THE BENEFITS OF INTELLIGENT TRANSPORT SYSTEMS: MODELLING THE EFFECTS OF DIFFERENT ITS SYSTEMS

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ABSTRACT

Mobility and transportation are the engine to economic growth of a country. Unfortunately this engine shows the signs of the times (i.e. congestion, accessibility and road safety problems), since it is often designed without much consideration for the increasing population of a country, especially in the developing world. At the moment, in nearly all urban areas in South Africa, the common signs of an ineffective traffic and transport (management) system can be experienced: traffic jams during peak hours, little or no use of public transport by the affluent population group, unreliable and unsafe trains and taxis, and unsatisfied customers. Many researchers worldwide are looking for opportunities to improve the situation by implementing technology in the transportation field. Although the research efforts are increasing, the field itself is still new and not explored to its full potential. The annual ITS (Intelligent Transport Systems) world conference has only been organised for the last seven years.

ITS is the integrated application of advanced sensor, computer, electronics, and communications technologies and management strategies providing traveller information to increase the safety and efficiency of surface transportation systems (Intelligent Transport Systems Deployment Network).

According to the ITS Co-operative Deployment Network[1], the following are the projected benefits of ITS expected in the US (period 1996-2015);

- 44% accident cost savings
- 41% time savings
- 6% emissions/fuel savings
- 5% operating cost savings
- 4% agency cost savings
- Less than 1% other savings[2].

It is not easy to estimate the impact of ITS measures. The fact that ITS is still a relatively new field, results in limited practical experience. Current expectations are mainly based on modelling exercises. This paper gives an overview of ITS measures that have been modelled and the expected effects based on the modelling exercises.

Possibilities to model ITS measures are still very limited. This paper provides an overview of ITS modelling results in general and gives an indication of ITS measures, which look promising in the developing world.

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[1] Courtesy of Apogee Report on Global ITS Benefits; http://www.nawgits.com/nawg/itsaware/mod1/sld012.htm

[2] Security improvement is an important expected benefit as well, but it was not mentioned in the Courtesy of Apogee Report

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1. INTRODUCTION

One of the main problems facing our society today is the ever-increasing need for transport. Gone are the days when the demand in transport was met merely by the establishment of new roads and other transport infrastructure. Development in the transportation field is now progressively tending towards optimising the use of existing facilities through careful planning, management and maintenance. The latter is made possible by the introduction of Intelligent Transport Systems (ITS). This entails the application of integrated computer related technologies that are applied to transport systems to improve efficiency and effectiveness of transport and traffic conditions.

Since ITS is a relatively new development (except traffic signal control) in the transportation field, the need to model ITS is of utmost importance. Developing a model for simulating the effect of ITS measures could assist the process of transport-related decision-making, based on the greatest benefit of ITS proposals to existing users.

Traditional transport models are not equipped to simulate all different ITS measures and driver behaviour changes caused by ITS. During a European study researchers were asked what ITS measures should be available in micro simulation models (Hugosson, et al, 1997). The result is shown in Figure 1.

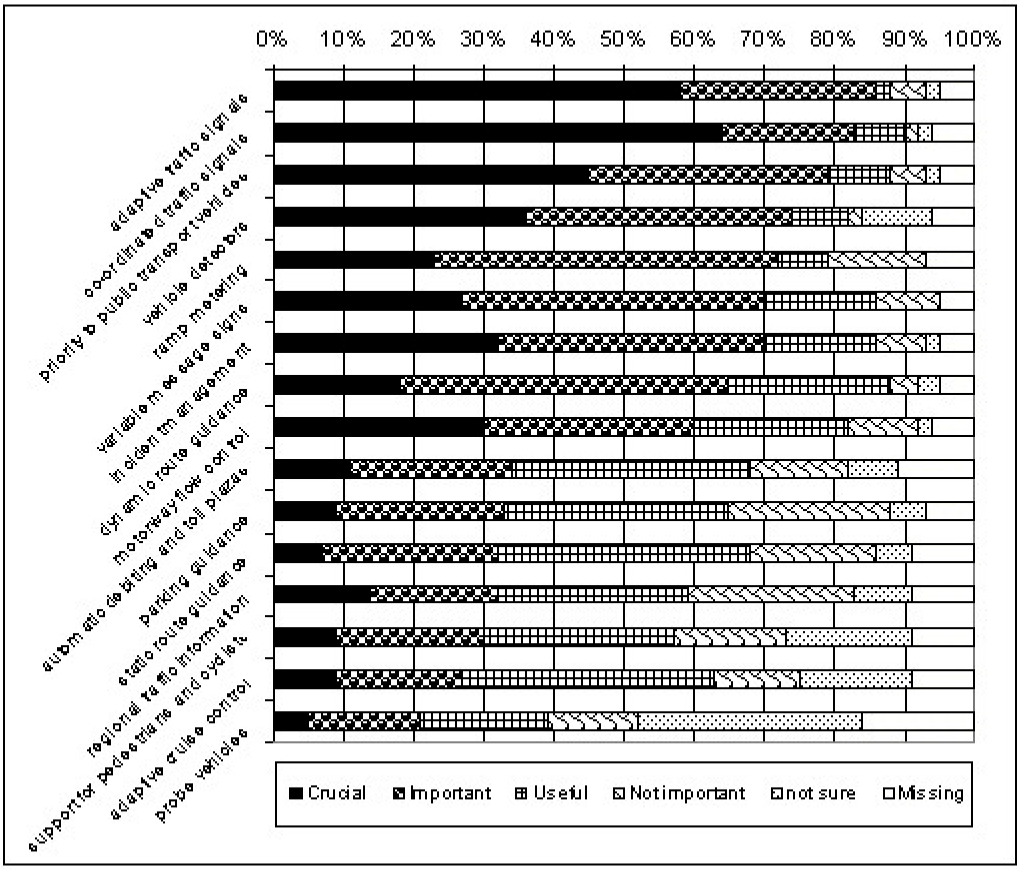

Figure 1. Overview of the required ITS measures in simulation tools (n=44)
Source: Hugosson, et al, 1997.

Subsequently, much research has focussed on the comparison of various ITS measures using micro-simulation models. The aim of this paper is not to repeat these comparisons. A brief review of the situation based on the work of a European consortium (Schmidt et al, 1999) is presented in Table 1.

Table 1. Comparison of ITS measures available in (micro) simulation models.

	Micro simulation model				**4-step model**
Measure	**CORSIM**	**AIMSUN2**	**INTEGRATIO N**	**CONTRAM-I**	**EMME/2**
Adaptive Urban Traffic Control	Some US features could be used for Swedish conditions. *SCORE: 1*	Some good features, DLL could be used for truly VA control. *SCORE: 4*	As for AIMSUN2 but with possible external interface. *SCORE: 3*	No explicit modelling. Delay impact as input. *SCORE: 2*	No explicit modelling. Network effects if combined with micro? *SCORE: 2*
Motorway Flow Control	Lane blockage, but not MCS could be modelled. *SCORE: 2*	Could be realised, but not to the level of safety indicators. *SCORE: 3*	Very good, without the need for explicit modelling. *SCORE: 4*	New V/D function needed. Bad queuing representation need. *SCORE: 2*	No queuing representation. *SCORE: 1*
Incident management	By changing incident duration. No rubberneckin g effects. *SCORE: 3*	By changing incident duration. No rubbernecking effects. *SCORE: 4*	By changing incident duration. No rubbernecking effects. *SCORE: 4*	By changing capacity, incl. Rubberneckin g effects. *SCORE: 3*	By changing capacities and splitting O/D, but no dynamics. *SCORE: 1*
Pre-trip information via radio	No explicit modelling. Departure time impact as input. *SCORE: 1*	No explicit modelling. Frequency of updating can be used. *SCORE: 2*	No explicit modelling. Capacity constraints can be used. *SCORE: 2*	No explicit modelling. O/D- matrices for 5-min periods can be used. *SCORE: 3*	Not possible to model. *SCORE: 0*
Planning and evaluation of Variable Message Signs (VMS)	Does not contain a route choice model. *SCORE: 0*	Prepared for VMS control algorithms but route choice model dubious. *SCORE*: 3	Behaviour and control algorithms cannot be modelled. *SCORE*: 2	Can be modelled by manipulation. *SCORE*:2	Cannot model reference case without information but some aspects of VMS can be modelled. *SCORE*: 1
Route choice effects of road pricing	No route choice. *SCORE: 0*	No equilibrium assignment. No generalised cost. *SCORE: 1*	Equilibrium assignment with generalised cost possible but not validated. *SCORE: 2*	Equilibrium assignment with generalised cost possible. *SCORE: 4*	Equilibrium multi class generalised cost assignment. *SCORE: 5*
Dynamic speed control	No explicit modelling. *SCORE: 1*	No explicit modelling. A new ISA[3] vehicle can be introduced. *SCORE: 3*	No explicit modelling. *SCORE: 1*	Not possible to model. *SCORE: 0*	Not possible to model. *SCORE: 0*

Source: Schmidt et al, 1999

3 ISA = Intelligent Speed Adaptation

CORSIM, AIMSUN, INTEGRATION and CONTRAM-I are different micro-simulation models, each having advantages and disadvantages in modelling ITS. EMME/2 is a traditional 4-step model, which is equipped to simulate some ITS measures. The investigators scored the different models an a scale from 0 to 5[4].

Table 2. Efficiency of different ITS measures.

Measure	Speed	Travel time	Throughput	Shock waves[5]
Autonomous Adaptive Cruise				
Control[6]	0%	-1.5%	0%	-80%
▪ 50%	-3%	+1%	+1%	-73%
▪ 50% and special lane (SL)	-1%	0%	+1%	-71%
▪ 50%, SL and short headways	-1%	-1.5%	+1%	-84%
▪ 60%, SL and short headways				
Autonomous Adaptive Cruise	N/A	N/A	+7%	N/A
Control[7]	N/A	N/A	+2%	N/A
▪ 40%				
▪ 100%	N/A	N/A	+18%	N/A
Cooperative Adaptive Cruise Control[7]	N/A	N/A	+100%	N/A
▪ 40%				
▪ 100%				
Dynamic road profile[8]	-30%	N/A	30%	N/A
Dynamic road profile[9]	-5.9% to +43.9%	N/A	-1.6% to 17.7%	-4%
Dynamic Route Information Panel[10]		0% to –42%[11]		
Homogenise via speed limits (VMS)[12]	-9.8% to +1.5%	N/A	-6.6% to +1.6%	+4.8%
Freeway Management System[13]	+16% to +62%	-13% to –48%	+8% to +25%	N/A
Intelligent Speed Adaptation[14]	-10%[11]	+1%[11]		
Paylanes[9]	-15.7% to	-42% to –56%	-1.9% to +2.4%	N/A
▪ Paying drivers	+3.1%	+15.2% to		
▪ Non-paying drivers		+25.3%		
Peak lane[9]	-5.6% to 50.7%	N/A	-1.5% to +18.1%	-4%
Ramp metering[9]	-5.2% to +8.2%	N/A	-1% to +0.8%	+0.6%
Ramp metering[15]	+13%	-28%	0% to +24%	N/A
Ramp metering[16]				
▪ Morning peak	N/A	-21% to +45%[17]	N/A	N/A
▪ Evening peak	N/A	-23% to +22%	N/A	N/A
Road-trains[18]	0%	0%	More freight	0%
Toll Roads[19]	N/A	-23% to – 31%	-16% to 0%	N/A

N/A = Not Available

4 Score 0 = model not equipped to simulate this measure at all; Score 5 = measure can be simulated very well by the model
5 Number of Shock waves is indication for the road safety situation; some studies use number of stops.
6 Vanderschuren, et al, 2000
7 VanderWerf, et al, 2002
8 Tampère, 1999
9 Stemerding et al, 1999
10 Straaten, van, 2001
11 Estimated; based on different graphs
12 The speed is reduced from 120 km/h to 90 km/h
13 Thomas, 2001
14 Lui, 2000
15 Cloete, 2002
16 Westra et al, 2002
17 There is a positive impact on the travel time on the highway and a negative impact on the secondary road network.
18 Hoogvelt, et al, 1999
19 Oberholzer, et al, 2001

2. OVERVIEW OF BENEFITS OF DIFFERENT ITS MEASURES

Besides the problem of a limited amount of ITS measures that can currently be modelled, the question that arises is what are the most efficient measures. To give a more comprehensive view on the efficiency of different ITS measures, it would be necessary to add direct and indirect costs as well. Unfortunately this falls outside the scope of this paper.

To give an impression of the efficiency of ITS measures, data from different studies (using different models) has been collected and compared. The extent of the comparison was limited due to time restraints. A broader comparison will follow in the future. Table 2 summarises the comparison.

The reader has to keep in mind that the results of these studies have been calculated using different dynamic models. Some studies include an increased demand in the future, others don't. Moreover, the research period of different studies varies, which influences the findings. Despite these differences, a general impression of the impact of ITS measures in Europe can be achieved.

The effect of Autonomous Adaptive Cruise Control (AACC) on speed, travel time and throughput (traffic flow) is minor in the study described by Vanderschuren et al (2000). Nevertheless, the reduction of shock waves, which is an indication of an improvement of the road safety situation, is phenomenal. Another study done by VanderWerf et al (2002), indicated that more advanced Adaptive Cruise Control (Cooperative Adaptive Cruise Control) will have a major impact on the throughput. Twice as many vehicles will be able to use the road if 100% of the vehicles have Cooperative ACC.

Dynamic road profiles (4 smaller lanes with lower maximum speed instead of 3 traditional lanes) during peak hour clearly increase the capacity of the road (indicated by the throughput). An estimated capacity increase of 30% is very promising. The study done by Stemerding et al (1999) indicated that the overall throughput increases with about 5%. In this study the maximum speed decreased from 100 km/h to 70 km/h. The decrease of the number of stops (4%) is an indication that the road safety situation has improved.

Dynamic Route information Panels are Variable Message Signs (VMS), which inform the driver about congestion ahead and/or expected travel times. The study by Van Straaten (2001) shows that these types of VMS reduce the severity of congestion. Average travel times decrease by up to 42%.

Homogenising via speed limits does not always result in more homogenised traffic, at least not with a new maximum speed limit of 90 km/h. The total throughput in this study decreases with 2%; more traffic is using the secondary road network (Stemerding et al, 1999). Moreover, the amount of stops increases which is negative for the road safety situation. Analysing the details, the author reckons that the limits of the used software might have influenced the results as well.

The effects of a freeway management system are very promising. Estimated decreases of travel times up to 48% are remarkable. An estimated increase of the capacity of the road (throughput) of up to 25% is a hopeful indicator as well (Thomas, 2001).

The results partly appear so positive because a freeway management system is a combination of:

- Variable Message Signs (VMS);
- Radio reports;
- Advanced mobile information systems, such as in-vehicle monitoring;
- Automatic toll collection or electronic fare payment and
- CCTV security surveillance (incident management) and vehicle identification.

The aim of Intelligent Speed Adaptation (ISA) is an improvement of road safety. As it is not possible for drivers to exceed the speed limit, the average speed of vehicles decreases (34% of the vehicles previously exceeded the speed limit). The changes in total travel time are minor. Although this study does not provide shockwave information, it is expected that ISA will reduce shockwaves and therefore improve the safety situation on the roads. Peak lanes manage to decrease the congestion risk and keep the flow more homogenised. The total throughput increases with about 5% and a 5% return of traffic travelling during peak hour (currently at other times) is estimated (Stemerding et al, 1999). The road safety situation improves slightly.

Stemerding et al (1999) have modelled ramp metering as well. The general outcome is that the throughput does not change (neither on the highway nor on the secondary roads) and the speed increases slightly; 8% overall. A first estimate of the benefits of ramp metering in South Africa (Cloete, 2002) also indicate an increase of speed (+13%) and a decrease of the travel time (-28%). In this study the transferability of developed world models was not investigated. Results might therefore not be completely accurate. The results of the ramp metering study done by Westra et al (2002) indicates that ramp metering can have a positive and negative impact on the travel time. Overall the Travel time increases with 2% in the morning peak. In this study the total travelled distance was also analysed. The distance hardly changes; neither in the morning peak nor in the evening peak.

Road trains are vehicles longer than currently allowed in Europe. The modelling exercise clearly shows that freight can be transported without any negative effects for the speed, travel time or safety of other road users. Nevertheless, the road deterioration in South Africa due to heavier vehicles indicates that other aspects have to be reviewed before introducing new type of lorries (Hoogvelt et al, 1999).

The introduction of toll collection on freeways will change the driver behaviour. Some drivers will use an alternative road, which will decrease the intensities on the freeways (decreases up to 16%). Due to this change of behaviour travel time will decrease by between 23% and 31% (Oberholzer et al, 2001).

3. PROMISING ITS MEASURES IN SOUTH AFRICA

The University of Cape Town has recently developed an interest in Intelligent Transport Systems and micro-simulation modelling. As a first step an investigation of the ITS field was done. To be able to analyse the applicability of ITS in South Africa a further split between private cars and public transport is needed.

This chapter therefore provides an overview of available ITS measures for (see also table 3):
- Infrastructure;
- The private vehicles and
- Public Transport.

The aim of Intelligent Transport Systems can vary. The main aims identified are as follow:
- *Efficiency (management)*; Measures aim to optimise the use of road capacity, reduce unnecessary and inefficient driving,
- *Safety and security*; Safety related ITS measures will aim to reduce accidents and dangerous situations while security systems will reduce the risk of personal attacks or attacks on personal goods,
- *Pre-trip information*; Information provided before a trip has started,
- *On-trip information*; Information provided while a person is undertaking the trip,
- *Ticketing and pricing*; Collection of financial means and

- *Enforcement and control*; The use of ITS systems to assist the police and other law enforcement institutions.

Table 3. Overview of ITS measures per application area.

Areas of application	Transport					Infrastructure	
	Private vehicles		Public transport			Highways	Secondary roads
	Cars	Trucks	Trains	Buses	Taxis		
Efficiency (management)	▪ Navigation systems ▪ Parking systems ▪ Cruise control		▪ *High-speed ground transportation*	▪ *Public transport priority (scoot)*		▪ *Ramp metering*	▪ Traffic control (scoot)
			▪ *Fleet management (monitoring)* ▪ *System integration* ▪ *Electronic ticketing* ▪ *Transportation demand management via information provision*			▪ *Variable speed limits* ▪ *Lane management* ▪ *Electronic toll collection* ▪ *Incident management*	
Safety and security	▪ Navigation systems ▪ Parking systems ▪ Cruise control ▪ Warning systems ▪ *Intelligent Speed Adaptation* ▪ Black box systems		▪ *High-speed ground transportation*			▪ *Variable speed limits* ▪ *Lane management* ▪ *Incident management* ▪ Warning systems ▪ *CCTV cameras*	
			▪ *Fleet management (monitoring)* ▪ *Electronic ticketing* ▪ *CCTV camera's*				
Pre-trip information	▪ Real time information					N/A	
On-trip information	▪ Real time information ▪ Navigation systems ▪ Parking guidance		▪ Real time information ▪ *System integration*			▪ Waning systems ▪ Parking guidance	
Ticketing and pricing	▪ Road pricing ▪ *Electronic toll collection*		▪ *Electronic ticketing*			▪ *Lane management* ▪ *Electronic toll collection*	
Enforcement and control	▪ *Automatic Vehicle identification* ▪ *Intelligent Speed Adaptation*			▪ *Automatic Vehicle identification* ▪ *Intelligent Speed Adaptation*		▪ *Automatic Vehicle identification* ▪ *Intelligent Speed Adaptation* ▪ *Weight in motion*	
			▪ *Electronic ticketing*				

Table 3 provides an overview of the ITS field. The different systems deserve a further description. Within the limited space of this paper it is not possible to provide a full description of each ITS measure. Moreover, it is not possible to provide all arguments why certain ITS measures have been identified to be useful in South Africa. In general the aim is to select systems, which have a broad benefit for the society. Systems, which aim to provide benefits for the individual user, many private car systems, are not selected.

Systems identified to be beneficial in the South African context are:

- Intelligent Speed Adaptation for private vehicles and public transport (mini-bus taxi);
- Electronic toll collection with the aim to generate additional funds;
- Automatic Vehicle identification, mainly to assist in law enforcement;
- High-speed ground transportation to provide a more environmental friendly long distance mode;
- Fleet management to monitor public transport (including mini-bus taxi) vehicles;
- System integration to provide a better public transport system for the majority of the population;
- Electronic ticketing to decrease the security situation connected with cash flows and be able to generate accurate demand data;
- Transportation demand management via information provision;
- CCTV camera's to improve security;
- Ramp metering to homogenise traffic flows on the highway systems;
- Variable speed limits to homogenise traffic flows on the highway systems;
- Lane management to increase capacity without building additional lanes;
- Incident management to decrease the negative impact of an accident and
- Weight in motion to reduce the road damage caused by overloaded trucks.

4. CONCLUSIONS AND RECOMMENDATIONS

Estimates of the effects of Intelligent Transport Systems (ITS) based on micro simulation models are very promising. Most promising is a general expectation of decreasing travel times and increasing road capacity. As road building has proven not to be the answer to congestion, a further investigation of ITS measures is recommended. The author of this paper is currently working on a PhD in this direction.

The investigation of the effects of the introduction of ITS measures in the developing world (i.e. South Africa) has only started recently. As South African problems are often similar to developed world, for example congestion, possible measures might be the same. Nevertheless, the question is, if developed world models can be applied in the South African context. The author has the impression that certain behaviour, for example lane change behaviour, is different. The University of Cape Town will investigate these types of differences in the near future.

In the PhD several of the selected ITS measures, which look promising in the South African context, will be included. Some measures will be realised by using dynamic simulation models, mainly the infrastructure measures. With regards some of the measures related to public transport, a case study is planned.

The modelling of ITS measures is still problematic. Many possible ITS measures are not in the models. Moreover, included measures are not always programmed in the manner required by the researcher. The expectation is that this problem will reduce over time as a lot of emphasis is put into the improvement of micro-simulation models. Moreover, this hopefully will improve the suitability of these models in the South African situation as well.

Modelling of ITS measures in South Africa deserves further research effort. Moreover, the expected effects and cost of different ITS applications should be looked at, in an integrated way.

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