THE FEASIBILITY OF ITS AS A TOOL FOR IMPROVED NETWORK OPERATIONS FOR FREEWAYS IN SOUTH AFRICA

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ABSTRACT

South African is a country in transition where first and third world standards need to meet one another. The demands of the majority of the people in South Africa are mainly focused on social upliftment of the poor, education and health as well as the provision of basic services such as housing, clean water and sanitation. Because of these demands on Government resources, the development of transportation infrastructure did not keep up with the demand especially in urban areas such as Gauteng. Traffic congestion is experienced on these freeways where traffic volumes ranges between 100 000 and 180 000 on a daily basis.

Traffic congestion has a negative impact on freeway network operations. In order to improve the current situation, various alternatives are being explored. These alternatives can be categorized as follow:

- Expansion of the road network by means of the provision of new infrastructure;
- The upgrading/widening of existing infrastructure; and
- Optimization of existing infrastructure by means of congestion management utilising Intelligent Transportation Systems (ITS).

The first two options are well known. The costs and benefits of these options can be modeled and quantified. However, congestion management, and especially ITS were developed in technological advanced countries since the early 1990's. ITS as an integrated traffic and congestion management tool has however not been tested in South Africa. The implementation of ITS on national freeways is therefore different to technological countries in the sense that South Africa's needs and user population are different.

The South African National Roads Agency Limited (SANRAL) initiated an ITS pilot project focused on freeway management in order to:

- determine user requirements
- develop functional specifications
- develop a regional architecture
- determine benefits and costs of various ITS applications
- determine the feasibility of ITS as a tool to increase road capacity
- measure the effectiveness of the above mentioned against other options such as expansion of the road system and value engineering upgrading of the existing road network
- measure the effectiveness of the systems implemented

The feasibility stage of the project was completed and concluded that ITS subsystems for capacity improvement for recurrent congestion is not feasible if compared especially to value engineering optimization of infrastructure. However, ITS as a tool for freeway

network management and especially incident management is regarded to be feasible and certain ITS subsystems such as ramp metering, Closed Circuit Television (CCTV), Variable Message Signs (VMS) and a control centre will be implemented on a pilot project basis. However, it is critical that ITS systems are not implemented in isolation but are considered as part of the provision of new road infrastructure.

KEY WORDS
INTELLEGENT TRANSPORTATION SYSTEMS/NETWORK MANAGEMENT/COUNTRY IN TRANSITION/FEASIBILITY

1. INTRODUCTION

Traffic congestion is experienced on South African freeways in urban areas. Traffic congestion has a negative impact on productivity, the running cost of vehicles, the time people spend with their families and the environment. In order to improve the current situation, various alternatives are being explored. These alternatives can be categorized as follow:

- Expansion of the road network by means of the provision of new infrastructure;
- The upgrading/widening of existing infrastructure; and
- Optimization of existing infrastructure by means of congestion management, utilising Intelligent Transportation Systems (ITS).

The first two options are well known. The costs and benefits of these alternatives can be modeled and quantified. However, congestion management, and especially ITS were developed in technological advanced countries since the early 1990's. Although Electronic Toll Collection (ETC) has been implemented successfully, ITS as an integrated traffic and congestion freeway management tool management has not been tested in South Africa.

The implementation of ITS on national freeways is different to technological advanced countries in the sense that South Africa's needs and user population are different. South Africa is a mixture of developing/developed country where fewer people have access to information sources such as the Internet. Cities in technological advanced countries are mostly densely populated with little opportunity to construct new road infrastructure, whilst South African urban areas are not densely populated, the planned freeway system is not in place and cost of land as well as construction costs is much lower. As a result, the construction of new freeways is more viable.

Therefore, it was needed to determine the South African ITS user profile, which will enable us to determine driver's needs, interest for, and their reaction to advanced ITS technologies. It must also be determined which ITS applications are feasible for implementation and whether the private sector shows an interest to become involved with ITS, that may increase the feasibility of certain ITS applications. As mentioned previously, other options such as capacity improvements and new infrastructure can also improve traffic congestion. The feasibility of ITS versus these options must be determined.

The implementation of ITS will require that standards, specifications and a regional architecture are available to ensure interoperability between different ITS applications. Legal and institutional issues also need to be addressed and taken into account during the finalization of standards, specifications and an ITS architecture.

2. PROPOSED PROJECT

2.1 Project process

The development of the project is done according to the following stages.

2.1.1 Project Feasibility Stage

During this stage, user requirements, functional specifications and a broad regional architecture must be developed. This stage also includes a desktop study of international best practice, micro simulation traffic modeling, a preliminary benefit/cost analysis of individual sub-systems and the development of a preliminary project design that is regarded to be feasible for implementation. The feasibility of the identified project must be weighed up against the construction of a parallel freeway or upgrading of the existing infrastructure.

2.1.2 Design Stage

During this stage, the project determined during the feasibility stage will be designed in detail. The stage will be used to draw up technical specifications and refine the functional specifications, user requirements and regional architecture developed during the feasibility stage. The needs and interests of private roll players and the possibility of public/private partnerships will be taken into account in the detail design of the project.

2.1.3 Implementation and monitoring stage

In order to determine physical benefits of the subsystems implemented, and to refine technical and functional specifications, user needs and architecture, the efficiency of system will be monitored after implementation.

2.2 ITS applications/subsystems identified for the project

The project is focused on freeway management systems. The ITS applications/subsystems identified for the evaluation during the feasibility stage were:

For recurrent traffic congestion:

- Ramp metering
- Dynamic Speed Control

For incident detection

- Inductive Loops
- Closed Circuit Television (CCTV)
- Aerial Surveillance
- User calls (Cell phones, SOS phones and traffic police)

For traveler information:

- Variable message signs (VMS)
- Traffic Radio
- Short Text Messages (SMS)

- Internet
- Call centre

For incident response and clearance:

- Emergency vehicles
- Courtesy vehicles

In addition to the above, a suitable communication backbone, a model for a control management centre where roadside data will be collected and processed, as well as a functional specification, user requirements and a regional architecture needs to be developed.

2.3 Pilot Project Site

The Ben Schoeman freeway was identified to be the most suitable site for the pilot project. The six lane freeway is one of the most congested in South Africa with volumes ranging for different sections between 100 000 and 160 000 on a normal working day. The freeway links the Pretoria and Johannesburg metropolitan areas. The site stretches over 22km's and include 2 systems interchanges and 5 access interchanges.

There is a planned parallel freeway (PWV 9) to the west of the Ben Schoeman freeway that is under evaluation as a possible measure to alleviate congestion on the Ben Schoeman freeway. Furthermore, the Ben Schoeman was already evaluated and found to be suitable for so-called value engineering improvements whereby the existing 6 lane cross section could be upgraded to 8 lanes. Reducing lane and the slow shoulder widths from 3,7m and 3m to 3,35m and 1,7m respectively achieves the new cross section. A new fast lane shoulder as well as some auxiliary lanes between interchanges needs to be constructed as well.

The site is therefore suitable to evaluate the different sub-systems and to measure the efficiency of these subsystems to improve the capacity of the freeway compared to the construction of new infrastructure or the improvement of the existing infrastructure.

3. FEASIBILITY STAGE RESULTS

3.1 User requirements, Functional Specifications and Architecture

The development of user requirements, functional specifications and a regional architecture were regarded essential to provide a basic framework in which ITS subsystems for this project could be developed and evaluated. It will also ensure that future interoperability with ITS applications/modules excluded from this project could be attained. A steering committee involving all roll players from different spheres of government (local provincial and national) was formed to ensure a coordinated effort.

The approach followed to develop the architecture is two-fold. Firstly top-down and secondly bottom-up. The top down approach comprised the adoption and adaptation of internationally developed user requirements and architecture. User requirements from both the European (KAREN) and United States of America (USA) architectures were utilized and adapted to reflect South African needs and circumstances. These architectures also formed the building blocks for development of the regional architecture. Turbo architecture software, an architecture development tool, was used to develop and visualize the regional architecture.

The above-mentioned approach ensured that user requirements and functional architecture could be developed at a fraction of the cost and time if compared to Europe and the USA.

The bottom-up part of the user requirement and architecture development will take place during the detailed design stage. The lessons learnt as a result of problems encountered during this stage will be incorporated to refine the user requirements and architecture. Further refinement will take place on an ongoing basis during the implementation and monitoring stages.

A decentralized architecture with nominal overall coordination was adopted. This architecture provides for independent operation of the major modules. However, one module is designated as the overall server and coordinator.

It is assumed that the module-operating organization would have delegated power and responsibility to provide the coordinator of all modules with the ability to enable optimization of the whole transport system.

The architecture itself provides several advantages. The architecture enhances the ITS market by providing a common platform for systems integration, both at the level of architecture and the level of deployment. At the deployment level the architecture will contribute to developing consensus standards for ITS interfaces and data exchange. Such standards have the following benefits and impacts:

- Expand market and lower costs. Open-ended standards may result in an expanded market for ITS products and services, with resulting price competition and lower final costs to the end user. Such an expanded market may in turn result in network externalities, where simply having more users may mean additional cost reductions or increased benefits for users.
- Compatibility. Open interface standards also provided many technical benefits to the end user, including: portability, inter-operability, and easier data exchange between ITS applications.
- Technology innovation. ITS standard may impede long term adoption of innovative technologies surrounding a given standard.
- Vendor interests. Long term benefits of standards to ITS product and service vendors may be very favorable.

3.2 Central Management Centre

Different models for a Central Management Centre were explored. The chosen model for this project might however be different from the model to be adopted in future due to the pilot nature of this project. The different models evaluated were:

- A centralized management centre,
- A centralized management centre with outsourcing of some functions such as incident response, communications, public transport etc.; and
- A decentralized management centre with direct links to existing metropolitan traffic control centers.

For the purposes of the pilot project, the decentralized management centre was opted for. The central management centre for the project will collate and process all data received from incident detection systems. The processed data will be forwarded to emergency control centers from the different metropolitan councils from where emergency vehicle dispatching will take place.

The launch of a 115 number for traveler information and traffic incident reporting is under evaluation. The implementation of such a number will require the provision of a call centre which may only became feasible if ITS is deployed on a larger scale and other ITS modules such as public transport is activated.

It is envisaged that the control management centre will continuously monitor clearing of incidents and assist emergency personnel to ensure efficient clearing thereof.

In order to minimize costs, it was concluded that an “off the shelve” central system based on NTCIP communications protocol should be tailored for the project specific needs.

3.3 Communication Backbone

The technologies evaluated for the communications backbone were optic fibre, GPRS, GSM, trunked radio, and dial-up connections by means of landline. None of the options were ruled out and an approach of “horses for courses” was adopted.

Although the initial implementation costs of optic fibre are high in comparison to the other options, the transfer rate of data (in excess of 100 MB/s) and low operating costs made it the obvious choice for the communication backbone between the Central Management Centre (CMC) and roadside equipment such as CCTV, VMS, inductive loops and other emergency management centres. However, the possibility to utilize GPRS for the above-mentioned was not ruled out and is still under investigation.

GSM were earmarked for communications between the CMC and emergency/maintenance vehicles (alternatively trunked radio), remote VMS, and remote inductive loop counting stations.

Dial-up connections can be used as an alternative to GSM as well as optic fibre for communications between the CMC and other emergency management centers, affected authorities, remote VMS’s and inductive loop counting stations.

3.4 Traffic and Incident Detection Systems

3.4.1 Inductive loops

An extensive network of inductive loops is already in place and will therefore be utilized for measurement of traffic flow and speed. The data will be processed and utilized for ramp metering and incident detection purposes.

3.4.2 Closed Circuit Television (CCTV)

The installation of CCTV is cost effective and provides excellent data for traffic management purposes, provided that an adequate communication backbone is in place for data transfer. Since an optic fibre backbone will be installed for the project, a CCTV system that provides full coverage of the freeway will be installed. Apart from incident detection and traffic management purposes, CCTV images can also be used for security and policing purposes.

3.4.3 Aerial Traffic Surveillance

The provision of CCTV cameras for the project makes aerial traffic surveillance unnecessary. Aerial surveillance is expensive and has restrictions such as 15-20 minute cycle times and the impact of poor weather (when the occurrence of incidents are higher) on operations.

3.4.4 SOS Phones

A survey conducted amongst users of the Ben Schoeman freeway, showed that 85% of users own cellular phones. The provision of SOS call boxes next to the road will therefore add very little value to improve incident detection and was therefore not considered for implementation.

3.4.5 User Calls (GSM)

As mentioned, 85% of users of the Ben Schoeman freeway own cellular phones. Calls from cellular phones will require no additional cost to authorities although an efficient system for "call taking" should be in place.

3.5 Traveler Information Systems

3.5.1 Internet

A web page for the dissemination of traffic related information, such as expected travel times; traffic speed and incidents will be developed. Since 49% of respondents of the survey indicated that they have access to the Internet, a traveler information web page will be an effective medium for pre-trip traveler information to road users and the dissemination of traffic information to radio stations for inclusion in their traffic reports. Very few respondents (22%) were willing to subscribe to an e-mail traffic information service. Traveler information will therefore be made available to the public at no charge.

3.5.2 SMS Services and Cellular Phones

Eighty five percent of users on the Ben Schoeman own cellular phones. The dissemination of traffic and incident information by means of SMS will be implemented. Such a service will require a public private partnership. Two payment options, namely monthly subscription or a charge per call is envisaged. The survey conducted indicated that 54% of cellular phone owners would be interested to subscribe to SMS traffic information service.

3.5.3 Variable Message Signs (VMS)

The provision of VMS infrastructure is expensive due the static positioning of these signs and the high frequency required to provide traveler information in time to road users. Some VMS signs will be included in the project at some strategic decision taking positions of the project site. Apart from these signs, the installation of network wide, semi-dynamic signs at strategic decision taking positions is earmarked for implementation. The signs will provide estimated travel times between fixed points.

3.5.4 Traffic Radio

Traffic radio is the most effective medium for the dissemination of traffic information. The survey conducted showed that 89% of respondents listen to traffic reports broadcasted on commercial radio stations. Eighty percent of them use the information for non-specified purposes. Unfortunately, information provided in traffic reports is currently in many instances suspect and not up to date. It will be a function of the Central Management Centre to provide correct and updated traffic information to commercial radio stations. The provision of Highway Advisory Radio (HAR) is under investigation. The provision of such a service can be done cost effectively, but will be dependent on the issuing of a broadcast license by the independent broadcasting authority.

3.6 Traffic Management Systems for recurrent Congestion

3.6.1 Ramp Metering

Different options for ramp metering were evaluated by means of the Paramics micro simulation model of the project site. The options evaluated were:

- Isolated or local systems where metering at a specific ramp is independently of other on-ramps,
- Coordinated systems where ramp metering is applied in a coordinated manner based on traffic flow conditions in the system as a whole, and
- Integrated systems where ramp metering is applied in combination with other traffic control measures such as signal timing and VMS.

It was concluded that the isolated/local system option was most feasible for the pilot project. From the modeling conducted, it was calculated that ramp metering might increase throughput with 8% and reduce travel times by 5%. Geometric improvements to on-ramps are required to accommodate the implementation of ramp metering. Some interchanges were not suitable for ramp metering due to congestion levels experienced at these interchanges. The implementation of ramp metering will cause unacceptable queue lengths with an adverse impact on the supporting road network.

3.6.2 Dynamic Speed Control

The implementation of a dynamic speed control system will require the provision of overhead dynamic signs at at least an 1 000m spacing. As a result of the high cost for providing the necessary infrastructure and the relatively low benefit in terms of improved travel times (modeled to be only 2%), dynamic speed control was found to be unfeasible for implementation. A dynamic speed control sign will however be provided at a rear end accident hot spot where insufficient sight distance is available.

4. **BENEFIT/COST EVALUATION OF ITS SUB-SYSTEMS**

The costs and benefits of the different sub-systems were calculated. The value of time, vehicle operating costs and accident costs were taken into account to calculate benefits to the road user over a five-year period. Maintenance and operational costs for the five-year period were also taken into account in the benefit/cost evaluation. Benefits derived from some of the subsystems such as an Internet website, traffic radio etc. are virtually impossible to calculate in terms of a monetary value. These benefits are indirect and are more focused on customer satisfaction such as allowing users to do trip planning (time of departure, route to be taken etc). Another example of indirect benefits that strengthen the need for implementation is the potential use of CCTV for improved roadside security and assistance with policing. Indirect/non-measurable benefits were taken into account to determine the sub-systems that should form part of the pilot project on the Ben Schoeman Freeway. The systems identified and estimated implementation costs of each are summarized in table 1.

Table 1

	Implementation Cost (2003 Rand)	5 Years Operating Cost (2003 Rand)
Freeway Management		
- Ramp Metering	R 10 m	R 1 m
Incident detection		
- Inductive loops	R 1 m	R 2 m
- CCTV (Complete road coverage)	R 3,5 m	R 1 m
- User calls (GSM)	-	R 1 m
Traveler information		
- Internet	R 1 m	R 1 m
- SMS/Cellular Phones	-	-
- VMS	R 4 m	R 2 m
- VMS Semi Dynamic	R 2 m	-
- Traffic radio (traffic reports)	-	R 0,5 m
Communication backbone	R 3.5 m	R 1 m
Central Management Centre (decentralized)	R 3 m	R 18 m
TOTAL	R 28,5 m	R 27,5 m

Note: R8= $1

5. FREEWAY MANAGEMENT AND INCIDENT MANAGEMENT VS. PHYSICAL CAPACITY IMPROVEMENTS

Freeway management as a tool to improve travel times during recurrent congested periods was evaluated against the benefits derived if physical expansions such as lane additions or new freeways were to be implemented. The Ben Schoeman freeway was evaluated and found to be suitable for so-called value engineering improvements whereby the existing 6 lane cross section could be upgraded to 8 lanes. The results for the different options are summarized in Table 2.

Table 2

Action	Implementation Cost (2003 Rand)	Additional Operations & Maintenance cost for 5 years (2003 Rand) (expressed as a present value)	Travel hours saved in peak periods over 20 years	Additional throughput in peak periods that can be achieved over 20years (vehicles)	Cost/ Throughput (2003 Rand)	Benefit/ cost Ratio
Ramp metering	R 10 m	R 15,2 m	2 million	7,2 million	R 17	6,1
Dynamic Speed Control	R 34 m	R 39,3 m	0,82 million	0,8 million	R 60	0,7
Addition of 1 lane	R 133 m	R 15,2 m	18,6 million	44,9 million	R 24	7,1
Provision of a parallel 4-lane freeway	R 690 m	R 89,3 m	21,5 million	118,5 million	R 11	1,6

Note: R8= $1

Due to relative low road construction cost in South Africa, the benefit/cost ratio for the addition of a lane by means of value engineering (paragraph 2.3) outperformed all the other options. The construction of a parallel freeway system did not outperform the ramp metering option. As part of the evaluation of the feasibility of the different options, the demand for capacity must be taken into account. According to the micro-simulation conducted for this project, a freeway management system cannot provide sufficient capacity to address current capacity demands. The addition or upgrading of infrastructure still requires high capital costs and especially ramp metering provides some reduction in travel times and an increase in throughput effectively (cost/throughput).

Lane additions and the construction of additional infrastructure can however not manage non-recurrent congestion resulting from incidents. Improved response time to incidents will reduce fatalities as well as overall delays. Incident detection and traveler information systems are therefore regarded to be essential for improved network operations.

7. CONCLUSIONS

The development of user requirements, functional specifications and regional architecture is essential to provide a framework in which ITS projects can be designed in order to ensure interoperability within the project and with other ITS modules that may be added in future. The adoption and adaptation of user requirements, functional specifications and architecture that were developed in technological advanced countries/regions can enable transitional countries to produce it at a fraction of the cost and in a fraction of the time.

Knowing the road user needs and thereby developing a road user profile, assists in determining the feasibility of different ITS sub-systems.

The relative low land and road construction costs in South Africa makes the implementation of especially value engineering improvements, to reduce recurrent congestion, more feasible than the implementation of ITS related measures such as ramp metering. The evaluation of ITS versus other options for capacity improvements should take into account capacity demand. Although ITS can not always addresses this demand, it is a cost effective measure to provide some increase in throughput. The capital costs for such infrastructure upgrading is high if compared to ITS related options.

Lane additions and the construction of additional infrastructure cannot manage non-recurrent congestion resulting from incidents. Some of the benefits derived from subsystems such as an Internet website, traffic radio etc. are virtually impossible to calculate in terms of a monetary value. These benefits are indirect and are more focused on customer satisfaction. Improved response time to incidents will reduce fatalities as well as overall delays. Incident detection and traveler information systems are therefore regarded to be essential for improved network operations and user satisfaction.

ITS and especially freeway management systems can alleviate but not address recurrent traffic congestion. Adequate road capacity should therefore also be provided to ensure effective road network operations.

8. REFERENCES

This paper was compiled from various documents that were produced as part of the project development.