Putting the "Intelligence" into Intelligent Transportation Systems

David Verma, BA (Eng), NCBC (systems), MCSE, (systems)
Senior Transportation Specialist (Intelligent Transportation Systems)
Beca Infrastructure Ltd (Auckland)

ABSTRACT: Current approaches to the deployment of “Intelligent Transportation Systems” are largely based on relatively unsophisticated roadside equipment implementations and back end systems, effectively relying on human operators to provide the “Intelligence” in order for them to operate correctly.

This paper therefore aims to provide an insight into how decision support systems, can be used to create truly “Intelligent Transportation Frameworks” using commodity off the shelf hardware and Internet based communications to facilitate more effective road network operations, reduce operator stress and improve pre-emptive decision making and planning (Of vast importance to TDM initiatives).

By highlighting the issues of developing and maintaining such a system and the use of hardware and software abstraction techniques, this paper will present approaches that can be used to prevent tie in to specific manufacturers products and minimize product development (particularly software), investments and activities.

This paper will also cover distributed non-geographically dependent systems design considerations and why Traffic Management Centres are a thing of the past.

Finally this paper will evaluate and describe the role of neurally networked self-learning applications in transportation and look at the future use of true artificial intelligence in “Intelligent” Transport Systems.

WHERE THE REAL "INTELLIGENCE" RESIDES IN AN INTELLIGENT TRANSPORTATION SYSTEM

The term "Intelligent Transportation Systems", (ITS) was originally used to describe a fusion of Transport and Information technology hardware, software and communications systems. These systems were intended to enable roading authorities to utilise technology to assist them to better manage and be informed about what was happening on their roads. Despite the fact that the resulting ITS systems are now sometimes seen as mission critical, (a case in point being tunnel management systems), these systems themselves are often manually operated and require operator interventions to validate actions.

The primary contention of this paper is that most "Intelligent Transportation Systems" are in fact decision support systems. In order to truly create an "Intelligent" Transportation System we need to better capture the "Intelligence" currently invested in the operator and the organization.

This can be achieved by placing a focus on understanding functional and business drivers as well as operational responses and automating these actions as far as practicable.

The aim of this paper is therefore to provide an insight into how decision support systems, can be used to create truly "Intelligent Transportation Frameworks" using commodity off the shelf hardware and Internet based communications. The aim of which is to facilitate more effective network operations, reduce operator stress and improve decision making.

WHAT IS A DECISION SUPPORT SYSTEM AND HOW DOES THIS RELATE TO AN ADVANCED TRAFFIC MANAGEMENT SYSTEM?

The single most obvious area in ITS to expect to find "Intelligence" is in the area of Advanced Traffic Management Systems, (ATMS). A simple way to consider the relationship between ATMS and ITS is to see ATMS as a decision support system for an Operator.

The ITS Society of Canada website defines ATMS as:
"..ATMS systems comprise inputs (traffic-flow data), data processing capability (both at intersections and by computers in a traffic control center, or, for fully integrated ITS systems, in a transportation management center), and outputs (timings to traffic signals, VMS messages to motorists, incident advisories to tow trucks, and so on)."

If you accept that the fundamental premise for the use of ATMS is to better manage events/incidents that occur on the motorway, inform drivers, improve safety and measure the performance of the network then you also need to accept that whilst some actions can be automated others will depend on the skills of a trained Operator.

This places the Operator in a unique position of stress, often reliant on interpreting a number of different systems and information sources simultaneously in order to make the best possible decision in relation to the current circumstances that they have to deal with.

The traditional approach (1985-2003) to supporting this "Intelligence" role in a Traffic Management environment was to supply a centralised ATMS system. This system collected information from a variety of different ITS devices and either allowed the operator to make decisions based on situational analysis or predefined action response plans. Systems of this type are usually referred to as "monolithic enterprise applications" in that they use an all encompassing approach and often feature proprietary software and hardware components that can only be changed by the system's vendors.

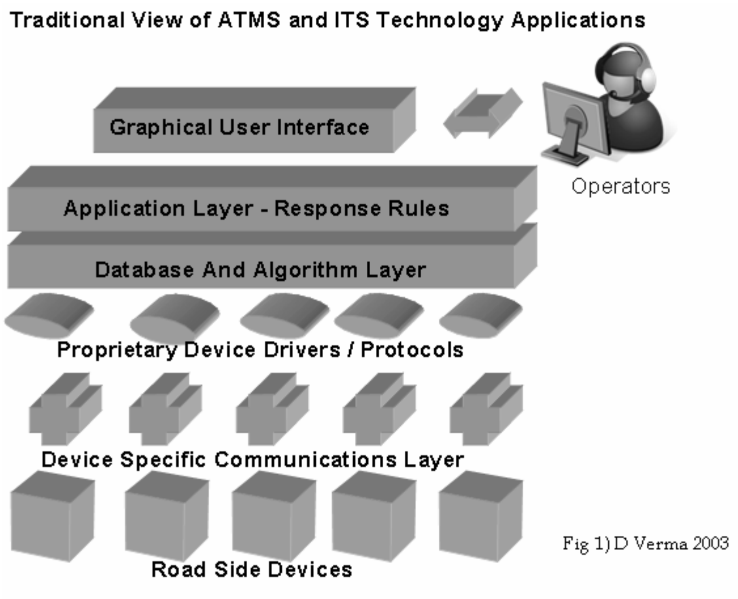

Fig 1)Typical ATMS Design (D Verma 2003)

This approach however represented a significant step forward in the use of ITS equipment to empower operators and road controlling authorities enabling them to better manage their networks. However in practice the monolithic enterprise application type ATMS software environment also resulted in a number of key issues for Roading Authorities:

- Geographical limitations – all the software and processing needed to be centrally located as did the Operators. This placed significant communications and resource constraints on what ITS equipment could be managed by ATMS systems and from where. (As a direct result most ATMS ITS infrastructure had an urban, highway/motorway focus).
- High costs – most ATMS systems were relatively new and at the time much of the development costs for ATMS systems deployed were borne by Roading Authorities.
- Limited communications options for roadside ITS devices resulted in the requirement to use proprietary and often consequently extremely expensive equipment to facilitate largely analogue communications networks.
- There was a subsequent lack of flexibility in terms of changing ATMS systems to meet evolving business needs and changes in operational requirements.
- Dependence on both highly qualified (expensive) technical support staff to maintain the ITS equipment and the ATMS software involved and experienced Operators who were able to best utilise the system.

Whilst ITS ATMS systems are relatively recent, in power and water utility companies and in the area of military operations, deployment of decision support systems and automation surrounding mission critical operational systems has been a priority for many years.

Turban (1995) defines a decision support system as: "an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights.

It is important to recognize that this view is still Operator centric. However unlike most current ATMS systems all the possible permutations of rules and processes combined with appropriate reactions to an event are presented to an Operator in order for them to make a decision on.

In such systems typically the ability to then proceed with an automated response or manually intervene is also subject to a permutation of rules and approaches that are calculated as being the best recommended course of action. The activity of the Operator is effectively supervised by the system. A core feature of such systems is the ability of the System to "learn" from responses and "recall" a response if a situation repeats itself again.

Fortunately current thinking on ITS ATMS design (2003-present) has changed substantially with more of a focus on the definition and incorporation of decision support capabilities, modular business rules, abstraction of roadside device drivers and a change to a distributed model for the capture and processing of data.

A good example of this type of approach is evidenced by the architectural principles embodied in products such as STREAMS from Transmax, (formerly Intelligent Transport Systems Queensland).

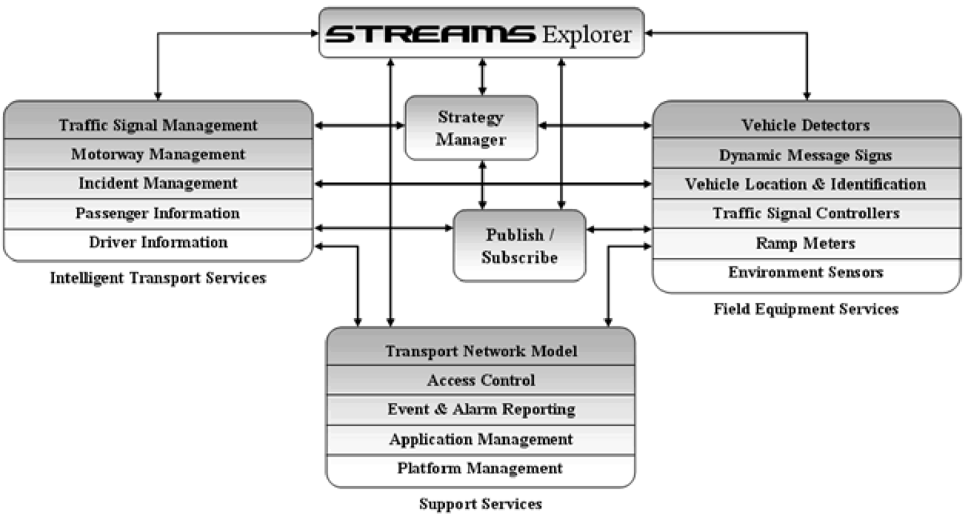

Fig2) Transmax STREAMS Architecture (2007)

From the image above (taken from the Transmax STREAMS Architecture website) the features of note are the Strategy Manager and the Intelligent Transport Services modules. Both of which are consistent with the notion of abstracted decision making and modular business rules inclusions. This diagram also serves to illustrate a significant point about "Turn Key" systems and their applicability. It is important to note that core Intelligent Transport services can only be delivered if the primary functional purpose of those services is clearly understood in the context of the operational requirements of the business for whom the system is deployed.

Even if the basic underlying traffic management equipment signals and communications systems are identical it is unlikely that the business functional requirements of different agencies would be exactly the same. It is also highly unlikely that the business drivers of those agencies would be exactly aligned. This leads to the next key consideration in increasing the "Intelligence" of ITS systems understanding "Intelligence" in the context of business functional requirements.

THE ROLE OF BUSINESS INTELLIGENCE IN DEFINING ROLES AND FUNCTIONS

Many ITS and ATMS deployments historically have featured largely organic lifecycles and have been driven by very specific service needs. Historically this process of adding functions to meet immediate service requirements created a position where Roading Authorities ended up with a collection of best of breed ITS equipment and supporting back-end software. Typically these systems were not capable of being interconnected or interoperable.

To prevent this situation and to increase the capabilities of such systems, business analysis is required to obtain the right approach to developing an ITS functional architecture. In many cases the functional relationships between operational activities can be expressed diagrammatically with several layers of nested functions being included:

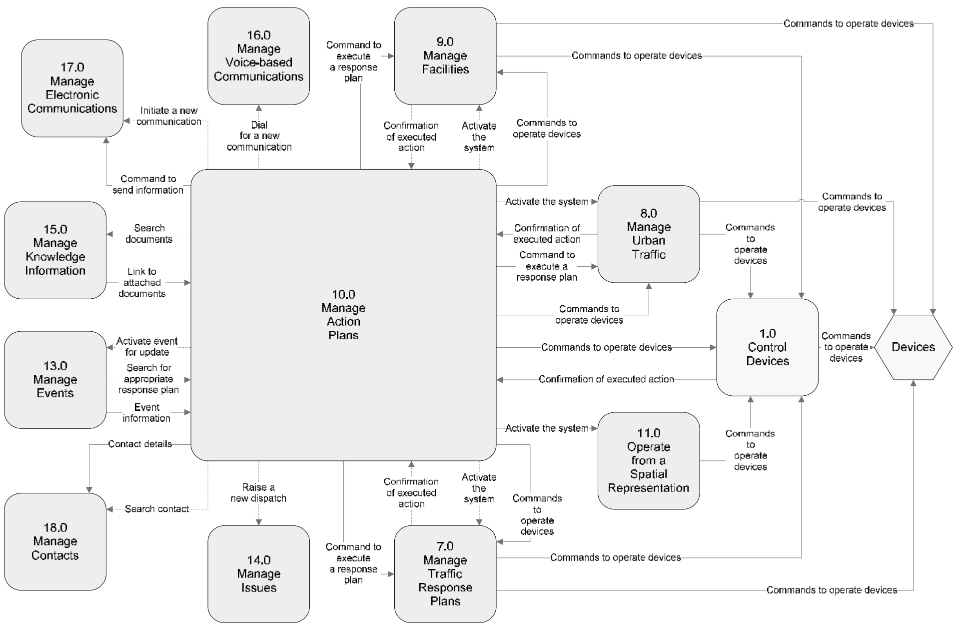

Fig 3) Functional Requirements TMC Action Plans (F Tavernier 2007)

The diagram above demonstrates that the interconnections between functions must be understood well prior to trying to design interconnections or inter-operability between ITS systems and equipment.

THE ROLE OF NEURAL SYSTEMS INTERCONNECTIVITY PRINCIPLES TO SUPPORT DECISION MAKING SYSTEMS DESIGN

A core principle of any ITS system is the notion of Interoperability and Interconnectivity. This in a nutshell equates to the idea that any system should be able to talk to any other system using a common set of communications protocols and a suite of common centrally defined data objects.

Comparatively a core principle of any "learning" system is the ability for it to make dynamic interconnections between relevant underlying components and then enact relevant actions. This concept is of significant importance in "Intelligent" decision support systems which must be able to learn from previous reactions and escalations of issues to ensure that procedures are enacted automatically and faster the next time they are required.

Neural systems interconnectivity principles allow software components to interconnect and interoperate with a variety of other software components based on a set of stored or "learned" responses to events. More significantly once a neurally designed system has "learned" how to achieve relevant connections to resolve issues or meet needs it retains this situational understanding for re-use and application – automatically.

In order to accomplish this software components need to be modular and designed to expose connectors that allow them to establish many to many relationships and execute dynamic responses and actions.

Neural processing theory is currently being used as the foundation for a whole range of software that is designed to learn dynamically and "grow" its capabilities.

Architecture for ITS systems to support a higher level of functional performance and operational capability should therefore at the very least be object oriented, highly modular and preferably written in high level coding languages that are highly portable and will run across multiple different types of infrastructure such as Java.

MANAGEMENT WITHOUT INFORMATION IS IMPOSSIBLE – THE EVOLVING ROLE OF DATA COLLECTION AND ANALYSIS

Decision support systems depend on the quality and quantity of the data that they are able to access in real time from a variety of sensors and historical records.
Increasingly as more focus is placed on managing demand (Travel Demand Management - TDM) the ability for Roading Authorities to continue to rely on the data collected from their systems alone in order to manage, measure and maintain network performance, safety and sustainability will decrease.

The ability for Roading Authorities to leverage external information sources, with which they can increase the capabilities of their in house ITS / ATMS decision support infrastructures, will ultimately impact on the effectiveness and responsiveness of their ITS systems. This position will impact on the ability to deliver to business functional requirements and external stakeholder expectations.

WHEN TO USE COMMODITY APPROACHES IN DECISION SUPPORT SYSTEMS ARCHITECTURES

The use of commodity communications fabrics, hardware and software should be seen as a given design principle for the development of Intelligent Transportation Systems. When considering the use of the word commodity the term in the context of this paper does not equate to "cheap" rather "readily available, market priced and sometimes pre-assembled or pre-packaged".

Decision support systems builds should be based around commonly available off the shelf operating systems with widely commercially supported components such as underlying database software and device driver libraries. As far as practicable efforts should be made to minimise any bespoke software development rather focussing on choosing components which are already productised and effectively "shrink wrapped" for reuse. From a Roading Authority perspective this approach would reduce risks and mitigate costs in areas where software development can not be avoided.

Ideally software components should only be selected if they have an Application Programming Interface (API) or can be connected to or controlled using typical web services such as XML, ebXML or SOAP.

CONCLUSIONS

The future for more "Intelligent" Transportation Systems lies in enabling technologies that will allow operators to focus on priority issues whilst business as usual activities become increasingly fully automated. Decision making from a network management point of view is also likely to be nearly fully automated.

RECOMMENDATIONS

- Roading Authorities need to ensure that Operator skill levels and training increase to cope with more complex decision making toolsets and a far more complex operating paradigm.
- ATMS systems considered for use by Roading Authorities need to incorporate decision support capabilities, modular business rules, abstraction of roadside device drivers and a change to a distributed model for the capture and processing of data.
- Architectures for ITS systems to support a higher level of functional performance and operational capability should be object oriented, highly modular and preferably written in

high level coding languages that are highly portable and will run across multiple different types of infrastructure such as Java.

- Decision support systems and ATMS software should be based around commonly available off the shelf operating systems with widely commercially supported components such as underlying database software and device driver libraries. As far as practicable efforts should be made to minimise any bespoke software development rather focussing on choosing components which are already productised and effectively "shrink wrapped" for reuse.

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Diagrams :

Fig 1) D VERMA Typical ATMS Design – From ATMS Summary Report Transit New Zealand 2003

Fig 2) Transmax STREAMS Architecture Diagram – Transmax Australia URL: http://transmax.com.au/streams/architecture.htm

Fig 3) Functional Requirements TMC Action Plans- F Tavernier / D Verma 2007 Beca Infrastructure Ltd / Beca Applied Technologies Ltd for Transit New Zealand - ATTOMS Functional Architecture design – Draft.