A CASE FOR SMARTER CITY GROWTH: A STRATEGIC ANALYSIS OF CAPE TOWN'S PHASE 1A BRT SYSTEM AND ITS SUPPORTING LAND USE ENVIRONMENT

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ABSTRACT

Cape Town's high quality Phase 1a BRT starter service (MyCiTi) commenced operating between the CBD and Table View in May 2011, in a combination of segregated bus lane and mixed traffic environments. Peak ridership of the completed MyCiTi Phase 1a service is forecast to be 3,252 pax/hr/dir, which is low compared to international BRT norms. This paper reports the findings of a research project which undertook to: investigate the potential for underutilisation of the BRT system's capacity in the short-medium term; and assess the importance of complimentary transport interventions to increase ridership on, and supporting land use interventions to accelerate and incentivise an appropriate land use response to, the MyCiTi Phase 1a system. An analysis of the MyCiTi Phase 1a system was undertaken to determine the maximum practical capacity relative to projected passenger demand. It was estimated that the completed MyCiTi Phase 1a service will have a maximum practical capacity of around 12,500 pax/hr/dir. Forecasting and backcasting spreadsheet models were developed to assess the impacts of a 'Business as Usual' approach with respect to land development and mode share within the West Coast corridor, against an alternative 'Smarter City Growth' scenario. Whilst the spreadsheet models make numerous simplifying assumptions, the appraisal demonstrates that alternative policy pathways may be needed to bring about systematic and structural changes to the prevailing 'Business as Usual' urban development model in order to support the MyCiTi system. On the basis of the research findings, the paper concludes with a recommendation that complimentary packages of land use interventions and travel demand management programmes need to be formulated and aligned to the rollout of Integrated Rapid Public Transport Networks.

1. INTRODUCTION

Since the mid 1990's, planning legislation[1] and policy directives in South Africa have promoted high density, mixed use forms of development. In terms of these directives, it has become generally accepted that a process of 'city restructuring' and focused growth along high density development corridors is necessary to overcome the inefficient spatial structure and low average population densities characteristic of South African cities. However, these directives are proving difficult to achieve. There are few examples of emerging high density, mixed use development corridors and South African cities remain characterised by dispersed low density formal development and disconnected concentrations of predominately outlying high density informal settlements.

High quality public transport systems are required to attract market support for corridor based land use intensification (Banister, 2008). However, the quality of South Africa's existing public transport services are generally perceived to be unsatisfactory (DoT, 2005), catering for a predominantly 'captive' commuter market. Without significant improvements in the quality of South Africa's public transport services, car dependence and car dependent forms of urban development are likely to persist.

In response to the perceived inadequacies of South Africa's public transport systems and increasing private motor vehicle dependence, the National Public Transport Strategy and Action Plan (DoT, 2007) prioritised the planning and construction of high quality road-based Bus Rapid Transit (BRT) systems together with the revitalisation of passenger rail systems in the form of Integrated Rapid Public Transport Networks (IRPTNs). The West Coast corridor was selected as Cape Town's BRT demonstration phase due to high peak period congestion levels, the absence of suitable segregated right-of-way public transport alternatives and the presence of fewer minibus-taxi operators than on other corridors (CoCT, 2010). Cape Town's high quality Phase 1a BRT 'starter' service (MyCiTi) commenced operating between the CBD and Table View in May 2011, in a combination of segregated bus lane and mixed traffic environments.

The City of Cape Town generated passenger demand projections for the MyCiTi Phase 1a trunk routes using the City's EMME/3 transport model. The MyCiTi Business Plan[2] indicated a projected southbound travel demand of 3,252 passengers per peak hour per direction (pax/hr/dir) at the system's maximum load point (CoCT, 2012). The projected demand is relatively low compared to observed international BRT norms. The BRT corridors plotted in figure 1 have mean ridership of ±9,500 pax/hr/dir, with some corridors carrying as many as ±36,000 pax/hr/dir. This suggests underutilization is possible, at least in the early years of the MyCiTi Phase 1a system.

This paper reports the findings of a research project[3] which undertook to:

a) investigate the potential for underutilisation of the BRT system's capacity in the short-medium term; and
b) assess the importance of complimentary transport interventions to increase ridership on, and supporting land use interventions to accelerate and incentivise an appropriate land use response to, the MyCiTi Phase 1a system.

The paper is divided into seven sections. The following section describes the method used to quantify the maximum practical capacity of the Phase 1a MyCiTi system, and presents a summary of the results of the capacity analysis. Section 3 presents the results of a population density analysis of the West Coast corridor undertaken to determine the potential public transport supportive population. Section 4 presents the projections of simplified forecasting and backcasting spreadsheet models. Two development scenarios are considered: a *'Business as Usual'* scenario based on prevailing development trends; and a *'Smarter City Growth'* scenario which assumes a higher future public transport mode share and a higher level of development intensity. Section 5 then discusses the results of the capacity analysis and the outputs of the forecasting and backcasting models in terms of the abovementioned development scenarios. Section 6 considers the effectiveness of land use interventions and complimentary travel demand management programmes intended to increase the demand for travel and accelerate modal shift in favour of public transport. Section 7 concludes with recommendations based on the findings of the research.

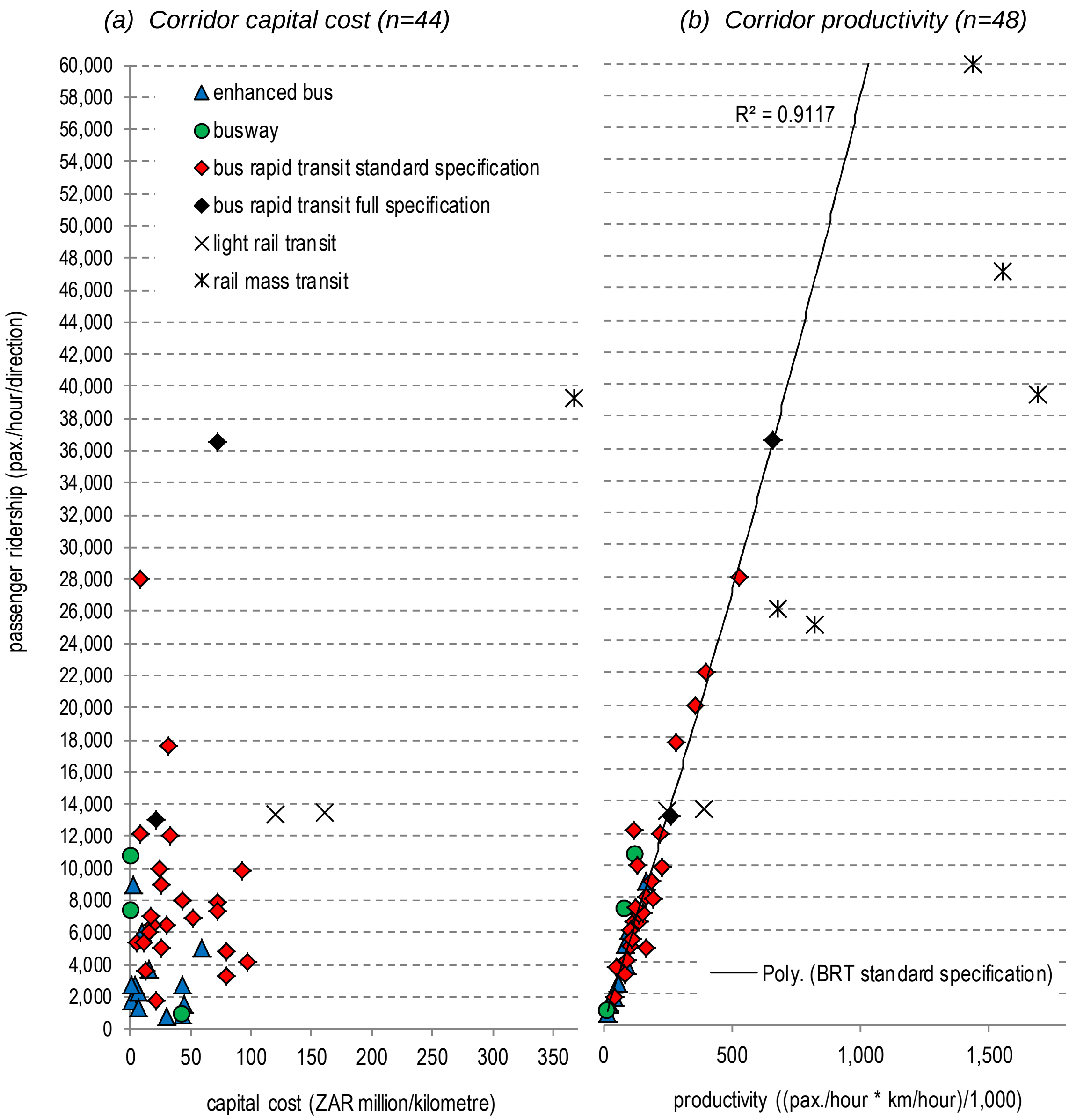

Figure 1: ***Peak public transport corridor passenger ridership, by capital cost and productivity***

Data sources:

1. Passenger ridership, capital cost and mean operating speed data are derived from a variety of sources compiled by Bruun and Allen (pers comm 2012), Finn *et a(* (2011), Hidalgo *et al* (2010) and MacDonald (2012). In the case of daily passenger ridership data, it is assumed that 15% of trips occur in the peak hour. Capital cost values in USD have been converted to ZAR using an exchange rate of 1 USD:9 ZAR.

Notes and limitations:

1. 'Full specification BRT' is defined as a corridor with the following features: physically segregated median-aligned 'closed' trunk service busways; feeder and trunk service fare integration; pre-boarding fare control; and level-boarding trunk stations that facilitate feeder-trunk service transfers. 'Standard specification BRT' is defined as a corridor with physically segregated trunk service busways, but not all (at least two, Wright and Hook 2007) of the other features that a 'full specification' system has. 'Busway' is defined as a bus system operating on a physically segregated lane that is permanently and exclusively for the use of public transport vehicles. 'Enhanced bus' is defined as a system which may employ a combination of BRT, and other bus prioritization and service quality enhancement features, but does not have a physically segregated busway over most of the service route length.
2. The comparison of capital costs on a corridor basis can result in a misrepresentation in instances where other corridors share a portion of the infrastructure.
3. Comparisons of system performance should include a range of environmental and societal benefits, in addition to the cost and productivity characteristics presented in the figure.

2. MYCITI PHASE 1A BRT SYSTEM ANALYSIS

Transport systems generally operate poorly when running at maximum capacity and are therefore rarely designed or planned to operate at maximum capacity. For this reason, an assessment of maximum theoretical capacity also needs to consider the *practical* capacity of the system (Van As and Joubert, 2002).

The capacity of mass transit systems is measured in terms of the number of passengers that can pass by a point of maximum load in one direction (pax/hr/dir)[4]. The fundamental equation for calculating capacity, at a set service frequency, for conventional 'fixed stop' bus operations, is shown in Equation 1 (TCQSM, 2003).

$$C = VPH * CAP$$

or

$$C = \frac{60}{INT} * CAP$$

Equation (1): Fundamental capacity calculation

Where:
C = capacity (pax/hr/dir)
CAP = maximum person capacity per vehicle
VPH = vehicles per hour; and
INT = interval, in minutes (minimum headway for safe and reliable operation)

Calculating the maximum practical capacity for combinations of conventional fixed stop bus operations and 'enhanced' network operations (limited stop and express services) is a more complex undertaking which requires the consideration of a range of interacting variables. The Transit Capacity and Quality of Service Manual (2003) indicates that BRT system capacity, in terms of the number of buses/hour that a BRT system can accommodate, is a function of: (1) bus loading area vehicle capacity (i.e. berths); (2) bus station vehicle capacity; (3) bus lane vehicle capacity; and the interactions between these variables (see Figure 2) (TCQSM, 2003). The equation and variables required to calculate the vehicle capacity (in terms of buses per hour) of a bus loading area is shown in Equation 2 (TCQSM, 2003).

$$B_l = \frac{3{,}600(g/C)}{t_c + t_d(g/C) + t_{om}} = \frac{3{,}600(g/C)}{t_c + t_d(g/C) + Zc_v t_d}$$

Equation (2): Capacity of a bus loading area calculation

Where:
B_l = loading area bus capacity (bus/h)
3,600 = number of seconds in 1 hour
g/C = green time ratio (the ratio of effective green time to total traffic signal cycle length)
t_c = clearance time(s)
t_d = average (mean) dwell time(s)
t_{om} = operating margin(s)
Z = standard normal variable corresponding to a desired failure rate; and
c_v = coefficient of variation of dwell times.

The capacity of a *bus station* is a function of the number of effective loading areas and the capacity of the sum of the *bus loading areas* per direction. In this regard it is important to note that it has been observed that linear stops are only partially effective and each additional loading area will add less capacity than the loading area before it (TCQSM, 2003). The capacity of a *bus facility* is a function of the critical bus station capacity and the type of service (operational procedures). Bus facility capacity is determined primarily by the capacity of the critical bus station which produces the longest headway between buses (typically longest dwell times). Bus facility capacity is ultimately dependent on the exclusivity of the bus facility when enhanced network operations are utilised (TCQSM, 2003).

The MyCiTi Phase 1a capacity calculations are based on the trunk T01, T03a, T04a routes identified in the MyCiTi Business Plan (CoCT, 2010, 2012) and have been calculated in terms of: (1) conventional fixed stop services; and (2) enhanced network operations (limited and express stop services). The assumptions, variables and outputs of the equations used to calculate the capacity of the MyCiTi Phase 1a system are provided in Annexure A. A summary of the outputs of the capacity calculations per MyCiTi Phase 1a milestone, based on existing and potential green phase (g/C) ratios, is provided in Figure 3.

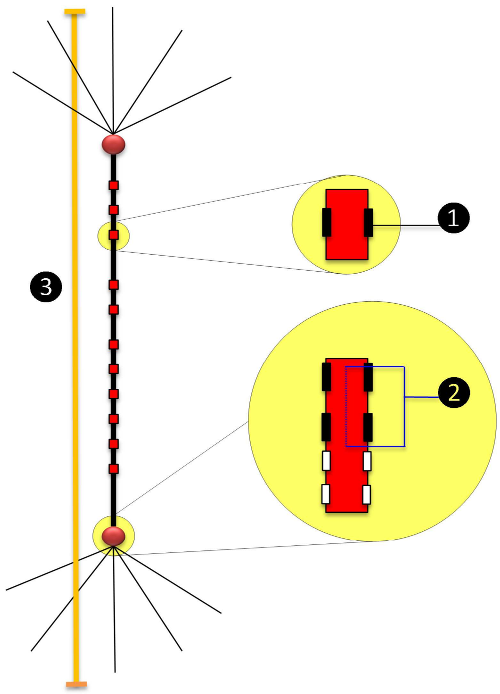

Figure 2: BRT system primary capacity determinants

Notes:
1. Bus loading areas (berths)
2. Bus station
3. Bus facility (routes)

MyCiTi Phase 1a Milestones	Conventional network operations (fixed stop service) (pax/hr/dr)			Enhanced network operations (limited stop/express services) (pax/hr/dr)		
	Existing g/C	Potential g/C (0.6)	Potential g/C (0.8)	Existing g/C	Potential g/C (0.6)	Potential g/C (0.8)
Milestone 0: Trunk service between Cape Town CBD and Tableview and interim feeder / distribution services.	1,200	2,100	2,400	-	-	-
Milestone 1 & 2: Permanent inner city and Tableview feeder / distribution services.	2,100	3,700	4,200	4,100	5,200	5,900
Milestone 3: Trunk service extended to Atlantis with feeder / distribution services.	2,100	3,700	4,200	8,300	10,400	11, 800
Milestone 4: Trunk service extended from Table View to Du Noon.	2,100	3,700	4,200	10,000	12,500	14,200

Figure 3: Summary of results of the capacity analysis per MyCiTi Phase 1a milestone for conventional and enhanced network operations

Notes:
1. The MyCiti Phase 1a capacity calculations and related assumptions are detailed in Annexure A. The calculations have been undertaken at a high level to provide an estimated order of magnitude. An empirical survey-based peak hour statistical analysis would be required to provide more precise results.

2. Existing traffic signal g/C ratios were obtained from the CoCT: Traffic Control department (see Figure A.4). A default value of 0.4 g/C was adopted for unknown g/C ratios.

The results of the MyCiTi Phase 1a capacity calculations reflected in Figure 3 indicate that conventional fixed stop network operations will reach a capacity limit ranging between 2,100 – 4,200 pax/hr/dir, depending on the applied g/C ratio. The existing g/C ratio places a significant limitation on the capacity of the MyCiTi trunk routes in terms of the number of buses/hour that critical stops such as the Table View and Civic Centre stations can accommodate. Potential signal time values of 0.6 g/C and 0.8 g/C were adopted to illustrate the impact of signal time ratios on the capacity of the MyCiTi system. For practical reasons the maximum practical capacity (pax/hr/dir) values associated with a signal time ratio of 0.6 g/C are considered to be the upper capacity limits of the MyCiTi Phase 1a system.

The calculations show that the capacity of the MyCiTi Phase 1a system increases significantly as additional loading areas become operational, which provides the opportunity to introduce enhanced operational procedures (limited stop and express services). There are large capacity increases associated with the introduction of enhanced operational procedures for milestones 3 and 4. The calculations indicate that the MyCiTi phase 1a system will have a maximum practical capacity limit of ±12,500 pax/hr/dir.

3. WEST COAST POPULATION DENSITY ANALYSIS

A demographic analysis was undertaken to determine the potential public transport supportive population and extract approximate population growth rates within the West Coast corridor. The average ‘gross population density’[5] of the MyCiTi Phase 1a catchment area was approximated at ±14 du/ha in the 2010 base year, or 44 people/ha using the average household size of 3.2 for the Blaauwberg district (Statistics South Africa, 2003) (CoCT, 2008) (CoCT, 2011) (see Figures 4 and 5).

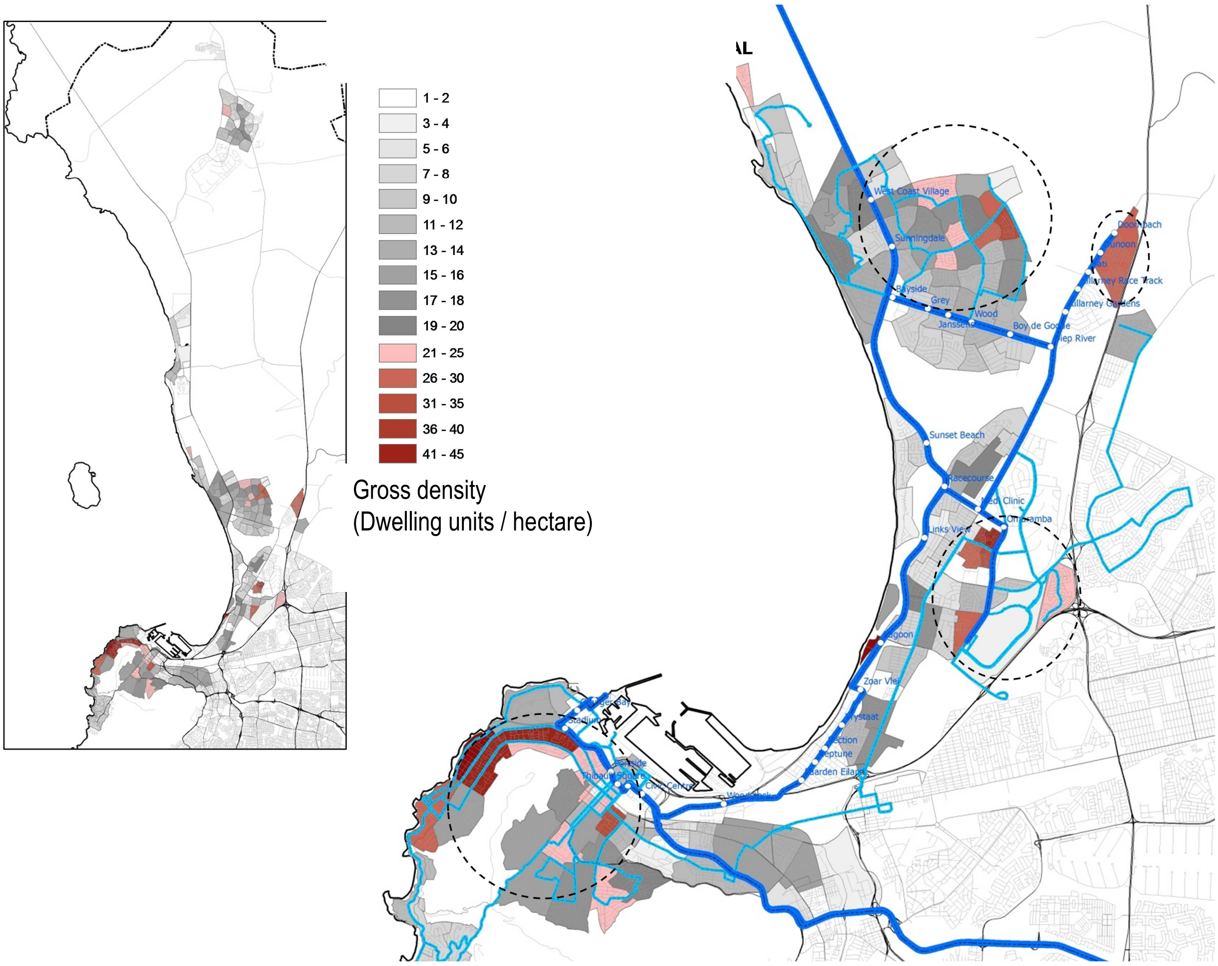

Figure 4: Spatial distribution of gross population density (2010) (Statistics South Africa, 2003) (CoCT, 2008) (CoCT, 2010) (CoCT, 2011)

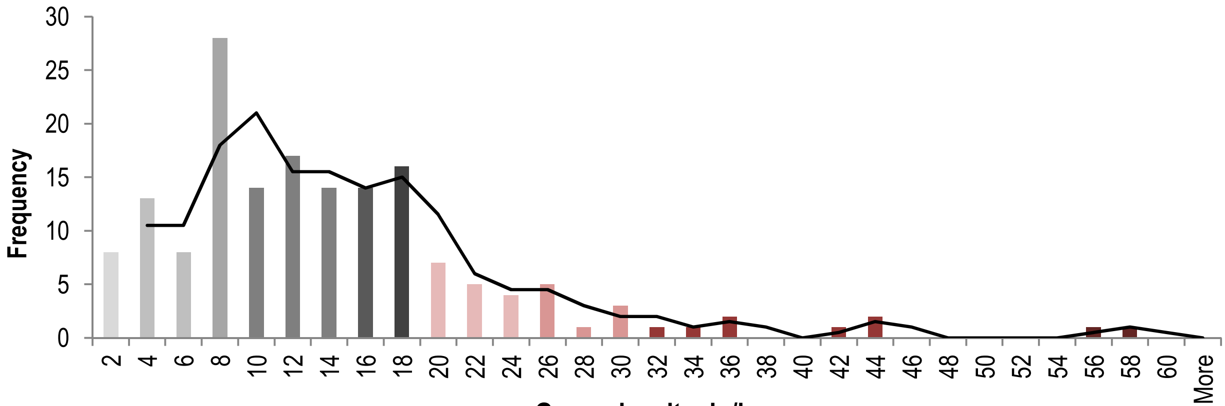

Figure 5: West Coast gross population density statistics (2010) (Statistics South Africa, 2003) (CoCT, 2008) (CoCT, 2010) (CoCT, 2011)

Notes for Figures 4 and 5:

1. The potential public transport supportive population of the MyCiTi Phase 1a system was determined using ArCGIS 9.3.1 software on the basis of a ‘proximity analysis’ of the trunk and feeder/distribution network to ‘select’ the City’s EMME/3 transport model zones within a maximum catchment radius of 800m from trunk and feeder/distribution stations.
2. The potential public transport supportive population was extracted from the ‘selected’ transport zones using the City’s ‘Urban Residential Growth Monitoring System’ as the 2010 base year population dataset (CoCT, 2011).
3. The Blaauwberg district average household size of 3.22 was applied to approximate the number of dwelling units (CoCT, 2008)). The gross population density for the 2010 base year was calculated by dividing the total number of dwelling units per transport zone by the transport zone area coverage.

4. Summary of descriptive statistics: mean 13.68; standard error 0.74; median 12.00; mode 8.00; standard deviation 9.53; sample variance 90.75

Limitations associated with Figures 4 and 5:

1. 20 du/ha ‘is an arbitrary number which has been used for illustrative purposes (see red shaded columns in Figure 5).
2. The population data is based on secondary sources and could not be independently verified.

The outputs of the population density analysis indicate that the West Coast corridor is characterised by dispersed low population densities and isolated medium density areas. The population distribution reflects the predominant suburban development model of low density market driven urban growth. Pockets of medium intensity formal development are linked to Cape Town CBD and Sea Point. Lower income medium density informal areas include Du Noon, Doornbach, Joe Slovo and Marconi Beam.

4. FORECASTING AND BACKCASTING DEMAND PROJECTION MODELS

The MyCiTi Phase 1a capacity calculations and the potential public transport supportive West Coast corridor population demographics provided the input data required to generate forecasting and backcasting spreadsheet models[6] which were developed to assess the impacts of a ‘Business as Usual’ approach against an alternative ‘Smarter City Growth’ scenario. The forecasting and backcasting spreadsheet models were developed in Microsoft Excel and make numerous simplifying assumptions (see notes and limitations under Figure 6 and Figure 7). For these reasons the outputs of the demand projection models must be considered indicative.

The forecasting spreadsheet model explores the relationships between passenger demand and future development in the West Coast corridor relative to the maximum practical capacity of the MyCiTi Phase 1a system. Using simple statistical regression analysis the impact of future corridor development on MyCiTi Phase 1a patronage was projected into the future for a range of public:private mode shares to determine how long it could take before the maximum practical capacity of the MyCiTi system is fully utilised. The outputs of the forecasting model are reflected in Figure 6.

POPULATION PROJECTIONS				MODE SHARE ASSUMPTIONS													
Year	West Coast population growth per year(%)	West Coast Population	Total PH southbound Travel demand	20	25	30	35	40	45	50	55	60	65	70	75	85	95
2000		163,166	8,060	1,612	2,015	2,418	2,821	3,224	3,627	4,030	4,433	4,836	5,239	5,642	6,045	6,851	7,657
2001	7.37	175,191	8,654	1,731	2,163	2,596	3,029	3,462	3,894	4,327	4,760	5,192	5,625	6,058	6,490	7,356	8,221
2002	7.37	188,103	9,292	1,858	2,323	2,787	3,252	3,717	4,181	4,646	5,110	5,575	6,040	6,504	6,969	7,898	8,827
2003	7.37	201,966	9,976	1,995	2,494	2,993	3,492	3,991	4,489	4,988	5,487	5,986	6,485	6,983	7,482	8,480	9,478
2004	7.37	216,851	10,712	2,142	2,678	3,213	3,749	4,285	4,820	5,356	5,891	6,427	6,963	7,498	8,034	9,105	10,176
2005	7.37	232,833	11,501	2,300	2,875	3,450	4,025	4,600	5,175	5,751	6,326	6,901	7,476	8,051	8,626	9,776	10,926
2006	7.37	249,992	12,349	2,470	3,087	3,705	4,322	4,939	5,557	6,174	6,792	7,409	8,027	8,644	9,262	10,496	11,731
2007	7.37	268,417	13,259	2,652	3,315	3,978	4,641	5,304	5,966	6,629	7,292	7,955	8,618	9,281	9,944	11,270	12,596
2008	3.29	290,522	14,351	2,870	3,588	4,305	5,023	5,740	6,458	7,175	7,893	8,610	9,328	10,045	10,763	12,198	13,633
2009	3.15	299,673	14,803	2,961	3,701	4,441	5,181	5,921	6,661	7,401	8,142	8,882	9,622	10,362	11,102	12,582	14,063
2010	3.15	309,113	15,269	3,054	3,817	4,581	5,344	6,108	6,871	7,635	8,398	9,161	9,925	10,688	11,452	12,979	14,506
2011	2.30	316,223	15,620	3,124	3,905	4,686	5,467	6,248	7,029	7,810	8,591	9,372	10,153	10,934	11,715	13,277	14,839
2012	2.30	323,496	15,979	3,196	3,995	4,794	5,593	6,392	7,191	7,990	8,789	9,588	10,387	11,186	11,985	13,583	15,181
2013	2.30	330,936	16,347	3,269	4,087	4,904	5,721	6,539	7,356	8,174	8,991	9,808	10,626	11,443	12,260	13,895	15,530
2014	2.30	338,548	16,723	3,345	4,181	5,017	5,853	6,689	7,525	8,361	9,198	10,034	10,870	11,706	12,542	14,215	15,887
2015	2.30	346,334	17,108	3,422	4,277	5,132	5,988	6,843	7,698	8,554	9,409	10,265	11,120	11,975	12,831	14,541	16,252
2016	1.69	352,187	17,397	3,479	4,349	5,219	6,089	6,959	7,829	8,698	9,568	10,438	11,308	12,178	13,048	14,787	16,527
2017	1.69	358,139	17,691	3,538	4,423	5,307	6,192	7,076	7,961	8,845	9,730	10,614	11,499	12,384	13,268	15,037	16,806
2018	1.69	364,192	17,990	3,598	4,497	5,397	6,296	7,196	8,095	8,995	9,894	10,794	11,693	12,593	13,492	15,291	17,090
2019	1.69	370,347	18,294	3,659	4,573	5,488	6,403	7,318	8,232	9,147	10,062	10,976	11,891	12,806	13,720	15,550	17,379
2020	1.69	376,606	18,603	3,721	4,651	5,581	6,511	7,441	8,371	9,301	10,232	11,162	12,092	13,022	13,952	15,812	17,673
2021	1.39	381,841	18,861	3,772	4,715	5,658	6,602	7,545	8,488	9,431	10,374	11,317	12,260	13,203	14,146	16,032	17,918
2022	1.39	387,148	19,124	3,825	4,781	5,737	6,693	7,649	8,606	9,562	10,518	11,474	12,430	13,387	14,343	16,255	18,167
2023	1.39	392,529	19,389	3,878	4,847	5,817	6,786	7,756	8,725	9,695	10,664	11,634	12,603	13,573	14,542	16,481	18,420
2024	1.39	397,986	19,659	3,932	4,915	5,898	6,881	7,864	8,847	9,830	10,812	11,795	12,778	13,761	14,744	16,710	18,676
2025	1.39	403,518	19,932	3,986	4,983	5,980	6,976	7,973	8,970	9,966	10,963	11,959	12,956	13,953	14,949	16,942	18,936
2026	1.39	409,127	20,209	4,042	5,052	6,063	7,073	8,084	9,094	10,105	11,115	12,126	13,136	14,147	15,157	17,178	19,199
2027	0.98	413,136	20,407	4,081	5,102	6,122	7,143	8,163	9,183	10,204	11,224	12,244	13,265	14,285	15,306	17,346	19,387
2028	0.98	417,185	20,607	4,121	5,152	6,182	7,213	8,243	9,273	10,304	11,334	12,364	13,395	14,425	15,456	17,516	19,577
2029	0.98	421,273	20,809	4,162	5,202	6,243	7,283	8,324	9,364	10,405	11,445	12,486	13,526	14,567	15,607	17,688	19,769
2030	0.98	425,402	21,013	4,203	5,253	6,304	7,355	8,405	9,456	10,507	11,557	12,608	13,659	14,709	15,760	17,861	19,963

Assumed existing modal split
CoCT modal split target (City of Cape Town, 2006)
IRT Milestone 1&2: Maximum theoretical capacity (5,200 pax/hr/dir at potential g/C ratio 0.6)
IRT Milestone 3: Maximum theoretical capacity (10,400 pax/hr/dir at potential g/C ratio 0.6)
IRT Milestone 4: Maximum theoretical capacity (12,500 pax/hr/dir at potential g/C ratio 0.6)

Figure 6: Forecasting model of southbound MyCiTi Phase 1a demand (pax/hr/dir)

Method and input data:

1. The public:private modal split and total southbound travel demand (person trips) crossing the Diep River was extracted from a survey undertaken during a typical weekday AM peak hour in 2000 (Van Wyngaardt, 2001).
2. The proportion of peak hour southbound travel demand relative to the population north of the Diep River in 2000 was calculated and applied to the broader West Coast corridor (excluding the Cape Town / Sea Point area).

Notes and limitations:

1. From a trip generation and distribution modelling perspective, economic activity is a critically important factor to predict commuter destinations in the peak hour. In this regard, Cape Town's CBD and surrounds are recognised as major commuting destinations and for this reason the southbound MyCiTi Phase 1a peak hour patronage has been forecasted.
2. The forecasting model assumes that the West Coast southbound peak hour travel demand increases proportionately to population growth and projects future travel demand up to 2030 using Dorrington's (2000) medium growth population projections for the West Coast corridor. This assumption is a potentially limiting factor as employment opportunities in the south (i.e. Cape Town CBD) are finite. Southbound travel demand is therefore unlikely to grow at a rate proportional to the growth of the West Coast corridor.
3. Phase 1a MyCiTi patronage is likely to be lower than the total public transport travel demand due to supplementary road based public transport services which connect the West Coast directly to other areas in the City.
4. The forecasting model is limited by a lack of consideration of public transport population market segments in terms of population demographics and socio-economic factors (i.e. age cohorts and household income).
5. The forecasting model does not consider the impact of latent peak hour travel demand.
6. In the short term, increased public transport MyCiTi mode selection is likely to result in de-congestion of peak hour road networks currently operating at (or close to) capacity. Reductions in the generalised cost of travel are likely to 'induce' increased traffic volumes, however, over the medium-longer term the capacity of the West Coast corridor road network is likely to remain fixed, thus when the R27 and Koeberg Road peak hour volumes reach capacity these routes will not be able to accommodate increased peak hour private travel demand. Whilst further 'peak spreading' is probable, the potential exists for increased public transport mode switching in response to increasing traffic congestion.
7. The public:private modal split and total southbound travel demand (person trips) baseline information is based on secondary sources which could not be independently verified.

The shaded cells represent points at which the projected demand reaches the maximum practical capacity of successive Phase 1a milestones. The forecasting model shows that the projected passenger demand is approximately 5,253 pax/hr/dir in 2030, assuming a 25% public transport mode share.

Projecting development trends based on the prevailing low density suburban development model is problematic because the intensity of future urban development and public:private mode shares may differ considerably to 'pre-MyCiTi' development trends. For these reasons, a scenario based quantitative 'backcasting'[7] modelling approach was adopted to explore the impact of alternative development scenarios on passenger demand for the MyCiTi Phase 1a system.

The backcasting model is based on the premise that demand for the MyCiTi service is sufficient to fully utilise the maximum practical capacity of the MyCiTi Phase 1a system. The model then works backwards using a range of public:private mode shares to determine the required southbound travel demand, population, and average dwelling unit density to quantify the potential extent of developable land which may be required to fully utilise the maximum practical capacity of the MyCiTi Phase 1a system.

Two scenarios were considered, a *'Business as Usual'* scenario based on historic development trends, and a *'Smarter City Growth'* scenario which assumed a higher level of development intensity and a higher public transport (MyCiTi) mode share. The 'Business as Usual' scenario assumes that no interventions are put in place to alter the prevailing development model and that there is a limited development response to the MyCiTi Phase 1a system in the form of land use intensification (redevelopment and infill development). The ‘Business as Usual’ scenario assumes that future development remains predominantly ‘car orientated’ and MyCiTi mode shares range from 25-30%.

The ‘Smarter City Growth’ scenario assumes that the process of urban development is proactively managed by the public sector. A range of institutional growth management mechanisms, enhanced development controls and development incentives on privately owned land in the West Coast corridor are put in place and proactive public land development programmes associated with lower income forms of housing delivery are implemented in conjunction with the introduction of a complimentary package of travel demand management tools and car use restraints. It is assumed that the packaged combination of land use interventions and travel demand management programmes results in increased land use intensity (gross development densities in the order of 25du/ha) and an increased public transport (MyCiTi) mode share (50-60%). The ‘Smarter City Growth’ scenario density and mode share assumptions are consistent with targets adopted by the Provincial Government of the Western Cape (PSDF, 2009) and the City of Cape Town (CoCT, 2006) (CoCT, 2012).

The outputs of the backcasting model indicate that the ‘Business as Usual’ scenario will require >193,810 dwelling units over an area of >12,921 ha to fully utilise the maximum practical capacity of the Phase 1a MyCiTi system. Conversely, the ‘Smarter City Growth’ scenario will require >96,905 dwelling units over an area of >3,876 ha (See Figure 7).

Land requirements at different development densities (ha)											Dwelling units (3.22 avg)	Population as a proportion of southbound demand	Southbound Travel Demand	Mode Share (%)	p/ph/d shortfall
10	15	20	25	30	35	40	45	50	55	60					
23,257	**15,505**	11,629	9,303	7,752	6,645	5,814	5,168	4,651	4,229	3,876	232,572	748,882	36,992	25	9,248
19,381	**12,921**	9,691	7,752	6,460	5,537	4,845	4,307	3,876	3,524	3,230	193,810	624,069	30,827	30	9,248
16,612	11,075	8,306	6,645	5,537	4,746	4,153	3,692	3,322	3,020	2,769	166,123	534,916	26,423	35	9,248
14,536	9,691	7,268	5,814	4,845	4,153	3,634	3,230	2,907	2,643	2,423	145,358	468,052	23,120	40	9,248
12,921	8,614	6,460	5,168	4,307	3,692	3,230	2,871	2,584	2,349	2,153	129,207	416,046	20,551	45	9,248
11,629	7,752	5,814	**4,651**	**3,876**	**3,322**	**2,907**	2,584	2,326	2,114	1,938	116,286	374,441	18,496	50	9,248
10,571	7,048	5,286	**4,229**	**3,524**	**3,020**	**2,643**	2,349	2,114	1,922	1,762	105,715	340,401	16,815	55	9,248
9,691	6,460	4,845	**3,876**	**3,230**	**2,769**	**2,423**	2,153	1,938	1,762	1,615	96,905	312,034	15,413	60	9,248
8,945	5,963	4,473	3,578	2,982	2,556	2,236	1,988	1,789	1,626	1,491	89,451	288,032	14,228	65	9,248
8,306	5,537	4,153	3,322	2,769	2,373	2,077	1,846	1,661	1,510	1,384	83,062	267,458	13,211	70	9,248
7,752	5,168	3,876	3,101	2,584	2,215	1,938	1,723	1,550	1,410	1,292	77,524	249,627	12,331	75	9,248
7,268	4,845	3,634	2,907	2,423	2,077	1,817	1,615	1,454	1,321	1,211	72,679	234,026	11,560	80	9,248
6,840	4,560	3,420	2,736	2,280	1,954	1,710	1,520	1,368	1,244	1,140	68,404	220,260	10,880	85	9,248
6,460	4,307	3,230	2,584	2,153	1,846	1,615	1,436	1,292	1,175	1,077	64,603	208,023	10,276	90	9,248
6,120	4,080	3,060	2,448	2,040	1,749	1,530	1,360	1,224	1,113	1,020	61,203	197,074	9,735	95	9,248
5,814	3,876	2,907	2,326	1,938	1,661	1,454	1,292	1,163	1,057	969	58,143	187,221	9,248	100	9,248

Scenarios

Business as usual

Smart city growth

Policy Guidelines

Provincial Spatial Development Framework (PSDF) density target 25du/ha

City of Cape Town: Mode share target 50-60% (City of Cape Town, 2006)

Figure 7: Backcasting model southbound MyCiTi Phase 1a demand (pax/hr/dir) (‘Business as Usual’ scenario vs. ‘Smarter City Growth’ scenario)

Method, input data and limitations

1. The projected MyCiTi Phase 1a demand at the maximum load point (3,252 pax/hr/dir (CoCT, 2012)) was subtracted from the maximum practical capacity (12,500 pax/hr/dir) to obtain the additional passenger demand required to match the maximum practical system capacity (9,248 pax/hr/dir).

2. The total southbound travel demand (person trips) crossing the Diep River was extracted from a survey undertaken during a typical weekday AM peak hour in 2000 (Van Wyngaardt, 2001).
3. The proportion of peak hour southbound travel demand relative to the population north of the Diep River in 2000 was calculated and applied to the broader West Coast corridor (excluding the Cape Town / Sea Point area). This assumption is a potentially limiting factor as employment opportunities in the south (i.e. Cape Town CBD) are finite. Southbound travel demand is therefore unlikely to grow at a rate proportional to the growth of the West Coast corridor.
4. An average of 3.22 people per dwelling unit was assumed to determine the total number of dwelling units (based on the average household size for the Blaauwberg District (CoCT, 2008). The extent of land required to accommodate the projected population was derived for a range of gross population densities.
5. The total southbound travel demand (person trips) baseline information is based on secondary sources which could not be independently verified.

Assumptions regarding the housing delivery rate in the West Coast corridor were applied to each development scenarios to estimate the time it could take to fully utilise the maximum practical capacity of the MyCiTi Phase 1a system (See Figure 8). These assumptions are based on research undertaken by the City of Cape Town which suggest that Cape Town's average citywide housing delivery rate (market and subsidised housing (excluding informal development)) is approximately 16,000 du/year (CoCT, 2012).

'Business as Usual' development scenario

Modal split	Dwelling units	Assumed rate of delivery		Density (du/ha)	Land required (ha)
		4500 du/year	16000 du/year		
25	232,572	51.7	14.5	15	15,505
30	193,810	43.1	12.1	15	12,921

'Smarter City Growth' development scenario

Modal split	Dwelling units	Assumed rate of delivery		Density	Land required (ha)
		4500 du/year	16000 du/year		
50	116,286	25.8	7.3	25	4,651
55	105,715	23.5	6.6	25	4,229
60	96,905	21.5	6.1	25	3,876

Figure 8: Housing delivery rate assumptions applied to backcasting scenarios

Notes and assumptions:

<u>Residential growth markets</u>	<u>Prevailing rate of citywide housing delivery (du / year)</u>
Private sector market delivery	6,000 – 9,400 (CoCT, 2012)
Subsidised housing delivery	8,300 (CoCT, 2012)
Informal sector growth	-
Average / year (metro)	**±16,000**

<u>Assumed West Coast housing delivery scenarios</u>

Business as Usual	4,500 du / year (Assuming that housing delivery spread throughout Cape Town)
Smarter City Growth	16,000 du / year (Assuming that future growth is focused along West Coast Corridor)

The above calculations indicate that at the current assumed rate of development in the West Coast corridor (4,500 du/year), it could take between 21 and 51 years to fully utilise the maximum practical capacity of the MyCiTi phase 1a system. However, if future growth is focused in the West Coast corridor the full MyCiTi system's capacity could be utilised within 6-15 years depending on the development scenario and associated MyCiTi mode shares.

5. DISCUSSION OF RESULTS

The outputs of the MyCiTi Phase 1a capacity analysis indicate that the maximum practical capacity of the MyCiTi system (12,500 pax/hr/dir) is likely to significantly exceed the predicted passenger demand (3,252 pax/hr/dir) when the full Phase 1a service becomes operational.

In considering potential implications, it is important to note that there must be a clear distinction between operational financial viability and the financial impacts associated with capacity underutilisation during the peak hour (which do not necessarily constitute a non-viable system). Similarly, the environmental and societal benefits of the investment represented by the MyCiTi Phase 1a service have not been discussed in this paper and would need to form part of a broader Multi-Criteria Analysis to assess the performance of the MyCiTi Phase 1a system.

Notwithstanding the abovementioned qualifications, it has been reported that there will be an estimated annual recurring operating deficit of approximately R255 million in 2012/13 for Phase 1a which is anticipated to increase to approximately R318 million by 2015/16 (CoCT, 2012). The potential underutilisation of MyCiTi Phase 1a system capacity is compounded by unbalanced passenger flows during peak periods which result in an inefficiently utilised 'commuter' service as buses are relatively empty in the return direction. The research outputs indicate that the distribution and density of the existing population and current public transport (MyCiTi) mode share in the West Coast corridor are too low to generate sufficient peak hour travel demand, suggesting that significant increases in the intensity of development and the public transport (MyCiTi) mode share are required to utilise the maximum practical capacity of the MyCiTi phase 1a system.

The forecasting model indicates that there are likely to be significant delays before passenger demand is sufficient to match the maximum practical capacity of the MyCiTi system if the prevailing 'Business as Usual' development model and associated low public transport (MyCiTi) mode share persists. The outputs of the forecasting model suggest that the capacity provided by the MyCiTi system may not be fully utilised over the lifespan of the MyCiTi infrastructure (estimated at ±40 years) if densification and mixed use developmental objectives and mode share targets are not realised. The outputs of the backcasting model demonstrate the benefits of an alternative 'Smarter City Growth' development scenario which requires significantly less developable land and could theoretically be developed at a much faster rate to increase passenger thresholds to support the MyCiTi Phase 1a system. Advantages associated with the 'Smarter City Growth' scenario include reduced car dependency, environmental benefits, cheaper and more sustainable MyCiTi operations and general urban efficiencies associated with high density compact corridor development.

6. PREPARING FOR SMARTER CITY GROWTH

From a land use perspective it is important to note that whilst investments in high quality public transport systems have the potential to 'restructure' cities through providing the capacity needed to support high intensity growth and development – land use intensification is unlikely to occur instantaneously following the construction or upgrade of public transport systems. Although public transport investments can have a positive impact on land values and commercial rents[8], the development response to mass rapid transit on actual development can be slow.

Cape Town's BRT system has been operational since May 2011. Whilst it is acknowledged that it is still operating as a 'starter system', there has been little evidence of a significant land use response. Belzer and Autler, 2002 attribute unrealised development expectations to confusion between increased land values stemming from public transport investments and market demand for particular 'real estate products' in close proximity to mass rapid transit systems. Belzer and Autler, 2002 suggest that public transport investments are unlikely to result in accelerated high intensity forms of development in the absence of a coordinated public transport supportive policy - even if land values are enhanced as a result of the mass transit investment.

From a travel demand management perspective, investments in high quality public transport systems such as MyCiTi have the potential to influence mode shares in favour of public transport. The literature suggests that the extent of modal shift is likely to be determined by dynamic responses to changes in supply and demand characteristics which affect the generalised costs of travel. In the same way that increases in the supply side of transport capacity in congested networks reduce the generalised costs of car travel and can 'induce'[9] new additional traffic, decreases in supply side capacity have the potential to 'suppress' traffic. The ability to suppress traffic is emerging as a useful transport management tool to 'lock in'[10] the benefits of public transport system improvements. The literature suggests that effective Travel Demand Management programmes which are synchronised with, and complementary to, the introduction of high quality mass rapid transport systems are likely to contribute towards accelerated and sustained public transport mode share increases.

The literature suggests that whilst land use interventions should adopt measures to concentrate the mix and intensity of urban activity in desired locations, travel demand management programmes must be formulated to provide incentives to attract public transport ridership, and disincentives to discourage car use. These measures should not be seen as new policy instruments as they are indicated as essential components of the IRPTN roll-out in the Public Transport Action Plan (DoT, 2007). The literature suggests that it is important that these measures are applied in a coordinated manner across a hierarchy of scales and carefully synchronised as part of an integrated package of interventions to provide an enabling framework for the emergence of a 'Smarter City Growth' model of urban development.

7. CONCLUSION

The research reported upon in this paper has demonstrated that there is considerable potential for underutilisation of the MyCiTi Phase 1a system in the short to medium term. An increase in total travel demand as well as significant increases in the public transport (MyCiTi) mode share is needed to accelerate the take-up of MyCiTi Phase 1a system capacity.

Based on the prevailing West Coast suburban development model, and the experiences of other cities which have implemented or upgraded mass rapid transit systems, it is considered unlikely that an alternative ‘Smarter City Growth’ development model will emerge in the short-medium term as a response to the MyCiTi investment in isolation from supporting development strategies, policies, tools and mechanisms. Alternative policy pathways and institutional mechanisms may be needed in conjunction with the phased IRPTN investment programme to bring about systematic and structural changes to the prevailing model of suburban development to accelerate land use responses to increase the demand for travel and the MyCiTi mode share.

On the basis of the research findings, it is recommended that a complimentary package of integrated urban development and travel demand management interventions is conceptualised and aligned to the phased rollout of IRPTN networks in Cape Town and other South African cities.

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ANNEXURE A:
MYCITI PHASE 1A CAPACITY CALCULATIONS

Bus availability:	- Sufficient buses are available to maximise the capacity of loading areas.
Bus occupancy:	- It is assumed that all future trunk buses are articulated 18m 142 person capacity vehicles which have a practical occupancy of 0.70 (approximately 100 people).
Dwell times	- Dwell time assumptions are based on existing and perceived demand. For example, Woodstock station is a rail/BRT interchange which is likely to have a longer dwell time (due to increased boarding and alighting) than an intermediate station such as Lagoon Beach station. - The effect of increased service demand at future milestone terminal points on boarding and alighting has not been factored into the calculations. Longer dwell times associated with future milestone terminal points are likely to decrease the maximum practical capacity of the MyCiTi Phase 1a system. - The impact of multiple boarding / alighting entry points on 18m (three) and 12m (two) buses has not been factored into the calculations.
Different routes are able to share bus loading areas.	- This will require the introduction of variable message signs at interchanges and terminal points of the service.
Express and limited stop services are able to pass buses docking at intermediate stations.	- It is understood that the only point where this is not possible is on the approach to Milnerton station where a passing lane has not been provided. These impacts are likely to be minor and have not been factored into the calculations. - Thibault Square station passing lanes are in mixed traffic. Potentially reduced capacities relating thereto have not been factored into the capacity calculations.
Feeder / distribution services	- The capacity of feeder and distribution services required to service the trunk system operating at maximum practical capacity has not been calculated. It is assumed that the capacity of the feeder / distribution services will be sufficient to serve trunk routes operating at the maximum practical capacity. This will depend on the feeder bus size, availability of berths for feeder buses, the frequency of the feeder bus service, the number of feeder buses operating, and the time taken to transfer from the feeder bus to the loading areas of trunk services.
Passenger capacity and bus loading area passenger holding areas	- The impact of variations between passenger arrivals during the peak hour has not been calculated. Passenger variations are likely to result in reductions to system capacity. - It is assumed that bus loading area passenger holding capacities within MyCiTi stations are of a sufficient size to accommodate passengers during the peak hour and/or bus headways are frequent enough to prevent overcrowding on bus loading areas.
Signal time g/C ratios:	- Milestone 0: Existing traffic signal g/C ratios were obtained from the CoCT: Traffic Control department (see Figure A.4). A default value of 0.4 g/C was adopted for unknown g/C ratios. - Milestones 1-5: Traffic signal g/C ratios were not available. Potential signal time values of 0.6 g/C and 0.8 g/C were adopted to determine the maximum practical capacity of the system. For practical reasons the maximum practical capacity (pax/hr/dir) values associated with a signal time ratio of 0.6 g/C are considered to be the upper capacity limit of the MyCiTi Phase 1a system. - The effect of intersections on system capacity between stations where buses enter mixed traffic conditions has not factored in to the calculations (i.e. impact of turning operations onto the R27).

Figure A.1: Assumptions informing the maximum practical capacity calculations

Vehicle type	No of vehicles	Vehicle occupancy						No of doors
		Max seated capacity	Max standing capacity	Wheel-chair	Total	Practical occupancy (85%)	Observed occupancy* (75%)	
18m articulated bus	8	53	87	2	142	121	100	3
12m solo bus	35	41-43	58	1	89	76	63	2

Figure A.2: Vehicle occupancy assumptions

Notes: The observed occupancy value of 75% is based on interview with Ron Haidon (24-05-2012). The reason for the lower than anticipated vehicle occupancy is that passengers prefer to wait for the next bus rather than standing for the duration of the journey.

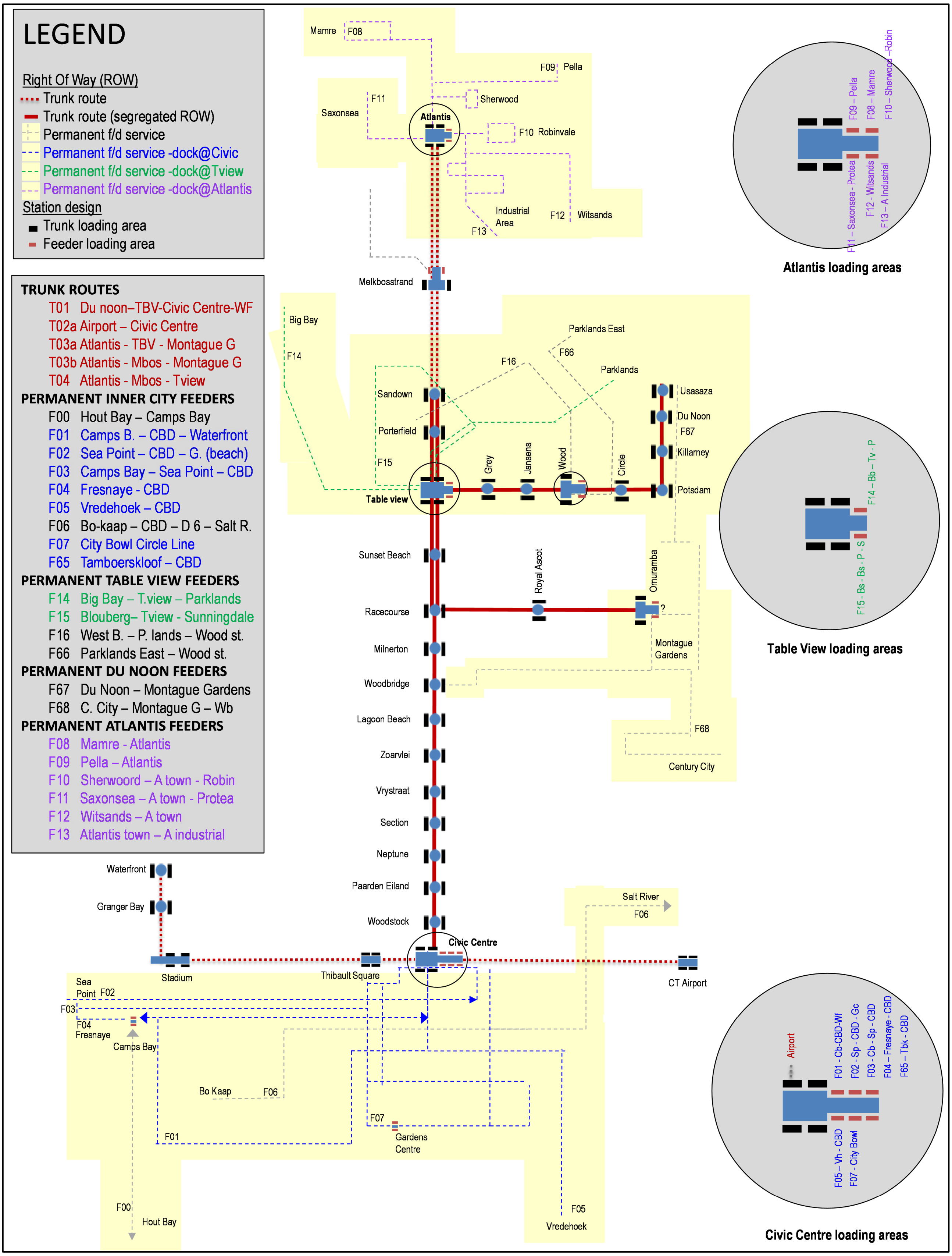

Figure A.3: MyCiTi phase 1a: conceptual route network and loading area availability (adapted from CoCT, 2010 and CoCT, 2012)

Station	Description / Comment	Average (mean) dwell time	Clearance time	Existing / Assumed g/C (green time ratio)	Potential g/C=0.6	Potential g/C=0.8	St normal variable corr. to desired failure rate	Coefficient of variation of dwell times	Existing / Assumed g/C loading area capacity (buses/hour)	Potential loading area capacity (g/C=0.6)
Atlantis	Terminal station	90	10	0.4	0.6	0.8	1.04	0.4	17	21
Melkbosstrand	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Sandown	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Porterfield	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Table View	Terminal station	90	10	0.38	0.6	0.8	1.04	0.4	17	21
Grey	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Jansens	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Wood	Feeder transfer	30	10	0.4	0.6	0.8	1.96	0.4	32	42
Circle	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Potsdam	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Killarney	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Du Noon	Standard	90	10	0.4	0.6	0.8	1.04	0.4	17	21
Usasaza	Terminal station	30	10	0.4	0.6	0.8	1.96	0.4	32	42
Sunset Beach	Standard	25	10	0.66	0.66	0.8	1.96	0.4	52	52
Omuramba	Standard	30	10	0.4	0.6	0.8	1.96	0.4	32	42
Royal Ascot	Standard	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Racecourse	Standard	25	10	0.68	0.68	0.8	1.96	0.4	53	53
Milnerton	No passing lane	25	10	0.77	0.77	0.8	1.96	0.4	57	57
Woodbridge	Standard	25	10	0.7	0.7	0.8	1.96	0.4	54	54
Lagoon Beach	Standard	25	10	0.7	0.7	0.8	1.96	0.4	54	54
Zoarvlei	Standard	25	10	0.68	0.68	0.8	1.96	0.4	53	53
Vrystraat	Standard	25	10	0.3	0.6	0.8	1.96	0.4	29	48
Section	Standard	25	10	0.29	0.6	0.8	1.96	0.4	28	48
Neptune	Standard	25	10	0.33	0.6	0.8	1.96	0.4	31	48
Paarden Eiland	Standard	25	10	0.21	0.6	0.8	1.96	0.4	22	48
Woodstock	Modal interchange	30	10	0.62	0.62	0.8	1.96	0.4	43	43
Civic Centre	CBD Terminal 1	90	10	0.22	0.6	0.8	1.04	0.4	12	21
Thibault Square	CBD Terminal 2 General traffic passing lane	30	10	0.4	0.6	0.8	1.44	0.4	37	48
Stadium	Standard	90	10	0.4	0.6	0.8	1.04	0.4	17	21
Granger Bay	General traffic passing lane	25	10	0.4	0.6	0.8	1.96	0.4	36	48
Waterfront	Terminal station	25	10	0.4	0.6	0.8	1.96	0.4	36	48

Milestone 0 | Milestone 1,2 | Milestone 3 | Milestone 4

Figure A.4: Loading area capacity calculations (buses / hour) for routes T01, T03a, T03b, T04

Notes:

1. Average (mean) dwell time: Depends on whether the bus is empty on arrival, the number of doors and passenger demand for boarding and alighting. Typical values are 60s downtown, 30s major stop, 15s outlying (TCQSM, 2003). These values are based on observations and discussion with the CoCT IRT department (Grey, 2012).
2. Clearance time: The time taken for the bus to start and travel its own length to clear the stop. Assumption: average of 10s (TCQSM, 2003).
3. Existing / assumed g/C (green time ratio): The average amount of green time for exclusive bus divided by length of traffic cycle. Existing traffic signal g/C ratios were obtained from the CoCT: Traffic Control department (CoCT, 2012). A default value of 0.4 g/C was adopted for unknown g/C ratios. Potential signal time values of 0.6 g/C and 0.8 g/C were adopted to illustrate the impact of signal time ratios on the capacity of the MyCiTi system.
4. Standard normal variable corresponding to a desired failure rate: A predetermined failture rate for how often a bus can arrive at a stop to find loading area(s) occupied. This variable applies an operating margin to dwell and clearance times to prevent 'failures' from occurring. A lower failure rate will result in lower system capacity. Assumptions: 2.5% (1.96) for outliers, 7.5-15% (1.44 - 1.04) for busy stops (TCQSM, 2003).
5. Coefficient of variation of dwell times: Results from fluctuating passenger demand and is calculated by dividing the standard deviation of dwell times by the average dwell time. Assumption: 40% (TCQSM, 2003).

Variables based on:

1. International benchmarks (TCQSM, 2003).
2. A survey undertaken to observe AM peak hour operations on a typical weekday (Grey, 2012).
3. Interviews with CoCT IRT officials (infrastructure, systems planning and operations) (Grey, 2012).

Loading area capacity (existing and potential)	Peak Period		Observed practical vehicle occupancy	Route capacity p/ph/dir
	Headway (min)	Vehicles / hour		

				n
Loading area capacity (existing g/C)	5	12	100	1,200
Loading area capacity (potential 0.6 g/C)	2.9	21	100	2,100
Loading area capacity (potential 0.8 g/C)	2.5	24	100	2,400

Figure A.5: Milestone 0 - maximum theoretical capacity (pax/hr/dir) of route T01: Table View – Civic – conventional 'fixed stop' service (pax/hr/dir)

Notes:

1. Milestone 0 does not have additional loading areas and from a practical perspective can only operate a conventional fixed stop type service.

Station	Description / Comment	Existing loading area (berth) capacity) (buses/hour)	Potential loading area capacity (g/C=0.6)	Potential loading area capacity (g/C=0.8)	No. loading areas (berths) / dirn	Cumulative # of effective loading areas	Bus Stop Capacity (buses/hour) with existing g/C ratios	Bus Stop Capacity (buses/hour) potential g/C =0.6	Bus Stop Capacity (buses/hour) potential g/C =0.8
Atlantis	Terminal station	17	21	24	3	2.45	42	52	59
Melkbosstrand	Standard	36	48	58	1	1	36	48	58
Sandown	Standard	36	48	58	1	1	36	48	58
Porterfield	Standard	36	48	58	1	1	36	48	58
Table View	Terminal station	17	21	24	3	2.45	41	52	59
Grey	Standard	36	48	58	1	1	36	48	58
Jansens	Standard	36	48	58	1	1	36	48	58
Wood	Feeder transfer	32	42	50	1	1	32	42	50
Circle	Standard	36	48	58	1	1	36	48	58
Potsdam	Standard	36	48	58	1	1	36	48	58
Killarney	Standard	36	48	58	1	1	36	48	58
Du Noon	Standard	17	21	24	1	1	17	21	24
Usasaza	Terminal station	32	42	50	1	1	32	42	50
Sunset Beach	Standard	52	52	58	1	1	52	52	58
Omuramba	Standard	32	42	50	1	1	32	42	50
Royal Ascot	Standard	36	48	58	1	1	36	48	58
Racecourse	Standard	53	53	58	1	1	53	53	58
Milnerton	No passing lane	57	57	58	1	1	57	57	58
Woodbridge	Standard	54	54	58	1	1	54	54	58
Lagoon Beach	Standard	54	54	58	1	1	54	54	58
Zoarvlei	Standard	53	53	58	1	1	53	53	58
Vrystraat	Standard	29	48	58	1	1	29	48	58
Section	Standard	28	48	58	1	1	28	48	58
Neptune	Standard	31	48	58	1	1	31	48	58
Paarden Eiland	Standard	22	48	58	1	1	22	48	58
Woodstock	Modal interchange	43	43	50	1	1	43	43	50
Civic Centre	CBD Terminal 1	12	21	24	2	1.75	21	37	42
Thibault Square	CBD Terminal 2 General traffic passing lane	37	48	56	2	1.75	64	83	98
Stadium	Standard	17	21	24	2	1.75	30	37	42
Granger Bay	General traffic passing lane	36	48	58	1	1	36	48	58
Waterfront	Terminal station	36	48	58	1	1	36	48	58

Milestone 0 | Milestone 1,2 | Milestone 3 | Milestone 4

Figure A.6: Bus station capacity calculations (buses/hour) - routes T01, T03a, T03b, T04

Notes:

1) <u>Cumulative # of effective loading areas:</u> Linear stops are partially effective as each additional loading area adds less capacity than the loading area before it. This is due to:
   - Rear loading areas being used less often than the first loading area;
   - Passenger delays due to variable use of loading areas which result in longer dwell times;
   - Bus interferance in terms of arrivals and clearance.

   (Values adopted from (TCQSM, 2003))

Bus station capacity (existing / potential)	Peak Period		Maximum practical vehicle occupancy (0.7% occupancy)	Route capacity (p/ph/dirn)
	Headway (min)	Vehicles / hour		
Loading area capacity (existing g/C)	2.9	21	100	2,100
Loading area capacity (potential 0.6 g/C))	1.6	37	100	3,700
Loading area capacity (potential (0.8 g/C))	1.43	42	100	4,200

Figure A.7: Milestone 1,2 Route T01 & T03 – conventional fixed stop service (pax/hr/dir)

Notes:

1. Vehicles/hour values are extracted from the minimum bus station capacity associated with the critical station (Civic Centre) (see Figure A.6).

Bus station capacity (existing / potential)	Peak Period		Maximum practical vehicle occupancy (0.7% occupancy)	Route capacity (p/ph/dirn)
	Headway (min)	Vehicles / hour		
Loading area capacity (existing g/C)	1.46	41	100	4,100
Loading area capacity (potential 0.6 g/C))	1.2	52	100	5,200
Loading area capacity (potential (0.8 g/C))	1.0	59	100	5,900

Figure A.8: Milestone 1,2 - Route T01 & T03 – enhanced service operations (pax/hr/dir)

Notes:

1. Vehicles/hour values are extracted from the lower value of 'origins' vs. 'destinations' bus station capacity (Table View) (see Figure A.6).

Possible combination of origins and destinations	Bus station capacity (buses / hour)		
	Existing g/C	Potential g/C (0.6)	Potential g/C (0.8)
Atlantis	42	52	59
Table View	41	52	59
TOTAL ORIGINS	**83**	**104**	**118**
Omuramba	32	42	50
Civic Centre	21	37	42
Thibault Square	64	83	98
Stadium	30	37	42
TOTAL DESTINATIONS	**147**	**199**	**232**

Figure A.9: Milestone 3 enhanced network operations bus station capacity (buses/hour)

Notes:

1. Bus station capacity is determined by the lower value of the sum of 'origins' vs. the sum of 'destinations' critical bus station capacity.

Possible combination of conventional, skip stop, express service routes	Peak Period	Max practical vehicle occupancy (0.7%)	Route capacity (p/ph/dirn)
	Vehicles / hour		

Atlantis – Civic Centre Atlantis – Omuramba Atlantis – Thibault Square Atlantis – Stadium Table View – Civic Centre Table View – Thibault Square Table View – Stadium Omuramba – Civic Centre Omuramba – Thibault Square Omuramba – Stadium	83 (existing g/C) 104 potential g/C (0.6) 118 potential g/C (0.8)	100	8,300 (existing g/C) 10,400 (potential g/C (0.6)) 11,800 (potential g/C (0.8))

Figure A.10: Milestone 3 capacity calculations (pax/hr/dir) based on possible enhanced network operation route combinations

Possible combination of origins and destinations	Bus station capacity (buses / hour)		
	Existing g/C	Potential g/C (0.6)	Potential g/C (0.8)
Atlantis	42	52	59
Table View	41	52	59
Dunoon	17	21	24
TOTAL ORIGINS	**100**	**125**	**142**
Omuramba	32	42	50
Civic Centre	21	37	42
Thibault Square	64	83	98
Stadium	30	37	42
TOTAL DESTINATIONS	**147**	**199**	**232**

Figure A.11: Milestone 4 enhanced network operations bus station capacity (buses/hour)

Notes:

1. Bus station capacity is determined by the lower value of the sum of 'origins' vs. the sum of 'destinations' critical bus station capacity.

Possible combination of conventional, skip stop, express service routes	**Peak Period**	**Max practical vehicle occupancy (0.7%)**	**Route capacity (p/ph/dirn)**
	Vehicles / hour		
Atlantis – Civic Centre Atlantis - Omuramba Atlantis – Thibault Square Atlantis – Stadium Table View – Civic Centre Table View – Thibault Square Table View - Stadium Dunoon – Civic Centre Dunoon – Thibault Square Dunoon - Omuramba Dunoon – Stadium	100 (existing g/C) 125 (potential g/C (0.6)) 142 (potential g/C (0.8))	100	10,000 (existing g/C) 12,500 (potential g/C (0.8)) 14,200 (potential g/C (0.8))

Figure A.12: Milestone 4 capacity calculations (pax/hr/dir) based on possible enhanced network operation route combinations

END NOTES:

1 The Development Facilitation Act (No. 67 of 1995), Local Government: Municipal Systems Act (No. 32 of 2000).

2 The MyCiTi Business Plan includes additional routes, however the projected demand for these routes has not been provided. For the purposes of this research it was assumed that the total southbound travel demand is 3,252 pax/hr/dir (CoCT, 2012).

3 Grey, P., 2012: *A case for smarter city growth: A strategic analysis of Cape Town's Phase 1a BRT system and its supporting land use environment*, Master of Philosophy (Transport Studies) 60-credit minor dissertation, University of Cape Town.

4 Capacity measurements in terms of pax/hr/dir calculate the number of passengers that can pass by a point of maximum load in one direction. It is important to note that single direction 'point to point' demand is not always an indicator of efficiency. The cost effectiveness of the MyCiTi Phase 1a service will be determined by its ability to achieve balanced passenger flows in a northern and southern direction rather than maximised 'point to point' single direction journeys.

5 Gross density measures the number of dwelling units per hectare (including other land uses such as industry, commercial, Education, public open space and infrastructure such as public roads).

6 The forecasting and backcasting models are spreadsheet models developed in Microsoft Excel which make numerous simplifying assumptions and do not consider the effects of endogenous variables and potential behavioural feedback loops.

7 "Backcasting' is a modelling approach which is based on imagining a preferred future vision as a starting point, and then determining which measures need to be put in place in order to progressively move towards realising the preferred future vision. Various definitions are provided in the literature. The Oxford Programme for the Future of Cities for instance describes 'backcasting' as defining and evaluating alternative images of the future, and casting back to the present (http://www.futureofcities.ox.ac.uk/research/transportfutures, accessed on the 8-06-2012). Zhao et al, 2011 describes 'backcasting' as a technique used to determine policy pathways best suited to achieving a desired end state which is particularly useful when radical trend-breaks are needed to avoid path dependencies, and when current trends and decision making forms part of the problem.

8 In Bogota, TransMilenio system improvements in accessibility and mobility have impacted on land prices resulting in 6.8-9.3% premium increases for every five minutes walking time from trunk stations (Ardila-Gomez, 2008).

9 The notion of *'induced traffic'* was first introduced in a report by the *Standing Advisory Committee for Trunk Road Assessment (SACTRA)* in 1994. Induced traffic is best explained through the adaption of travel behaviour when confronted with significant changes to the 'generalised costs' or constraints associated with travel.

10 The principle of 'locking in' benefits is based on the perceived ability of artificially maintaining a 'balance' in the generalised costs of travel following changes to the system capacity (either direct or indirect), through measures which make it more difficult for single occupancy vehicular travel (i.e. making car travel either slower or more costly).