THE FEASIBILITY OF USING MOBILITY PERFORMANCE MEASURES FOR CONGESTION ANALYSIS IN SOUTH AFRICA

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ABSTRACT

Urban areas across the globe have experienced alarming increases in traffic congestion over the past twenty years. As a result performance measures based on average travel time (referred to as *mobility performance measures*) have been studied by various institutions.

Several transport authorities in the United States have adopted these measures to monitor trends in travel patterns and to provide a platform for the comparison of congestion levels.

The most important functions of mobility performance measures are to:

- Evaluate existing mobility conditions;
- Indicate trends in traffic congestion;
- Assess the impact of public and private infrastructural investment;
- Compare levels of traffic congestion between major routes and cities; and
- Determine the impact of travel delays on the economy.

South Africa is also affected by increasing levels of traffic congestion, spurred by the rapid economic growth of the past fifteen years. There is currently no standardized system to monitor congestion and South Africa can therefore benefit from the use of mobility performance measures.

The objective of this paper is to investigate the feasibility of using mobility performance measures in South Africa to monitor trends in traffic congestion and the impact of transport improvement projects on urban transport networks.

INTRODUCTION

Traffic congestion is an increasing global problem, affecting the quality of life of billions of people. Many countries in the developing world face extreme congestion due to rapid economic growth and a lack the necessary infrastructure and planning.

South Africa experienced tremendous economic growth over the past fifteen years with the real GDP per capita growing from -3% in 1991 to +4.8% in 2007 (refer to Figure 1). The corresponding increase in income per capita led to higher spending and credit generating patterns, especially by the emerging middle class, causing an increase in vehicle sales (refer to Figure 2) and therefore also in traffic congestion.

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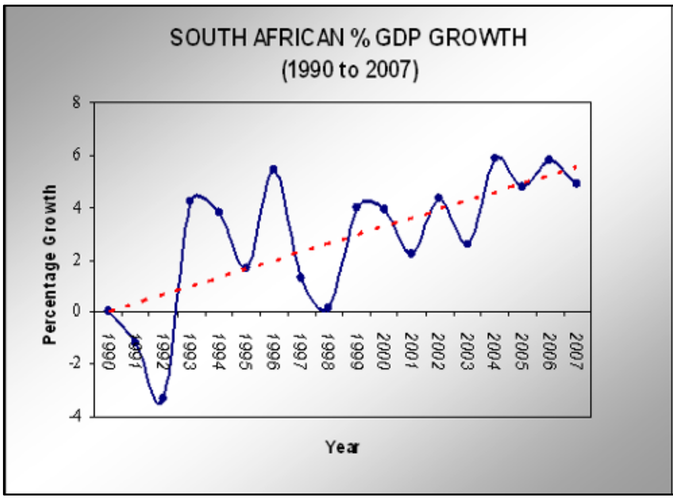


Figure 1: Growth in South African Real GDP (Reserve Bank Quarterly Bulletin)

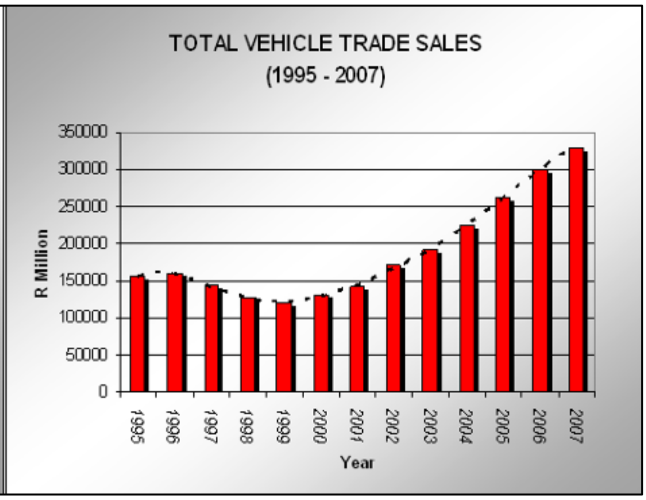


Figure 2: Growth in South African Domestic Car Sales (NAAMSA)

PROBLEM STATEMENT

Traffic congestion in South Africa are currently not measured on a regular basis order to monitor the impact of transport related improvements on an area-wide, intra-modal basis. Major investments are being made across South Africa to improve urban road networks, road based public transport and commuter rail services and it is estimated to continue well into the next decade. Whilst some of these projects focus on alleviating urban congestion experienced by commuters, many are aimed at improving transport capacity for the 2010 Soccer World Cup. The motivation for many transport projects is therefore not necessarily rooted in long term integrated planning, as should be the case, but rather a short term target.

How would the combined impact of these improvements be measured and assessed in the long term?

Traditionally the evaluation of transport performance is based on Capacity Analysis and Level-of-Services (LOS) as developed by the United States Transportation Research Board in their *Highway Capacity Manual, 2000.* Although this manual contains methods to obtain the LOS for corridors, the evaluation of area-wide congestion and the impacts of multimodal transport improvements are still being investigated.

In recent years performance measures based on average travel time (referred to as *mobility performance measures*) have been developed, aimed at determining the impact of area-wide congestion in a way that is easily communicated to the public. More than 85 cities in the United States have already adopted these measures to evaluate the impact of traffic congestion on their society and economy as part of an annual mobility report.

The question is therefore if South African cities can also implement these mobility performance measures to regularly evaluate trends in traffic congestion on our roads on a national level.

OBJECTIVE

The objective of this paper is to investigate the feasibility of using mobility performance measures in South Africa in order to monitor trends in traffic congestion and the impact of transport improvement projects on urban transport networks.

Determine mobility measures for urban areas in South Africa would enable authorities to:

- evaluate existing mobility conditions for people and freight;
- indicate trends in traffic congestion on a year-to-year basis;
- assess the impact of public and private investment in roads infrastructure and planning;
- compare traffic congestion between major routes and cities;
- compare South African conditions to those of other countries;

- determine the impact of travel delays on the economy;
- evaluate future traffic scenarios.

This paper therefore focuses on the investigation of:

- the suitability of existing internationally developed performance measures for South African conditions;
- the availability and suitability of required data-sources;
- South African case studies.

LITERATURE STUDY

A set of mobility performance measures was developed and formalized by the Texas Transportation Institute (TTI) from 2003 to 2005 and compiled into *The White Paper: The Keys to Estimating Mobility in Urban Area* to assist authorities in evaluating the status of congestion in their areas. This document recommends the use of travel-time based measures as opposed to V/C-Ratio and Level-of-Service (LOS) and states that mobility measures have several advantages over these conventional methods in that they:

- yield numeric values that can be easily compared for different scenarios and study areas;
- reflect transport related improvements better than LOS;
- can be corridor, route or network based;
- reflect the combined impact of all modes;
- are more easily understood by the public.

Mobility performance measures are categorized into individual indices, relating to the average commutor and absolute indices, relating to the transport network as a whole. The *Travel Time Index (TTI)* is the most commonly used mobility performance measure and compares travel times during congested conditions to travel times during ideal conditions. The TTI is therefore a ratio that indicates the additional time needed to travel a distance during peak travel as opposed to target (free-flow) conditions. The weighted average ratio for freeways, arterials and public transport can be calculated to obtain a corridor or area-wide index.

$$\text{TTI} = \frac{\text{Peak Period Travel Time Per Person}}{\text{Free-flow Travel Time Per Person}} \qquad (1)$$

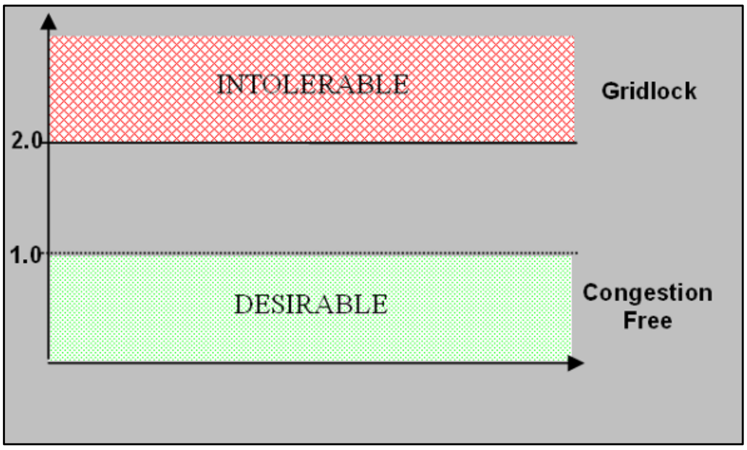


Figure 3 : Evaluation of TTI

The concept of a Travel Time Index is easily understood by the public. As indicated in Figure 3, a TTI of equal or smaller than 1 depicts congestion-free travel where average speeds are equal to or above the target speed. Where the TTI nears or exceeds 2, traffic is heavily congested and gridlock conditions occur as only half the free-flow speed is achieved.

Other mobility measures includes:

INDIVIDUAL MEASURES	ABSOLUTE MEASURES
Delay Per Person km [Person-minutes]	Total Delay [Person-Hours].
Delay Per Km [Person-hours]	Congested Travel [km]
Buffer Index (BI)	Percentage of Congested Travel [%]
Planning Time Index (PTI)	Congested Travel [Person-kms]
Texas Congestion Index (TCI)	Congested Travel [Person-hours]

Every mobility measure focuses on a different aspect of congestion. For example individual indices such as *Person Delay* per kilometer are useful in communicating to the public how many hours of time are wasted for each kilometer travelled, on a daily or yearly basis. Absolute measures such as *Total Delay* indicate the summed impact of delay on the whole assessment area. These values are of great use to authorities in the evaluation of the impact of improvement projects etc.

DATA REQUIREMENTS

An advantage of traffic mobility measures is that the required data is fairly basic and can be obtained by utilizing a variety of data sources. The necessary data is often already collected for other forms of traffic monitoring and modeling and can generally be easily obtained.

Travel times can be collected through direct or indirect methods, depending on transport mode that is being studied and the available technology. Direct methods includes travel time runs whilst indirect measures refer to ITS data, traffic modelling, traffic counts and even high resolution aerial imagery.

In South Africa electronic counting stations have been widely installed on primary National and Provincial Routes and serves as valuable database for travel time studies. Traffic models have been developed for most South African Metros, but the calibration of these models is usually infrequent. Where no electronic counting data or reliable traffic models are available, manual counts can be used to derive travel time information by means of the relationship between speed, flow and density.

CASE STUDIES

Two densely populated areas, Gauteng and The City of Cape Town, have been identified in order to evaluate the feasibility of using mobility measures to monitor performance of South African urban transport infrastructure. Approximately 27% of the country's population is concentrated in these two metropoles and both are severely affected by traffic congestion. Both metros are currently planning and implementing extensive transport improvement projects to alleviate the situation and mobility analysis would therefore be useful to monitor the impact of these projects.

Due to lacking resources and time limitations only the busiest route in each study area was analysed as part of this study. Several peak period scenarios were analysed, but only the am peak period scenario is discussed here: The focus was placed on the calculation of *Travel Time Indices (TTI)* to demonstrate how mobility measures are calculated and can be used for the comparison of different routes and scenarios.

SCENARIO 1: AM Peak Period

The 06:00 am to 09:00 am peak period in the peak direction is defined for the calculation of a realistic worst daily Travel Time Index for road users.

Peak period analysis is used because it is assumed that most peak period trips exceed an hour and the *morning* peak direction is used because it is generally more severe than the afternoon peak as indicated in Figure 4.

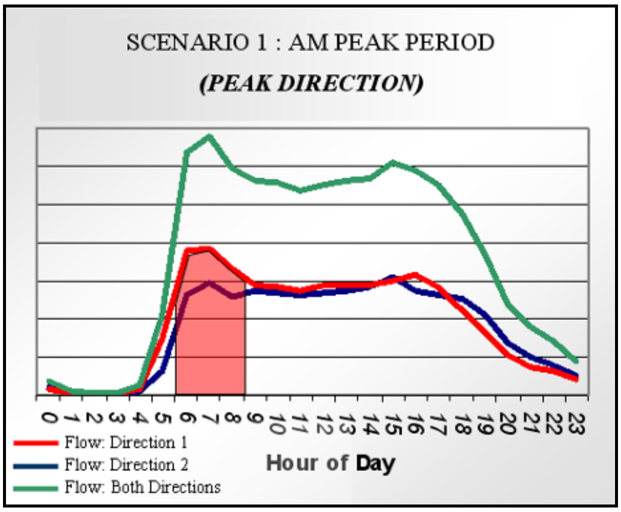


Figure 4: Scenario 1 am Peak Period

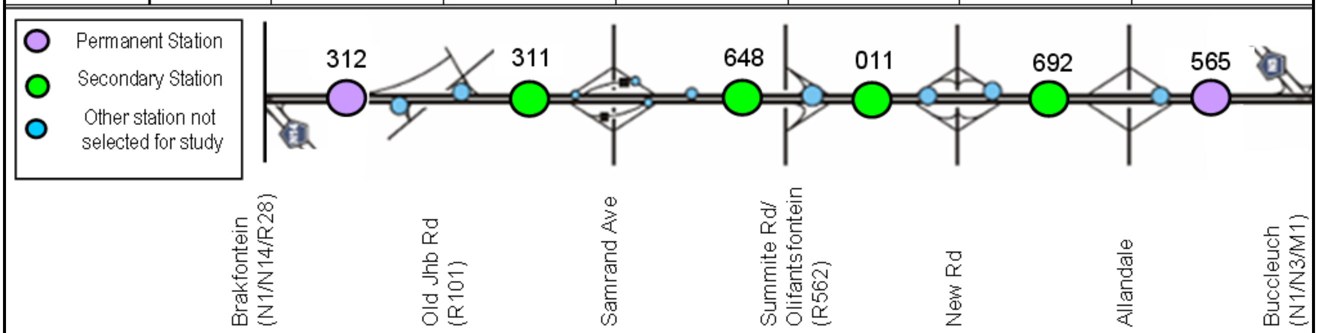
Study Area 1 : Gauteng

Description

The N1 between Johannesburg and Pretoria (Tshwane) carries up to 180 000 vehicles per day and is selected as Study Area 1. Electronic counting stations have been installed on this route as part of SANRAL's Intelligent Transport System (ITS) project and datasets are available from 2000 to 2007, with selected data for 2008. The data is used to calculate yearly Travel Time Indices for road segments from Brakfontein to Buccleuch. Annual average daily traffic properties for 2007 are listed below.

Table 1 : Summary of Daily Traffic Properties per Road Segment for 2007 (Case 1)

Station	312	311	648	011	692	565
Location	Brakfontein	Randjies-fontein	Headway Hill	Halfway House	Midridge Park	Kyalami
Segment Length	3.3	2.8	3.0	3.1	4.1	4.1
Lanes	6	6	6	6	6	8
AADT Both Directions	135305	112920	133745	140508	146963	179277
Speed Limit	120	120	120	120	120	120
Average Daily Speed	97.1	95.5	101.6	94.0	97.6	93.0
Average Daily 85th Percentile Speed	114.1	110.8	118.8	110.9	114.2	109.5



Evaluation

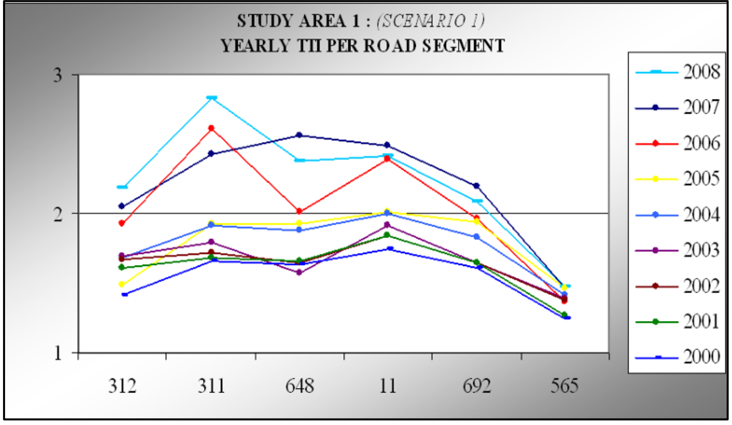


Figure 5 : TTI per Road Section (Case 1).

Analysis of the major (am) peak period (south bound) showed that average TTI values exceeding the critical value of 2.0 had been reached for most road segments in 2007 (shown in Figure 5 and listed in red in Table 2.)

The weighted average TTI for 2007 is 2.05, indicating that gridlock conditions are experienced throughout the peak period and that delays are unacceptable. The implementation of shoulder utilization between Annandale and Buccleuch Interchanges in 2006, is reflected by a decrease in the TTI for Station 565 from 1.47 in 2005 to 1.36 in 2006. (italised in Table 2). Unfortunately the positive effect from the additional lane has already been phased out in 2007, with the TTI being back at 1.46, probably due to traffic growth and induced traffic. The effects of ramp metering, introduced in October 2007 at Old Johannesburg Road, (Station 648), Samrand Road (Station 011) and New Road (Station 692) are more significant with all these road segments experiencing a reduction in TTI values in 2008. It would be insightful to compare results for 2009, once data is available, to see whether the effects of ramp metering are more lasting than that of extra capacity.

Table 2 : TTI per Road Section (Case 1)..

Year \ Station	312	311	648	011	692	565	Weighted Average
2000	1.41	1.60	1.58	1.74	1.56	1.24	1.52
2001	1.61	1.68	1.66	1.84	1.64	1.27	1.59
2002	1.68	1.71	1.65	1.85	1.64	1.38	1.62
2003	1.69	1.79	1.57	1.91	1.64	1.40	1.63
2004	1.68	1.92	1.88	2.00	1.83	1.42	1.74
2005	1.49	1.93	1.93	2.01	1.94	1.47	1.77
2006	1.93	2.61	2.01	2.39	1.96	***1.36***	1.92
2007	2.04	***2.56***	2.43	2.48	2.19	1.46	2.05
2008	2.16	2.83	***2.38***	***2.42***	***2.09***	1.48	2.07

Average values for the whole study area from Brakfontein to Buccleuch are indicated in Figure 6. Travel times have steadily increased over the last eight years in spite of efforts to improve the situation. It can however be argued that the traffic congestion would have been more severe had it not been for projects such as the Highway Management (ITS) Project.

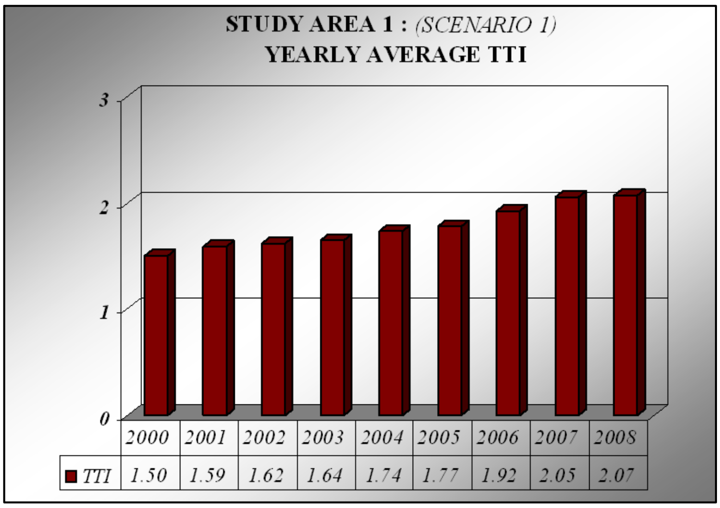


Figure 6 : Average TTI values (Case 1).

Study Area 2 : City of Cape Town

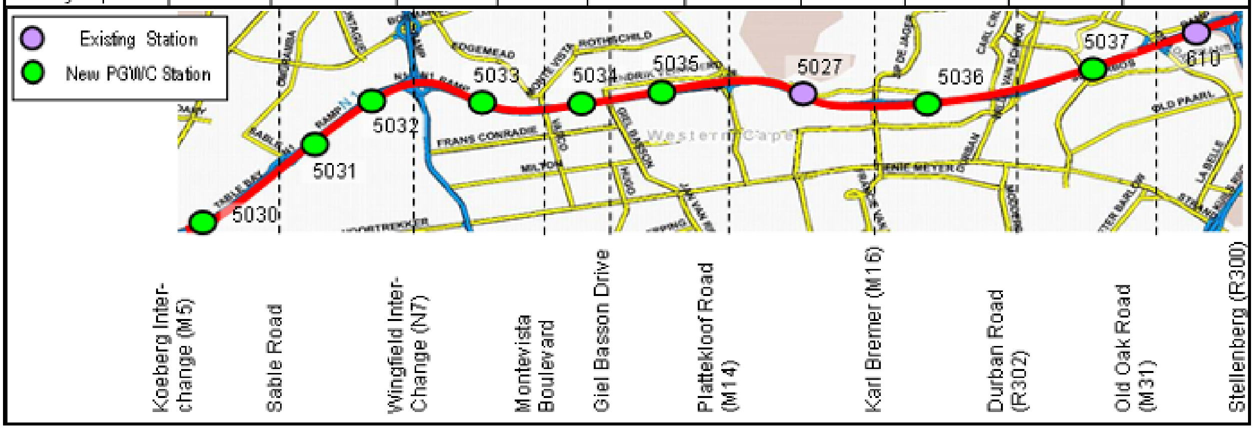
Description

Similar to Gauteng, the Cape Metropole experiences severe traffic congestion due to a rapidly growing population as well as growth in vehicle ownership. The most congested route is the N1 corridor between Brackenfell and the City Centre, carrying more than 120 000 vehicles per day on certain sections. The congestion is aggravated by insufficient public transport facilities and increasing residential development in the corridor's catchment area.

The route segment between R300 and Koeberg Interchanges falls under the authority of the Department of Transport and Public Works of the Western Cape Provincial Administration (PGWC). This segment is selected as Study Area 2 because of the recent installation of seven electronic counting stations (refer to Figure 5). The route compares well to Study Area 1 in terms of road characteristics and length. Consistent data for Study Area 2 is only available from 2007 and data from manual counts was used to calculate mobility indices for 2000 and 2004. The locations of the electronic counting stations are shown below and a summary of their annual traffic properties for 2007 is listed in Table

Table 3 : Summary of Daily Traffic Properties per Road Segment (Case 2)

Station	5030	5031	5032	5033	5034	5035	5027	5036	5037	610
Description	Koeberg to Sable	Sable to Century City	Century City to N7	N7 to Monte Vista	Monte Vista to Giel Basson	Giel Basson to Plattekloof	Platte-kloof to Jip Jager	Jip de Jager to Durban Road	Durban Road to Old Oak	Old Oak to R300
Segment Length	1.5	2.6	1.3	2.1	1.8	1.0	2.2	2.2	2.8	1.5
Lanes	6	8	8	6	6	8	7	6	5	6
AADT Both Directions 2007	119580	108725	116108	120425	107047	125769	133347	135608	106326	73961
Speed Limit	120	120	120	120	120	120	120	120	120	120
Average Daily Speed	92	100	99	98	100	100	93.0	96	90	95



Evaluation

Data for the am peak period in the peak direction (west bound) from 2000 to 2007 is shown in Figure 7 and listed in Table 4.

The Koeberg - Sable Road link (Station 5030) experienced a severe decrease in travel speeds which can be attributed to its close proximity to the city centre, as well as geometric shortcomings of the Koeberg Interchange. The TTI increased significantly from Durban Road to Old Oak Road and Old Oak Road to the R300 (Stations 5037 and 610). This can be ascribed to extensive new residential development in the Brackenfell area and the fact that only five lanes in total are present for this link.

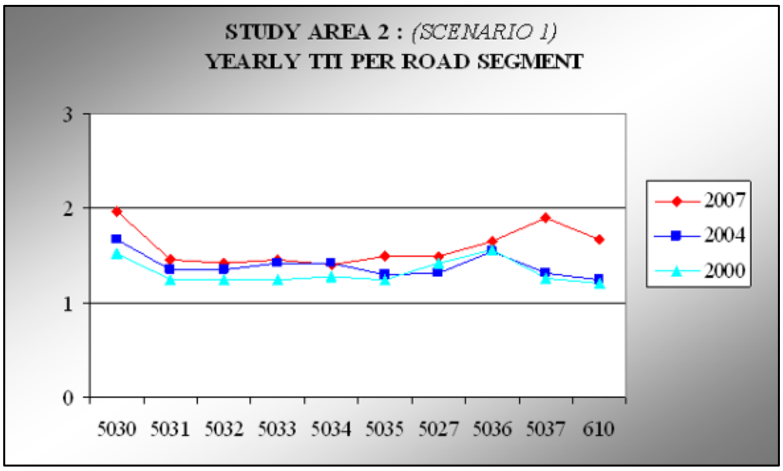


Figure 7 : TTI per Road Segment (Case 2).

Table 4 : TTI per Road Segment (Case 2).

Station / Year	5030	5031	5032	5033	5034	5035	5027	5036	5037	610	Weighted Average
2000	1.53	1.24	1.24	1.25	1.28	1.24	1.42	1.56	1.26	1.21	1.33
2004	1.66	1.35	1.35	1.43	1.42	1.30	1.32	1.55	1.32	1.24	1.41
2007	1.97	1.45	1.43	1.46	1.40	1.48	1.49	1.65	1.90	1.67	1.61

Average TTI values increased from 2000 to 2007 as indicated in Figure 8. Travel times for Study Area 2 showed less deterioration than values for Study Area 1. This is to be expected since the Gauteng Area experienced more economic and population growth than Cape Town. It does however seem that speeds reported from electronic counting stations for Study Area 2 have a lower limit of approximately 55 km/h, which seems too high. This do not correspond to information from other sources, where peak hour speeds for this route are reported as in the order of 20 km/h. This may be due to the fact that electronic loops have known problems in accurately reporting low speeds, causing TTI values for peak periods to be lower than are truly the case.

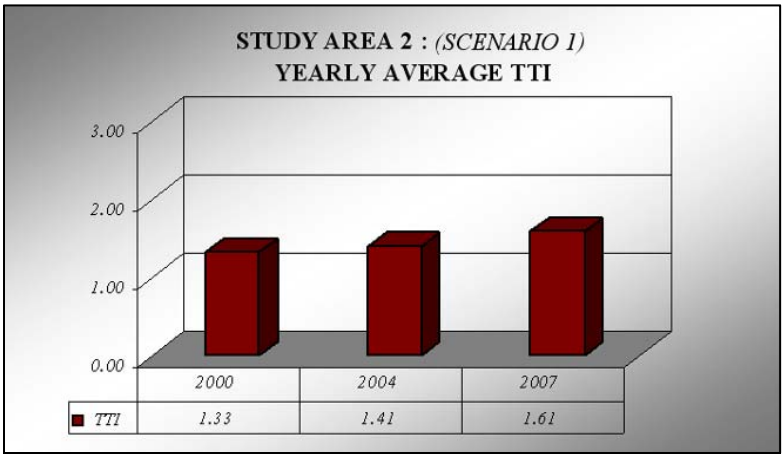


Figure 8 : Average TTI values (Case 2).

RECOMMENDATION AND CONCLUSION

The aim of this study was to test the feasibility and usefulness of traffic mobility measures to quantify congestion in the South African context, using previously developed mobility measures and existing data sources. Through Case Studies 1 and 2 it was demonstrated that these measures, of which the Travel Time Index (TTI) is the most generally used, can give a good indication of congestion levels.

Unfortunately there are several factors that challenges the general use of mobility performance measures in South Africa at the present time. The calculation of traffic mobility measures for larger study areas than a selected route is hampered by the unavailability and inconsistency of data. Although electronic counting stations are increasingly installed on major routes, the reliability of data is often reduced by many problems such as damaged loop detectors, software errors and power failures. It is also known that *(Texas Transportation Institute, 2002)* that low speed data from electronic counting stations is not accurate and that accuracy varies for different installations as also observed in this study. This reduces the reliability of mobility performance measures for peak periods, as accurate low speed data is crucial to determine and compare results.

Where electronic data is not available the conversion of short term traffic counts to speed data by using Van Aerde's speed-flow relationships from study areas with similar characterisitcs, gives satisfactory results. However, sample sizes are not large enough to give a realistic indication of long term data incorporating incidents. The conversion process is also time consuming and is therefore not practical for the analysis of larger study areas.

Many major routes are currently under construction causing increased delays and changes in traffic distribution across the network. Although mobility measures can be very useful in determining the impact of road works on the general flow of traffic, it should be taken into account that these values will give a skewed representation of congestion levels when compared to historic values.

This study has demonstrated that mobility performance measures can be of value in the South African context to determine existing mobility conditions, trends in traffic congestion, the impact of transport projects and comparison of congestion levels between urban areas. With electronic counting stations being increasingly installed on major routes and the technology improving rapidly, we will hopefully be able to obtain widespread and reliable data in the near future making extensive traffic mobility studies possible.

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