTMC specification is to define a framework within which existing or emerging standards are called up for each aspect of UTMC functionality that needs to be defined in detail if interoperability is to be ensured.

Figure 3, below, taken from the Specification for UTMC systems illustrates the UTMC concept.

Figure 3: UTMC concept [source Technical Specification TS001]



The UTMC specification focuses on defining:

- the interfaces between the modules of the systems, particularly user messaging, the user interface, file transfer, etc;
- those elements necessary for the sharing of information, particularly the common database.

Table 1, below, lists some functions considered in the development of the Technical Specification for UTMC Systems.

A number of these applications are closely aligned to current developments in South Africa.

Table 1: Typical UTMC applications [part of the list in the UTMC specification]

FUNCTION	EXAMPLES
Traffic Signal Control	SCOOT, fixed time, MOVA, bus priority
Mandatory Sign Control	Tidal flow, turning bans, weight limits
Direct vehicle control	Stopping vehicles at signals
Enforcement	Speed, parking, vehicle bans
Public Transport Management	Passenger information systems
Emergency Services Management	Green waves for emergency vehicles
High Occupancy Vehicle Management	HOV lane control
Parking Management	VMS systems, park and ride
Route Guidance	Dynamic route guidance
Road Pricing	Congestion charging
Network Monitoring	Automatic Incident Detection
Information Management	VMS systems, radio traffic bulletins
Event Management	Special plans for major events, street works
Static Database	Diary, street works register
UTMC System Operation	Fault monitoring and management
Miscellaneous Systems	Inter urban, motorway information systems

Of note is that traffic enforcement is on of the list of applications as opposed to the USA architecture where enforcement is specifically excluded.

1.4 Communications Standards

Communication standards are another area of ITS deployment that have received a great deal of attention worldwide. The development, promulgation and adoption of standards is of utmost importance to new technology developments and will be critical to the success of ITS deployment.

Well-defined and open standards will improve procurement processes, reduce costs and allow for interoperability.

However, due to the vast array of devices and technologies available it is commonly agreed that standards should not be over prescriptive, but rather provide guiding principles and detail of only certain key system components, thus still allowing room for innovation and ongoing development.

The USA have once again taken a leading role in developing ITS specific standards, in particularly in the key area of communications. The adoption of these communications standards allows authorities to transmit data from one device or system to another. The process of defining the standards is currently underway with a number of modules completed.

A few of the many ITS related communication standards are briefly outlined in the following paragraphs.

1.4.1 NTCIP

The USA ITS communications standard, NTCIP [National Transportation Communications for ITS Protocol] was originally conceived as an extension of a standard covering traffic signal controller communications.

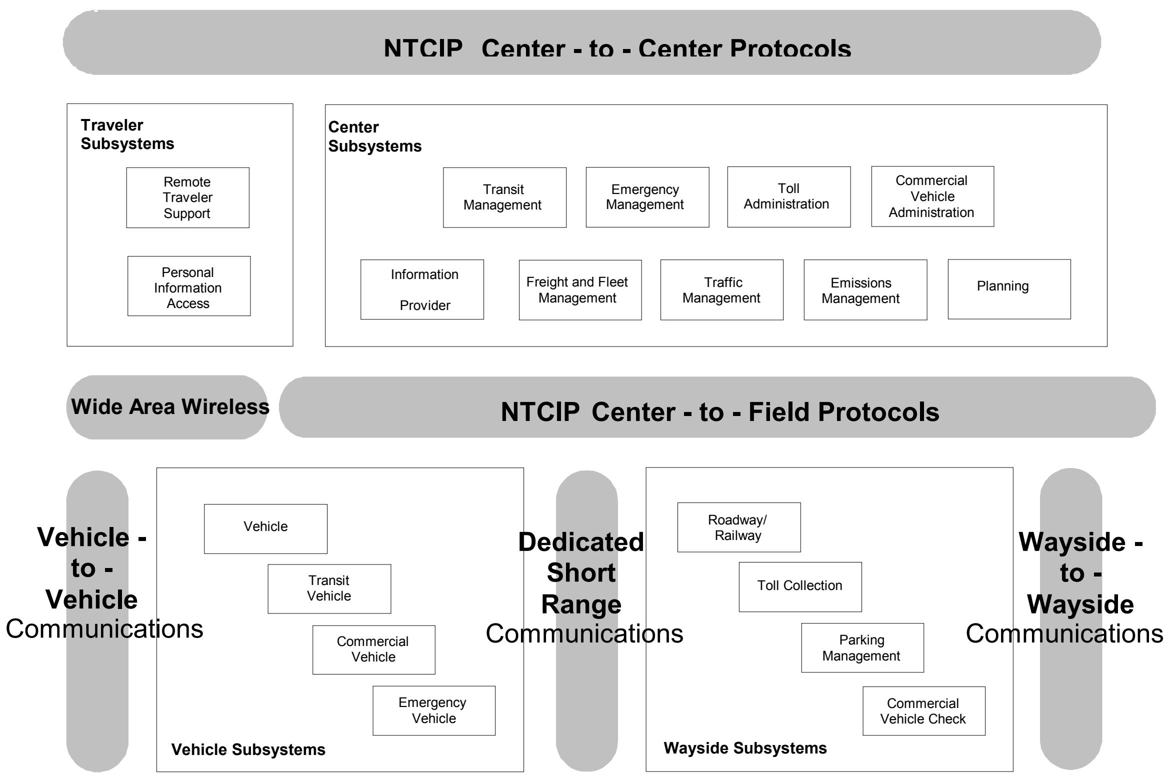
Through the adoption of features of several existing worldwide communication standards an open protocol has been developed, initially covering traffic controllers but now including a range of devices and traffic management centre related systems. The development process is ongoing.

Currently a wide range of devices can make use of the NTCIP communications standards. Figure 4, shows how NTCIP ties in with the USA ITS national architecture.

The UK UTMC grouping has carried out an investigation of the NTCIP communications standard. They concluded that it would be satisfactory to use the NTCIP standard for new UTMC applications.

The UK investigation does note that certain UK specific variations to the NTCIP may be necessary. This is in line with the general philosophy behind the development of the NTCIP standards in that broader participation will improve the overall quality and applicability of the standard.

Figure 4: Communications model – NTCIP and DSRC



Source: US National Architecture

1.4.2 Dedicated Short Range Communications

Dedicated Short Range Communications [DSRC] consists of short-range communication devices that are capable of transferring high rates of data between mobile or stationary vehicles and [usually] stationary devices near to the roadside. DSRC is also known as vehicle-roadside communications.

The communications overview shown in Figure 4 also shows the vehicle to wayside communications via DSRC.

The standardization of this range of communications systems is still ongoing. Standardization initiatives, such as STAR [STAndardisation of Inter-operable Road Tolling Systems based on DSRC] and other efforts lead by the ASTM, IEEE, ISO and other organizations are attempting to define an international standard. However, it would appear that this is one area of ITS related communications where standardization will be difficult due to the range of systems available and the protection of legacy systems.

However future migration to a common standard supporting various types of DSRC devices using either active and backscatter technologies, will eventually be achieved through market forces.

One of the most important areas of application for this communications format is electronic fee collection, usually tolls or parking fees. The broader interoperability of these systems ranges wider that the communications devices and will in future need to include collaborative financial systems.

2. Regional planning for Intelligent Transport Systems

A national ITS architecture will provide a common structure for the design of ITS. It defines the framework around which many different design approached can be developed, each one specifically tailored to meet regional needs while maintaining the benefits of a common architecture for current and planned systems.

A regional architecture must define the functions that must be performed by components and subsystems, where these functions reside, the interfaces and common flows between subsystems and the communications requirements for the information flows.

A regional architecture also needs to consider the detailed operational requirements relating to ITS deployment. Past experience, worldwide, has shown that ITS deployments frequently fail [or deliver less that optimum performance] due to operational, as opposed to technical, issues.

2.1 Overseas practice

The USA national ITS architecture is seemingly the only model to explicitly define the concept of a regional architecture within a national ITS framework. The UK UTMC loosely highlights the opportunity to mix elements of typical ITS applications on a needs basis at a local level.

The USA model recognizes the need to undertake the detailed planning of ITS systems on a regional basis, under the guidance of a broader national framework. Regional planning of ITS is seen as an extension of the overall transport planning process. The operational interaction of transport agencies is considered a priority in the development of a regional architecture.

The USA model promotes a systematic approach to regional planning using the national architecture as a guide and departure point.

Collectively, the framework documents from the UK and USA identify the following benefits of regional ITS planning:

- it facilitates communication between regional stakeholders to address operational and management issues of mutual concern,
- it allows ITS to be incorporated into mainstream transport planning within the region and hence promotes awareness to develop systems management and operations planning as part of an overall transport strategy,
- it provides a mechanism to identify regional requirements for ITS within the identified regional transport policy and strategy framework,
- it presents an opportunity to promote inter-agency coordination and cooperation within a region by sharing services and improving operational procedures, and
- it fosters the development of a master plan for prioritized ITS deployment, which provides the detail required for efficient and cost-effective development and operation of ITS.

It is clear that regional planning should not be done in isolation of national initiatives, however in South Africa, the development of a national architecture has lagged behind regional deployment. Thus, planning at a regional level is currently taking place in spite of the absence of a national guide. This is obviously a less than ideal situation. The rapid development of a national framework is required. The newly established ITS structures have recognized the urgent need and are proceeding accordingly.

The regional planning process identified in the USA model incorporates the following:

Concept planning – which addresses the issue of what transport management systems are required for a region and how individual systems can be integrated so that agencies can improve services delivery. The concept plan will consider these factors against the broader transport, and other, policy objectives for the region.

Implementation planning – which addresses the question of how stakeholders in a region can "organize" to implement the results of the concept planning process. The implementation plan will provide a road map for the successful deployment of an integrated mutimodal transport management system for a region, considering technical, operational and financial issues.

Project deployment – which addresses the deployment of individual components of the system on a detailed level.

Evaluation – which involved the quantitative and qualitative assessment of the benefits of the regional ITS deployments and identifies shortfall and means of further improving operational efficiency and system efficacy. This process is seen as ongoing.

These methods have been developed over time and reflect the current best practice available. Teamwork and co-ordination is cited as being the key to success in regional ITS deployment initiatives.

2.2 Regional planning in the CMA

The potential benefits of ITS have long been identified in the Cape Metropolitan Area. The metropolitan area traffic control system, providing real time adaptive control and equipment monitoring, has been in place for a number of years. Before this, a fixed time, traffic responsive plan selection system was operational in the central business district.

Public transport has benefited through the introduction of a call centre providing mutimodal trip planning facilities. A set of variable message signs controlling public transport lanes on the N2 freeway is in the process of be commissioned.

Smart card technology is being used in parking payment systems. A freeway management system, principally utilizing CCTV in the first phase of application, is currently being deployed. Automated incident detection will follow shortly.

These and other projects, listed in table 2 below, require regional co-ordination. The deployment status of the currently identified user requirements is shown in table 2.

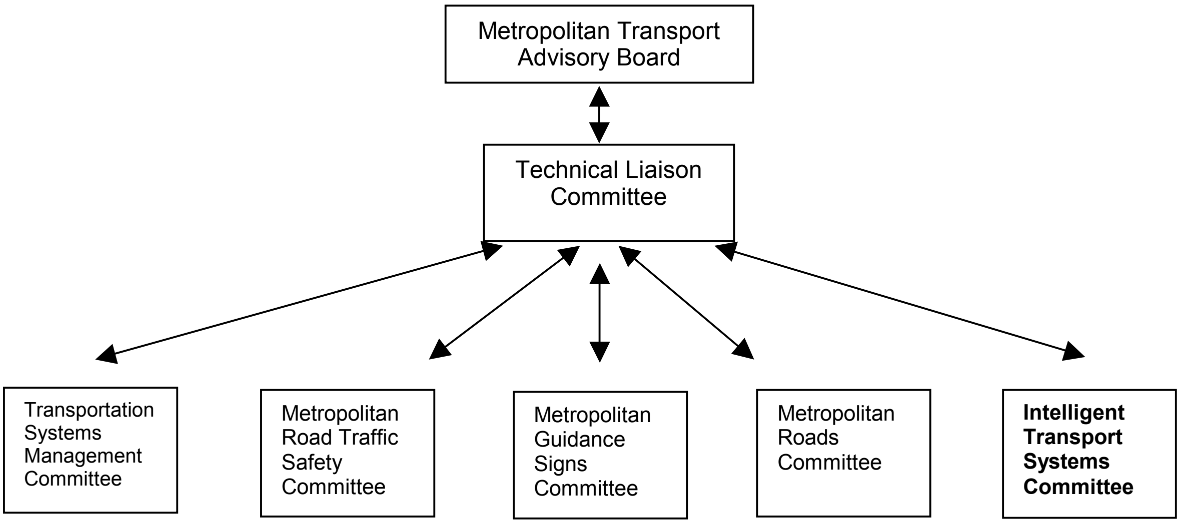
Table 2: Functional Elements of ITS systems in the Cape Metropolitan Area

FUNCTION	DEPLOYMENT STATUS	EXAMPLES
Traffic Signal Control	Implemented	SCOOT, fixed time
Mandatory Sign Control	Being considered	Tidal flow, turning bans, weight limits
Direct vehicle control [ramp metering]	Being considered	Freeway ramps
Enforcement	Being commissioned	Speed, red-light, parking, vehicle bans
Public Transport Management	Being considered	Passenger information systems, bus priority
Emergency Services Management	Implemented	Green waves for emergency vehicles
High Occupancy Vehicle Management	Being commissioned	HOV lane control
Parking Management	Being considered	VMS systems, park and ride
Network Monitoring	Being designed	Automatic Incident Detection
Information Management	Being commissioned	Internet, traffic bulletins, active database
Event Management	Implemented	Special plans for major events, street works
Static Database	Being Implemented	Diary, street works register, GIS
System Operation	Implemented	Fault monitoring and management
Traffic Surveillance Systems	Being implemented	CCTV

Mistakes have been made in the regional deployment process. Systems have been introduced with insufficient inter-agency liaison, resulting in inappropriate expenditure and sub-standard operation. These shortcomings have been identified and as a result a regional ITS steering committee has been established.

The steering committee has been formed under the auspices of the Metropolitan Transport Advisory Board and one of the sub-committees of the Technical Liaison Committee. The structure is shown below in Figure 5.

Figure 5: ITS structure in the Cape Metropolitan Area [CMA]



The advantage of this structure is that ITS has been introduced as a mainstream activity, part of “normal” transport planning and deployment process. It is envisaged that the ITS steering committee will form the primary liaison mechanism with national structures.

The aim of the committee is to co-ordinate the implementation of ITS related projects in the Cape Metropolitan Area. The committee will steer a regional concept planning initiative.

The aim of this exercise is to develop an ITS master plan for the region, providing a clear guide to future deployment requirements as well as a plan for the ongoing maintenance, upgrading and enhancement of existing ITS components. The preparation of the regional master plan will follow the regional planning process outlined in the USA national architecture model.

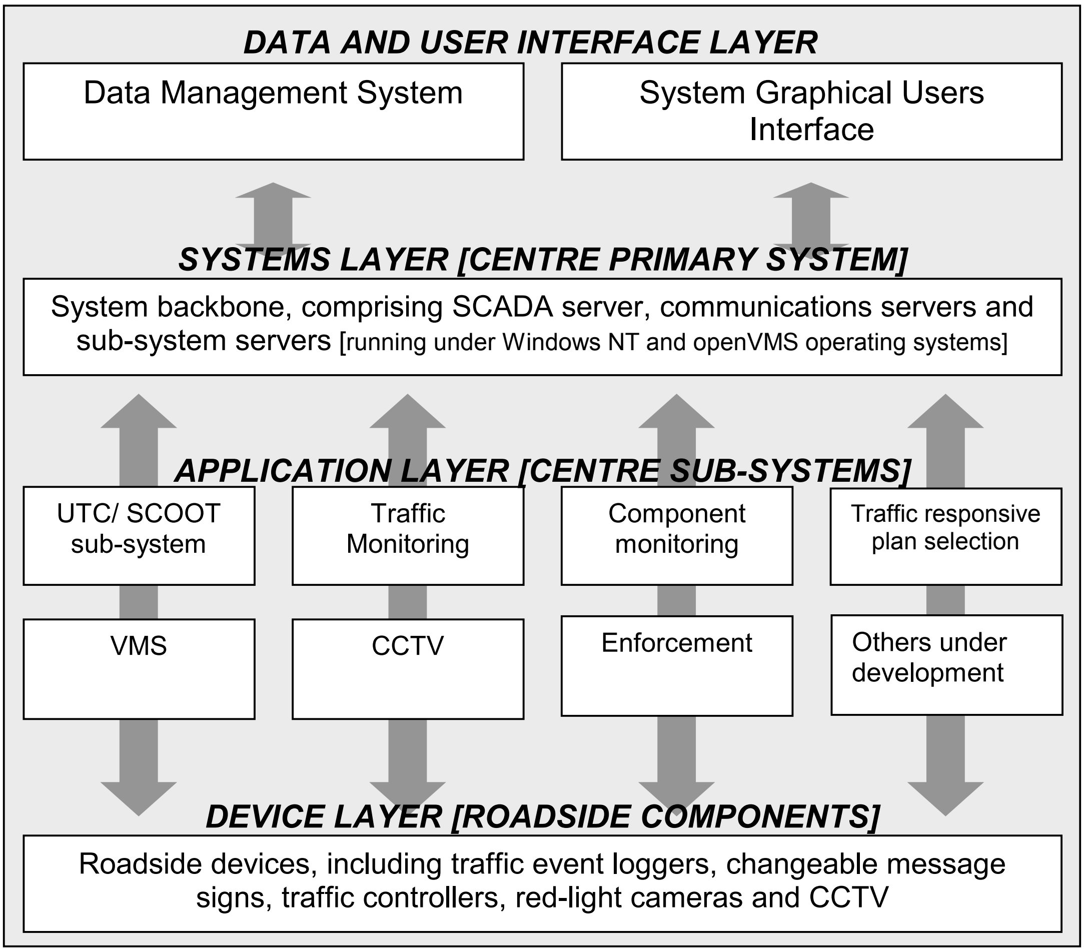
3. Concept architectural elements in the Cape Metropolitan Area

The CMA has provisionally adopted a concept architecture based on an adaptation of the UK UTMC and the USA National ITS Architecture. This model provides the benefits of a well tested architecture, aligned to international norms, while achieving backward compatibility in respect of the existing legacy systems.

The existing metropolitan area traffic control system is easily accommodated within the [provisional] regional architecture, which explicitly recognizes the migration from existing SCOOT systems. The “migration” path is seen as the key factor of the regional architecture.

The broad concept architecture is shown, below, in Figure 6. The modular architecture, which is essentially compliant with international models will evolve into a fully NTCIP compliant system. At present certain proprietary communications protocols are not NTCIP compliant but the interaction of sub-systems is not compromised by this limitation.

Figure 6: Concept architecture in the Cape Metropolitan Area [CMA]



Future functionality requirements will include roadside device to vehicle communications. The centre to centre and centre to roadside communications is depicted by the arrows.

Two issues are of prime importance in the [provisional] concept architecture:

Data Management System – including data typing, definition and exchange

Communications System[s] – including protocols, networking and communications media arrangements, and

If devices and sub-systems can **communicate and exchange data** the overall integration objectives of the open architecture are primarily fulfilled. This is a fundamental design principle that has been employed in the development of the [provisional] CMA regional architecture.

3.1 Data Management System

Of the two design issues the Data Management System is the easiest to deal with, as there are a range of standard interfaces and tools with which to undertake the development.

Transportation management systems use and collect large volumes of data. Certain functional components [or sub-systems] of transport management systems may require elements of data collected by other sub-systems.

For example a bus priority system [like BUS SCOOT] providing signal preemption processes information relating to the position of the vehicle requiring priority. This information [in an adapted and enhanced form] can be used by a public transport monitoring system that evaluates the service provided by operators.

In the CMA the data layer of the regional ITS architecture is currently being defined and developed. A comprehensive data management system, known as **ATraMS** [**A**dvanced **Tra**nsport **M**onitoring **S**ystem], is being developed to manage both dynamic and static information in a systematic and open format.

The data dictionary for the initial components of the data management system has been developed [using international guidelines where suitable] and final development of the functional modules is underway.

The data management tool will be SQL based with a GIS layer.

3.2 Communications System[s]

The Communications System is a more complex issue. Existing protocols utilized in the CMA are not “open” in certain instances. An evolutionary approach to the development of the overall system has been adopted.

This is in line with the underlying philosophy of the UK UTMC concept. UTMC has been developed to provide a means of integrating existing functional components.

The UK UTMC has investigated the USA NTCIP communications standard and found that the standard is generally acceptable, with certain adaptations, to the UTMC concept. The NTCIP standard has been adopted for the CMA regional ITS architecture.

Already certain components have been deployed with NTCIP related specifications. Additional developments, currently underway, also require NTCIP compliance.

4. Conclusions

A regional ITS architecture is a means, not an end. It is crucial that any regional ITS architecture development process be based on addressing real needs, identified from sound investigations and based on agreed policy requirements.

The development process itself can yield as much benefit as the product, especially for nontraditional stakeholders. The importance of agency in-reach, as well as out-reach and education, cannot be overstated in supporting a successful development process.

A regional ITS architecture is the most effective means of providing for regional ITS integration. The Cape Metropolitan Area is in the process of developing a regional ITS architecture that generally complies with common international norms and standards. A provisional regional architecture has already been defined for current deployment projects. A concept ITS master plan is in preparation.

However, well defined national guidelines are a requisite for effective long term regional planning. The development of the National ITS Architecture is underway and will produce the guiding framework and versatile tool with which to make smart decisions throughout the regional ITS architecture development process. The provisional regional ITS architecture will be validated against the national framework when it becomes available and inconsistencies will be addressed.

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