RESULTS OF THE APPLICATION OF A COST MODEL TO PUBLIC TRANSPORT SERVICES IN CAPE TOWN

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INTRODUCTION

The City Cape Town as a part of its ongoing public transport restructuring programme and in keeping with the recently promulgated National Land Transport Transition Act (22 of 2000) has done various studies to give direction to the restructuring of its public transport system. One study of this programme is the development of an understanding of the cost structure of public transport in the regions so that the costs, on the supply side, of changes to the existing system can be compared.

The paper summarises the work done to develop this understanding that will have impact on the evaluation of the strategies that will be considered. The paper covers three aspects of the study; namely the structure of the cost model, that default data collected for and used in the model and the initial findings from the application of the cost model.

STRUCTURE OF THE COST MODEL

Figure 1 shows the overall structure of the model to be composed of:

a) **Situation Input module**; whereby the user of the model inputs the passenger demand scenario and the public transport vehicle options to be tested.
b) **Vehicle Parameters Input module**; whereby the user is able to modify the default parameter values for the public transport modes.
c) **Calculation module**; whereby all the calculations are done
d) **Financial Analysis Output module**; whereby the user can view the financial / cash flow implications of the public transport service over the 20-year period of analysis; This includes a graphical output of the income and expenditure incurred over the analysis period.
e) **Economic Analysis Output module**; whereby the user can view the economic cost of the public transport service being considered over the analysis period of 20 years.
f) **Context Analysis Output module**; whereby the user can view a comparison in tabular form of the economic cost of servicing the passenger demand over a range of 1000 to 100 000 one-way passengers per day and in the peak hour and similarly in graphical form for a selected set of six transport modes.

A further component, which will serve to test the sensitivity of output values (such as total capital cost, annualized capital cost, total annual operating cost, total annual cost, average cost/passenger, average cost/passenger-km, changes to seven default vehicle parameter values to test the sensitivity of the outputs to these changes) will be added to future versions of the model.

ISBN: 0-620-28855-8

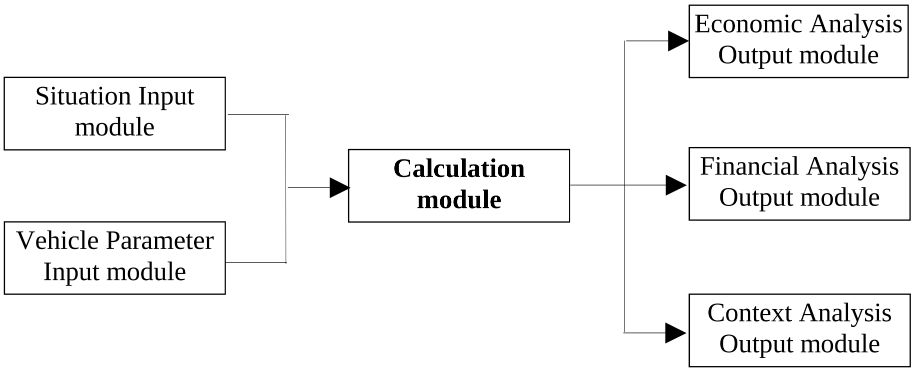


FIGURE 1: STRUCTURE OF THE PUBLIC TRANSPORT COST MODEL

Situation Input Module

The front page to the situation input module is shown in Figure 2.

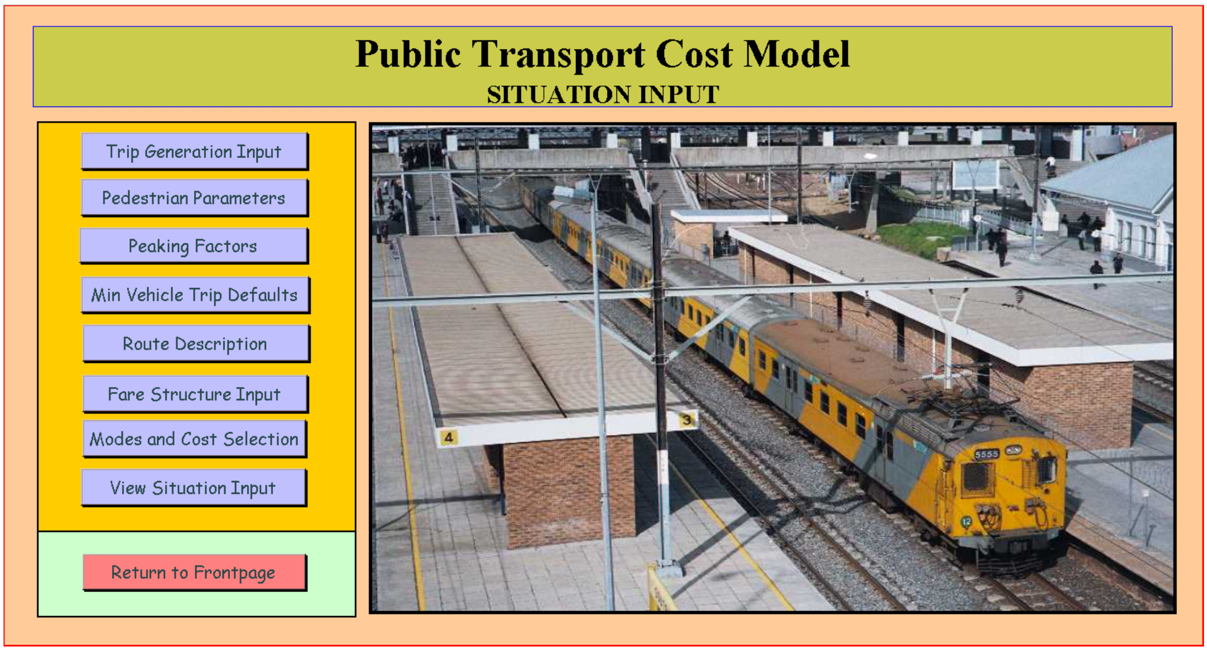


FIGURE 2: SITUATION INPUT FRONT PAGE

The situation for which the model is required to calculate public transport costs can be defined as follows:

a) **Trip generation**. The model is based on the number of passengers travelling on the route in the morning peak direction. The values can be input as am peak direction trips per day, in the peak period or in the peak hour. This can be provided in terms of the area to be served and its trip making characteristics (e.g. residential density, trip generation rate, and directional split) or as a passenger loading on the route. The model also allows for growth in passenger volumes over time which can be specified either as passenger values at year 0, 5, 10, 15 and 20 or as a percentage annual growth rate applied to the year 0 volumes.

b) **Pedestrian parameters** are specified in the case where the catchment in the residential area is to be defined by the maximum walking distance and ratios between route and stop spacing

c) **Peaking factors**. The peak hour and peak period passenger volumes determine the size of the vehicle fleet and the peak hour vehicle trips define the number of lanes required to cope with the passenger demand. As such values need to be applied to convert daily passenger volumes to hourly passenger volumes. Default values were developed from studies of passenger volumes at major modal interchanges in Cape Town, as shown in Table 1.

TABLE 1: PUBLIC TRANSPORT PEAKING CHARACTERISTICS (Percent of total day)

	TRAIN				BUS				MINIBUS				ALL PT MODES			
	Peak	2nd	3rd	Rem	Peak	2nd	3rd	Rem	Peak	2nd	3rd	Rem	Peak	2nd	3rd	Rem
Cape Town (2000) Low													**19**	**15**	**10**	**4,31**
Cape Town (2000) High													**25**	**23**	**12**	**3,08**
Bellville (2000)	15.92	11.71	6.66	5.05	19.35	17.54	12.33	3.91	17.84	14.69	11.73	5.57	17	14	9	4.65
Cape Town (2000)	26.45	23.68	12.00	2.91	24.19	20.53	12.99	3.25	18.83	13.20	5.75	6.22	23	21	11	3.45
Claremont (2000)	29.34	25.54	7.59	2.89	25.28	23.15	12.95	2.97	29.67	29.28	19.52	2.15	27	27	11	2.76
Khayelitsha (2000)	20.15	18.63	17.12	3.39	41.16	17.00	4.76	2.85	28.92	19.68	18.20	3.32	24	20	15	3.14
Mitchell's Plain (2000)	34.08	18.00	8.85	3.01	30.98	30.98	4.05	2.61	17.19	11.46	9.52	6.18	18	15	5	4.75
Mowbray (2000)	17.73	12.32	8.11	4.76	18.35	13.96	13.46	4.17	23.23	18.42	15.48	4.29	20	16	11	4.05
Wynberg (2000)	31.60	12.85	9.21	3.56	21.89	21.03	12.53	3.43	25.47	16.98	16.52	4.10	22	15	13	3.80
Average	25.04	17.53	9.93	3.65	25.89	20.60	10.44	3.31	23.02	17.67	13.82	4.55	21	18	11	*3.53*

d) **Minimum vehicle trips** can be specified to reflect the minimum permissible frequency of vehicles on the route. The default values are 2 vehicles/hour during the peak period and 1 vehicle/hour in the off peak.

e) **Classification of route components**. Since different speeds apply along different sections of the route, the route can be specified in relation to four generic classes; namely Central business district/ commercial (Class 3 and 4 roads and for rail between 0-10 km from the CBD; arterial class roads (Class 2 and 3 roads) and for rail between 10-20 km from the CBD; freeway (Class 1 roads) and for rail greater than 30 km from the CBD and Residential (Class 4 and 5 roads) and for rail between 20-30 km from the CBD.

f) **Description of modes and costs to be included**. The model allows the user to compare 20 alternative vehicle types as potential modes along the route under study; namely 7 train alternatives, 3 LRT alternatives, 6 bus alternatives and 2 minibus alternatives. Where a train of vehicles is to form the scenario the user can select the number of coaches as well as the vehicle type. The model offers the opportunity to select from the following vehicle types; namely 5M, 9M and 10M trains; one LRT vehicle; Midibus (as per the government's recapitalisation programme), standard bus, up-market bus as are being tested in Cape Town at present and the articulated bus, and the existing minibus and the minibus being proposed under the government's recapitalisation programme.

The model also allows the fare income for the route to be calculated.. The user is required to input the percentage of passengers in each of the distance or zonal categories in respect of the zonal and distance based fares; and the fares applicable to these distances and zones or the flat fare, which ever is applicable.

Vehicle Parameter Input Module

The following default values have been collected for all the vehicles that can be modeled:

a) Maximum speed in the four route types
b) Stop spacing along the four route types
c) Acceleration and deceleration rates
c) Passenger boarding and alighting or vehicle stopped time at stations
d) Time spent to turn vehicle around at the end of the route
e) Vehicle capacity over long and short routes
f) Capital cost of the vehicle, life to refurbishment, cost of refurbishment number of refurbishments, life of each refurbishment, stand by fleet, interest rate and residual value of the vehicle
g) Cost of land over each of the 4 route types, cost per lane of way, lane capacity, life of way
h) Cost of terminal /10 000 peak hour passengers or /peak hour vehicle, life of the terminal
i) Cost of stops, life of stop
j) Cost of depot/ vehicle, life of the depot
k) Energy consumption / vehicle-km and cost of energy
l) Operating costs based on cost/veh/year and cost/veh-km
m) Operating cost/track-km
n) Operating cost/station

Interest rates are also included in the cost calculations as is an opportunity cost factor for the economic analysis.\

The vehicle parameter values are summarised in Table 2.

Financial and Economic Output Module

The economic and financial analyses work together to produce 20-year analyses for each mode alternative. These include keeping track on the passenger volumes in each year and therefore the infrastructure needs to service these volumes. This in turn requires the costing of the expenditure in each year and then the memory of the age of the investment to be able to calculate the appropriate year for refurbishment and the residual values at the end of the analysis period.

Figures 3 and 4 show typical examples of the outputs from the financial module. These are accompanied by detail and summary tables. The economic analysis is also reflected in detail and summary table.

Context Analysis Output module

This modeule is discussed in more detail in the section on the initial aplications of the cost model.

TABLE 2a: SUMMARY OF VEHICLE PARAMETER VALUES

MODE	TRAIN 9M	TRAIN 10M	LRT	Midibus recap	Standard Bus	High quality bus	Articulated bus	Minibus	Minibus Recap
Travel speed CBD/Commercial in peak (km/h)	43	43	30	20	20	20	20	20	20
Travel speed Arterial in peak (km/h)	48	48	40	45	45	45	45	50	50
Travel speed Freeway in peak (km/h)	60	60	50	50	50	50	50	70	70
Travel speed Residential in peak (km/h)	57	57	50	30	30	30	30	50	50
Travel speed CBD/Commercial off-peak (km/h)	43	43	30	20	20	20	20	20	20
Travel speed Arterial off-peak (km/h)	48	48	40	50	50	50	50	50	50
Travel speed Freeway off-peak(km/h)	60	60	50	50	50	50	50	70	70
Travel speed Residential off-peak (km/h)	57	57	50	30	30	30	30	50	50
Stop spacing (km): CBD/Commercial	1.6	1.6	1	1	1	1	1	1	1
Stop spacing (km): Arterial/Inner section	2.0	2.0	2	2	2	2	2	2	2
Stop spacing (km): Freeway/Outer areas	5.0	5.0	5	5	5	5	5	5	5
Stop spacing (km): Residential	2.5	2.5	2	2	2	2	2	2	2
Acceleration: (m/s^2)	0.85	0.43	0.9	0.5	0.5	0.5	0.5	1.5	1.5
Deceleration: (m/s^2)	0.90	0.56	1.0	0.6	0.6	0.6	0.6	2	2
Passenger handling time(sec/space offerred)	-	-	-	25	25	25	25	40	40
Vehicle Stopped Time/stop (sec)	20	20	20	-	-	-	-	-	-
Time spent to turn vehicle(min)	4+0.5/coach	4+0.44/coach	2+0.5/ coach	1	1	1	1	0	0
Maximum volume/Capacity ratio	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Vehicle capacity (standing allowed)	255	170	220	35	90	80	170	15	18
Vehicle capacity (standing is not allowed)	191	127	170	35	60	50	120	15	18
Cost per vehicle/train(Rm)	8.45	1.05	12.3	0.303	0.860	1.132	1.887	0.16	0.15
Cost of refurbishment /vehicle / vehicle (Rm)	0.7	0.85	2.5	0	0.043	0.057	0.094	0	0
Time to refurbishment(years)	12	9.5	7.5	7	10	10	10	5	5
Life after refurbishment(years)	12	9.5	7.5	0	7	7	7	-	-
Number of refurbishments per vehicle	3	2	3	0	1	1	1	-	-
Stand-By Fleet (%)	5	5	5	10	10	10	10	10	10
Interest rate(%)	16	16	16	16	16	16	16	16	16
Residual Value (%)	10	10	10	15	15	15	15	15	15

TABLE 2b: SUMMARY OF VEHICLE PARAMETER VALUES

MODE	TRAIN 9M	TRAIN 10M	LRT	Midibus recap	Standard Bus	High quality bus	Articulated bus	Minibus	Minibus Recap
Capacity per lane(Veh/h)	20	20	60	500	300	300	250	700	700
Cost of way(Rm/lane-km)	9.6	9.6	6.5	1.3	1.3	1.3	1.3	1.3	1.3
Life of way(years)	40	40	40	20	20	20	20	20	20
Cost land(Rm/km/lane) CBD/Commercial	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Cost land(Rm/km/lane) Inner section	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Cost land(Rm/km/lane) Outer section	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Cost land(Rm/km/lane) Residential	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Interest rate(%)	16	16	13	16	16	16	16	16	16
Cost of Terminal (Rm/10 000 peak hour pass.)	2.98	2.98	1.46	-	-	-	-	-	-
Cost of Terminals(Rm/peak hour vehicle)	-	-	-	0.027	0.052	0.052	0.102	0.008	0.008
Life of terminals (years)	30	30	30	30	30	30	30	30	30
Interest rate (%)	16	16	16	16	16	16	16	16	16
Cost of stops (Rm/stop)	6.12	6.12	3	-	-	-	-	-	-
Life of stops (years)	30	30	30	-	-	-	-	-	-
Interest rate(%)	16	16	16	-	-	-	-	-	-
Cost of depot (Rm/train)	0.67	0.57	0.62	0.028	0.089	0.089	0.114	-	-
Life of depot(years)	30	30	30	30	30	30	30	-	-
Interest rate (%)	16	16	16	16	16	16	16	-	-
Energy consumption(Mjoules/veh.km)	10.2	8.9	25.2	12.1	23.2	19.4	32.4	11.3	6.7
Fuel Consumption(l/100km)	-	-	-	25	48	40	67	18	14
% of mileage as additional dead mileage	10	10	10	10	10	10	10	10	10
Cost of energy(R/Mjoule) (peak)	0.046	0.046	0.046	-	-	-	-	-	-
Cost of energy(R/Mjoule) (off-peak)	0.062	0.062	0.062	-	-	-	-	-	-
Cost of fuel(R/l)	-	-	-	3.5	3.5	3.5	3.5	3.8	3.5
(Other)Cost/veh.km(R/coach.km)	1.5	1.5	3.6	0.88	0.74	1.11	2.26	0.11	0.11
Cost/vehicle/year(R/vehicle/year)	160 000	160 000	260 000	108 500	147 000	222 000	252 000	28 000	28 000
Cost/lane-km/year(R/lane.km/year)	155 000	155 000	18 000	60 000	60 000	60 000	60 000	60 000	60 000
Cost/terminal/year (%of capital cost)	5	5	5	5	5	5	5	5	5
Cost/station or stop/year (Rm)	675 000	675 000	65 000						
Opportunity Cost(%)	2	2	2	2	2	2	2	2	2

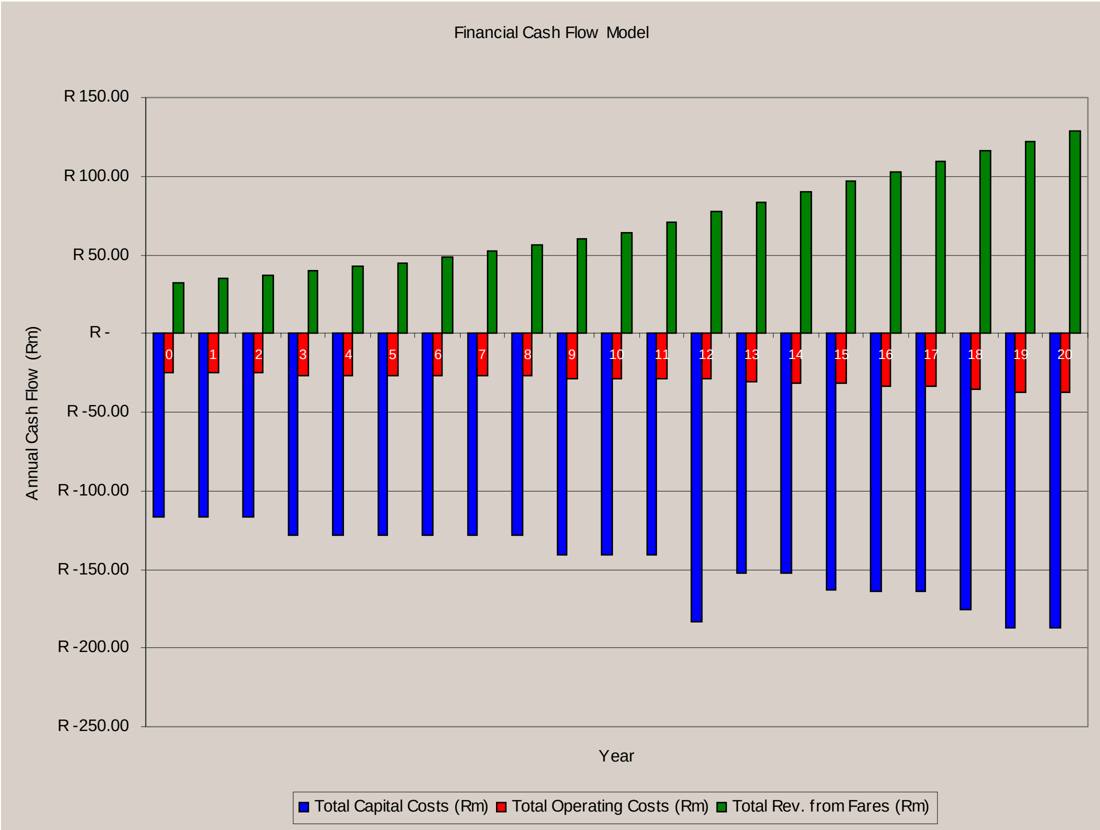


FIGURE 3: ANNUAL COMPONENT COST FROM FINANCIAL ANALYSIS

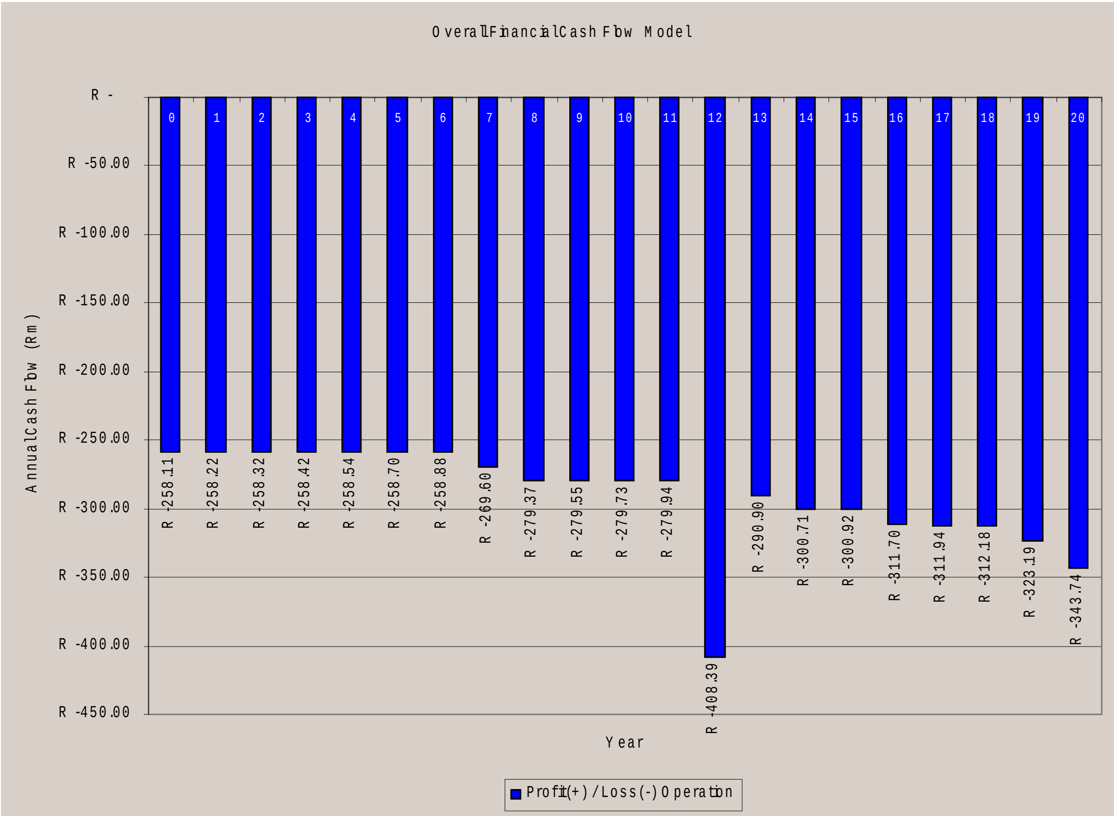


FIGURE 4: ANNUAL PROFIT AND LOSS FROM FINANCIAL ANALYSIS

INITIAL FINDINGS FROM THE APPLICATION OF THE COST MODEL

Cost values for modelling purposes

Table 3 shows the values that can be used for modelling purposes. This table includes the following information:

a) The first block of data refers to simple values that can be used in transportation planning models while the second block of data refers to the values used in the public transport cost model described in this paper.

b) Within the first block of data, information is given for the capital cost, the operating cost and the total cost per coach or single-vehicle /hr. The total cost refers to the average cost per hour for an operation where services are operated throughout the entire day. Most transportation planning models only study the peak period; in which case the total cost/coach-hr in the peak period should be used as this would calculate the total cost of the service over the entire day on the basis of peak period passenger and vehicle volumes.

c) The second block of data is a summary of the unit operating costs used in the public transport cost model described in the paper.

TABLE 3: PUBLIC TRANSPORT COSTS (Rands)

Mode	Train: 10M	Train: 9M	LRT	Midi bus	Std. bus	Up-market bus	Artic bus	Mini-bus	Recap. Mini-bus
COSTS FOR TRANSPORTATION PLANNING									
Cost/coach/hr (capital) PLUS	619.65	1272.15	2090.97	71.85	152.10	186.72	250.75	37.65	36.57
Cost/coach/hr (operating)	220.97	222.19	363.21	109.37	137.63	184.05	188.12	49.01	40.20
Total cost/coach-hr OR	840.62	1494.35	2454.18	181.22	289.73	370.77	438.86	86.67	76.77
Total cost/coach-hr in peak period	1625.70	3150.58	3497.61	262.96	420.16	538.06	636.44	120.28	106.55

	Train: 9M	LRT	Midibus	Standard bus	Up-market bus	Articulated bus	Minibus	Recap. Minibus
MODEL OPERATING COSTS								
Cost /coach/year PLUS	160 000	260 000	108500	147000	222000	252000	28 200	28 200
Cost/coach-km PLUS	1,50	3,6	0.88	0.74	1,11	2,26	0,11	0,11
Energy cost/coach-km PLUS	0,48	1,36	0,88	1,68	1,40	3,35	0,68	0,49
Cost/track km/year PLUS	155 000	18 000	60 000	60 000	60 000	60 000	60 000	60 000
Cost/terminal/year	5% of capital cost							
Cost/station/year	675 000	65 000	5% of capital cost					

Relative effect on cost of default parameters

Table 4 shows the percentages that each component cost is of the total cost for two volume conditions (10 000 and 50 000 one-way passengers / day), over two distances (20 and 30 km), for a 25% peak hour / total day passenger ratio and 2, 2, 2, 1 minimum vehicle frequency in the four types of operating hours.

TABLE 4: PERCENTAGE COST OF COMPONENTS

	20km									30km								
	10M	9M	LRT	Midi Bus	Std BUS	Up-market Bus	Artic. Bus	Mini Bus	Recap Mini	10M	9M	LRT	Midi Bus	Std BUS	Up-market Bus	Artic. Bus	Mini Bus	Recap Mini
CAPITAL COSTS	**10000 one-way passengers /day**																	
Cost of vehicles	8.4	46.4	39.7	29.6	41.3	41.8	47.8	36.6	39.4	7.5	43.5	40.9	28.1	38.8	40.0	45.2	34.5	37.3
Cost of way	57.4	33.5	43.0	0.0	0.0	0.0	0.0	0.0	0.0	58.0	35.4	41.7	0.0	0.0	0.0	0.0	0.0	0.0
Cost of terminals	0.2	0.1	0.2	6.4	7.5	5.8	7.7	4.5	5.1	0.2	0.1	0.2	6.0	7.0	5.5	7.3	4.2	4.8
Cost of stops	5.3	3.1	3.8	0.0	0.0	0.0	0.0	0.0	0.0	5.9	3.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0
Cost of depot	3.5	2.0	0.3	1.2	2.3	1.8	1.6	0.0	0.0	3.1	1.9	0.2	1.1	2.2	1.7	1.5	0.0	0.0
Total Capital Costs	74.8	85.1	87.1	37.2	51.1	49.4	57.1	41.1	44.5	74.8	84.5	86.3	35.2	48.0	47.2	54.0	38.6	42.2
OPERATING COSTS																		
Cost of energy	1.9	1.3	1.8	13.6	13.3	9.1	8.0	32.2	25.1	1.9	1.3	2.0	15.4	16.6	11.1	10.4	35.3	28.1
Cost of other	5.9	3.5	5.0	13.6	5.8	7.2	7.7	5.2	5.6	6.0	3.6	5.6	15.5	7.3	8.8	10.0	5.7	6.3
Cost of vehicle	6.2	3.6	4.6	34.8	28.9	33.6	26.2	21.0	24.2	5.6	3.4	4.7	33.1	27.2	32.2	24.7	19.8	22.9
Cost of way	6.7	3.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	6.8	4.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Cost of terminals	0.0	0.0	0.0	0.8	0.9	0.7	0.9	0.5	0.6	0.0	0.0	0.0	0.7	0.8	0.7	0.9	0.5	0.6
Cost of stops	4.4	2.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	4.9	3.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Operating Costs	25.2	14.9	12.9	62.8	48.9	50.6	42.9	58.9	55.5	25.2	15.5	13.7	64.8	52.0	52.8	46.0	61.4	57.8
TOTAL COSTS	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CAPITAL COSTS	**50000 one-way passengers /day**																	
Cost of vehicles	18.2	61.5	66.4	26.1	36.3	38.1	43.8	29.3	32.3	17.5	63.0	64.5	27.7	39.1	40.2	46.8	31.8	34.9
Cost of way	37.4	20.0	13.5	5.0	4.8	3.3	2.2	9.6	8.7	40.0	19.5	15.9	4.3	3.7	2.6	1.6	8.4	7.4
Cost of terminals	0.5	0.3	0.3	5.6	6.6	5.3	7.1	3.6	4.2	0.8	0.4	0.4	6.0	7.1	5.6	7.6	3.9	4.5
Cost of stops	3.8	2.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	3.7	1.8	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Cost of depot	7.6	2.7	0.1	1.1	2.1	1.6	1.4	0.0	0.0	7.3	2.8	0.1	1.1	2.2	1.7	1.5	0.0	0.0
Total Capital Costs	67.5	86.5	81.3	37.8	49.8	48.4	54.6	42.4	45.2	69.2	87.4	82.4	39.1	52.2	50.1	57.5	44.1	46.9
OPERATING COSTS																		
Cost of energy	2.6	1.2	2.7	14.7	15.8	10.9	10.2	32.7	26.4	2.3	1.0	2.5	13.2	13.0	9.1	7.9	30.3	24.0
Cost of other	8.7	3.4	7.9	14.8	7.0	8.6	9.8	5.3	5.9	7.6	2.8	7.1	13.3	5.7	7.2	7.6	4.9	5.4
Cost of vehicle	13.6	4.8	7.7	30.8	25.4	30.7	24.0	16.8	19.8	13.1	4.9	7.5	32.6	27.4	32.3	25.6	18.3	21.4
Cost of way	4.4	2.3	0.3	1.2	1.2	0.8	0.5	2.3	2.1	4.7	2.3	0.3	1.0	0.9	0.6	0.4	2.0	1.8
Cost of terminals	0.1	0.0	0.0	0.7	0.8	0.6	0.9	0.4	0.5	0.1	0.1	0.0	0.7	0.9	0.7	0.9	0.5	0.6
Cost of stops	3.2	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Operating Costs	32.5	13.5	18.7	62.2	50.2	51.6	45.4	57.6	54.8	30.8	12.6	17.6	60.9	47.8	49.9	42.5	55.9	53.1
TOTAL COSTS	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: These percentages are based on a 25% peak/daily passenger ration; 2,2,2,1 minimum vehicle frequency

The following aspects can be noted:

a) The high percentage of the total cost that is made up by the capital cost component in the case of rail vehicles. (The low percentage cost of vehicle capital cost component of 10M train results from the fact that the cost is taken as ½ of the cost of refurbishing existing 5M coaches to 10M standard as it is assumed that it will take 20 years to upgrade the existing fleet.).

b) Whereas the capital cost and the operating cost components are almost equal for road vehicles.

c) The high percentage of the cost component of energy for the minibus.

d) The low percentage of the operating cost component for rail vehicles.

c) The lower effect of passenger volume on the proportions of the cost component of road vehicles.

Effect of passenger volume on cost

The output of the context analysis output module is useful to show the effects of passenger volume on cost. Figure 5a and b shows the effect of passenger volume. To indicate the effect of passenger volume, cost values were calculated for a 20 km trip length, where the peak hour/total day passenger ratio was 0,25 and the minimum vehicle frequency of 2 vehicles in each hour of the peak period and 1 in the off peak hours

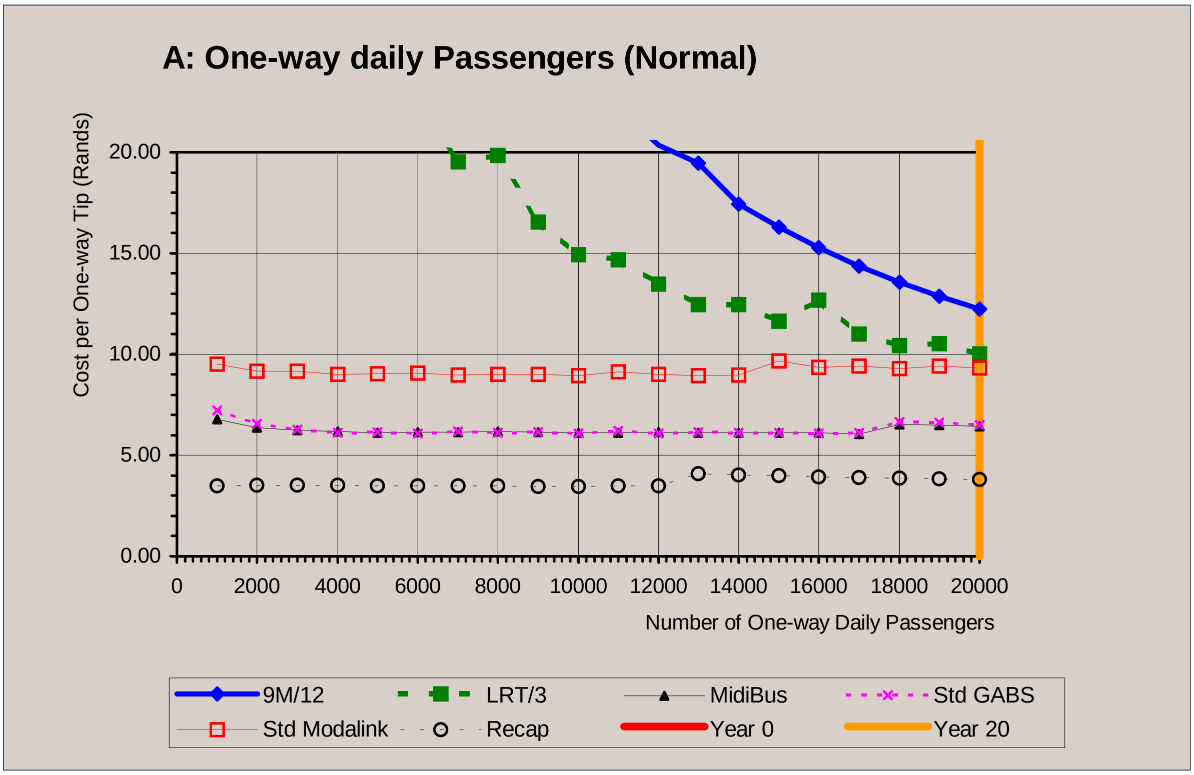


FIGURE 5: EFFECT OF PASSENGER VOLUME ON COST (1 000 to 20 000 one way daily passengers; over 20 km)

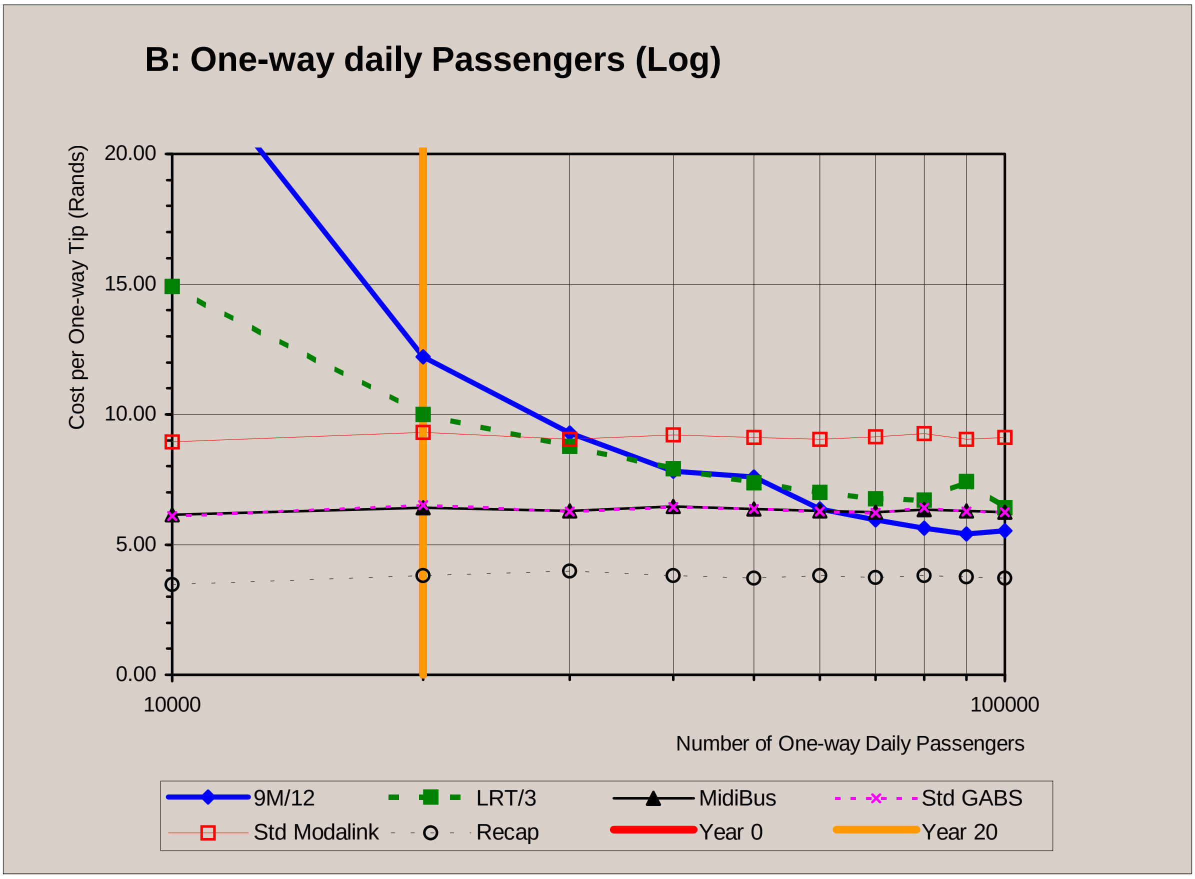


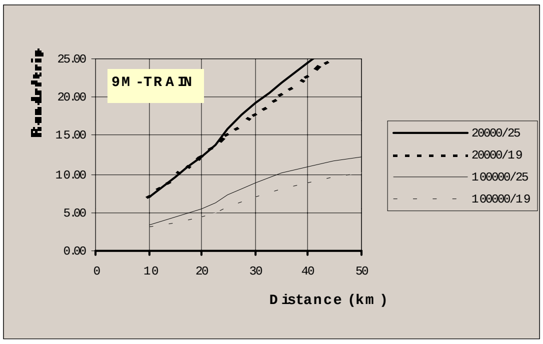
FIGURE 5b: EFFECT OF PASSENGER VOLUME ON COST (10 000 to 100 000 one way daily passengers over 20km)

Figure 5a shows the relationship in terms of daily one-way trips over the range 1 000 to 20 000 one-way trips/day. The relative cost advantage of the minibus over this range is obvious. The kinks in the curves are due to the need for additional infrastructure investment at these passenger volumes.

Figure 5b shows the relationship in terms of daily one-way trips over the range 10 000 to 100 000 one-way trips/day. (This is presented with the x-axis in log format to cover the range, as such the slopes of the curves are distorted.). It must be noted that the minibus has a daily capacity of approximately 40 000 one-way passengers / day on a dedicated facility. As such the role of the larger vehicles becomes more important even though they are shown to be more costly in the figure. The cost of the midibus is similar to that of the standard bus and the low-floor city bus is more costly (although the quality that it offers is superior). The 9M train is less costly than LRT above 40 000 one-way passengers/day and competitive with bus above 60 000 one-way passengers/day. (The HOV capacity of bus lane will not exceed 80 000 one-way passengers per day. Similar graphs are produced by the model in terms of peak hour volumes.)

Effect of distance on costs

The effect of distance on the cost of travel is shown is Figure 6 for two of the four major modes of transport under two peaking and two passenger volume combinations. The “kinks” in the rail mode is due to the substantial reduction in passenger capacity that results from the assumption that a greater percentage of passengers is prepared to stand for distances with in-vehicle times of less than 30 minutes (i.e. between 20 and 30 km). The bigger effect of peaking and passenger volumes on the cost of rail vehicles is due to the passenger capacity of these vehicles and the requirement of the model that a minumum number of vehicles be supplied per hour (In this case 2 in the peak period and 1 in the off-peak period).



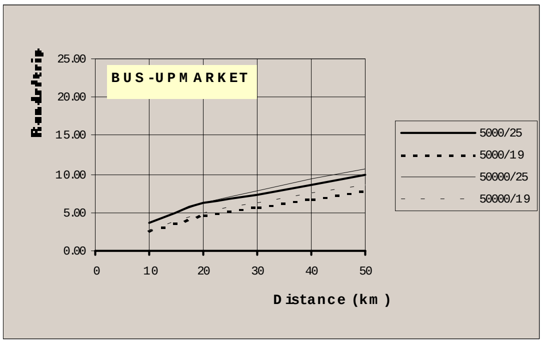


FIGURE 6: EFFECT OF TRAVEL DISTANCE ON COST

Effect of service frequency on cost

One of the requests faced by transport authorities is to improve service frequency; especially on services where the volume of passengers results in the operator minimising vehicle frequency to reduce spare capacity and costs. Table 5 shows the effect of changing the service frequency from a minumum of 2 vehicles/hour to 3 vehicles/hour in the peak hour and from 1 vehicle/hour to 2 vehicles/hr in the off-peak period. Costs were calculated for two distance values (20 and 30 km), for the range of passenger volumes between 1 000 and 100 000 one-way passengers /day and for the two peaking ratios (25% and 19% for the peak hour/daily trips ratio). The highlighted values show where the change in minimum service frequency results in a cost difference of more than 10% or more than 20%.

Changing the frequency standard for volumes exceeding 20 000 one-way trips / day on train services or exceeding 5 000 one-way trips / day on road services has no effect on the cost; because the passenger demand already results in the minimum service frequency being provided in the off-peak. However, for lower volume ranges one would generally use smaller vehicles; because of cost. It is interesting to note that for the lower volumes the longer trip length has a bigger effect on the effect of frequency on cost.

TABLE 5: EFFECT OF SERVICE FREQUENCY ON COST

	Daily		Peaking = 25,23,12									Peaking = 19,15,10								
km	Pass		10M	9M	LRT	Midi	Std bus	Up-bus	Artic	Mini	Recap	10M	9M	LRT	Midi	Std bus	Up-bus	Artic	Mini	Recap
20	1000	2,2,2,1	183.5	243.9	124.3	6.79	7.24	9.52	10.98	4.65	3.50	183.5	243.9	124.3	5.07	5.90	7.67	9.70	3.77	2.86
		3,3,3,2	205.0	285.6	141.2	7.23	7.96	10.23	14.62	4.67	3.56	205.0	285.6	141.2	5.46	6.67	8.43	14.62	3.77	2.86
	2000	2,2,2,1	86.26	122.0	62.17	6.37	6.57	9.17	7.95	4.66	3.51	86.26	121.9	62.17	4.71	5.02	7.11	6.15	3.71	2.81
		3,3,3,2	95.14	142.8	70.61	6.45	6.87	9.44	9.15	4.66	3.51	95.14	142.8	70.61	4.71	5.23	7.24	7.92	3.71	2.81
	5000	2,2,2,1	34.52	48.80	24.88	6.13	6.15	9.03	7.17	4.60	3.49	34.51	48.79	24.87	4.79	4.57	6.72	5.32	3.64	2.74
		3,3,3,2	38.07	57.15	28.25	6.13	6.15	9.03	7.36	4.60	3.49	38.07	57.14	28.25	4.79	4.57	6.72	5.39	3.64	2.74
	10000	2,2,2,1	18.38	24.41	14.91	6.13	6.10	8.95	6.84	4.56	3.47	18.37	24.41	13.65	4.71	4.57	6.72	5.22	3.63	2.72
		3,3,3,2	20.52	28.59	15.35	6.13	6.10	8.95	6.84	4.56	3.47	20.52	28.58	14.13	4.71	4.57	6.72	5.22	3.63	2.72
	20000	2,2,2,1	9.89	12.22	10.00	6.42	6.50	9.32	6.87	4.86	3.81	9.20	12.21	8.75	4.65	4.59	7.11	5.24	4.00	3.12
		3,3,3,2	10.27	14.31	10.19	6.42	6.50	9.32	6.87	4.86	3.81	10.27	14.30	8.90	4.65	4.59	7.11	5.24	4.00	3.12
	50000	2,2,2,1	4.72	7.60	7.36	6.36	6.35	9.13	6.99	4.96	3.71	4.28	6.25	6.15	4.98	4.87	6.92	5.34	3.89	3.01
		3,3,3,2	4.84	7.74	7.36	6.36	6.35	9.13	6.99	4.96	3.71	4.41	6.40	6.15	4.98	4.87	6.92	5.34	3.89	3.01
	100000	2,2,2,1	3.25	5.53	6.42	6.25	6.24	9.12	6.96	4.85	3.70	2.84	4.52	5.09	4.87	4.75	6.82	5.32	3.89	3.01
		3,3,3,2	3.28	5.60	6.42	6.25	6.24	9.12	6.96	4.85	3.70	2.85	4.56	5.09	4.87	4.75	6.82	5.32	3.89	3.01
30	1000	2,2,2,1	272.2	352.7	180.0	8.76	8.68	12.01	13.33	6.31	4.67	272.2	352.7	180.0	6.53	7.21	9.25	11.94	5.06	3.72
		3,3,3,2	310.6	431.5	199.7	9.43	10.30	13.07	17.76	6.34	4.76	310.6	431.5	199.7	7.12	8.91	10.38	17.76	5.06	3.72
	2000	2,2,2,1	128.7	176.4	90.01	8.31	7.84	11.16	9.33	6.34	4.70	128.7	176.4	90.01	6.35	5.93	8.63	7.41	5.01	3.74
		3,3,3,2	144.3	215.8	99.87	8.44	8.29	11.57	10.89	6.34	4.70	144.2	215.8	99.86	6.35	6.24	8.82	9.56	5.01	3.74
	5000	2,2,2,1	51.51	70.56	38.50	8.14	7.39	11.09	8.27	6.28	4.70	51.51	70.55	36.01	6.26	5.72	8.38	6.32	4.94	3.62
		3,3,3,2	57.72	86.33	39.95	8.14	7.39	11.09	8.55	6.28	4.70	57.71	86.32	39.95	6.26	5.72	8.38	6.43	4.94	3.62
	10000	2,2,2,1	27.24	35.29	23.07	8.10	7.39	11.09	8.03	6.24	4.67	27.23	35.29	20.54	6.21	5.67	8.38	6.22	4.92	3.62
		3,3,3,2	31.08	43.18	23.69	8.10	7.39	11.09	8.03	6.24	4.67	31.07	43.17	21.20	6.21	5.67	8.38	6.22	4.92	3.62
	20000	2,2,2,1	15.73	19.36	16.64	8.71	8.22	11.93	8.05	6.74	5.21	14.33	17.65	14.23	6.10	5.66	9.20	6.23	5.52	4.26
		3,3,3,2	16.25	21.60	16.88	8.71	8.22	11.93	8.05	6.74	5.21	15.55	21.60	14.35	6.10	5.66	9.20	6.23	5.52	4.26
	50000	2,2,2,1	7.54	11.21	12.92	8.61	7.93	11.53	8.29	6.92	5.07	6.73	9.81	10.27	6.72	6.21	8.85	6.54	5.37	4.11
		3,3,3,2	7.72	11.41	12.92	8.61	7.93	11.53	8.29	6.92	5.07	6.85	10.02	10.27	6.72	6.21	8.85	6.54	5.37	4.11
	100000	2,2,2,1	5.39	8.76	11.69	8.45	7.76	11.53	8.26	6.75	5.07	4.59	7.08	9.04	6.55	6.03	8.68	6.45	5.36	4.11
		3,3,3,2	5.40	8.83	11.69	8.45	7.76	11.53	8.26	6.75	5.07	4.59	7.10	9.04	6.55	6.03	8.68	6.45	5.36	4.11

>20% difference   Between 10 and 20% difference

Effect of peaking in passenger demand on cost

A similar table was produced to show the effect of peaking on cost. Two peaking ratios were used, namely 25,23,12 and 19,15,10 percent of total daily passengers for each of the three peak hours in the peak period. This output of the analysis is shown in Table 6, which shows that the peaking factor has a significant effect on cost; generally exceeding 20%. This is due to the additional capital cost required to service a route with the higher peaking factors. The train services do not experience this effect at low volumes (which are generally outside of their operating range) because sufficient capacity would be provided to meet the frequency specification.

The minimum service frequency and distance have a minimal effect on the change in cost produced by the change in peaking ratio.

TABLE 6: EFFECT OF PEAKING IN PASSENGER DEMAND ON COSTS

	Daily	Peaking	Frequency = 3,3,3,2									Frequency = 2,2,2,1								
km	Pass		10M	9M	LRT	Midi	Std bus	Up-bus	Artic	Mini	Recap	10M	9M	LRT	Midi	Std bus	Up-bus	Artic	Mini	Recap
20	1000	25,23,12	205.0	285.6	141.2	7.23	7.96	10.23	14.62	4.67	3.56	183.5	243.9	124.3	6.79	7.24	9.52	10.98	4.65	3.50
		19,15,10	205.0	285.6	141.2	5.46	6.67	8.43	14.62	3.77	2.86	183.5	243.9	124.3	5.07	5.90	7.67	9.70	3.77	2.86
	2000	25,23,12	95.14	142.8	70.61	6.45	6.87	9.44	9.15	4.66	3.51	86.26	122.0	62.17	6.37	6.57	9.17	7.95	4.66	3.51
		19,15,10	95.14	142.8	70.61	4.71	5.23	7.24	7.92	3.71	2.81	86.26	121.9	62.17	4.71	5.02	7.11	6.15	3.71	2.81
	5000	25,23,12	38.07	57.15	28.25	6.13	6.15	9.03	7.36	4.60	3.49	34.52	48.80	24.88	6.13	6.15	9.03	7.17	4.60	3.49
		19,15,10	38.07	57.14	28.25	4.79	4.57	6.72	5.39	3.64	2.74	34.51	48.79	24.87	4.79	4.57	6.72	5.32	3.64	2.74
	10000	25,23,12	20.52	28.59	15.35	6.13	6.10	8.95	6.84	4.56	3.47	18.38	24.41	14.91	6.13	6.10	8.95	6.84	4.56	3.47
		19,15,10	20.52	28.58	14.13	4.71	4.57	6.72	5.22	3.63	2.72	18.37	24.41	13.65	4.71	4.57	6.72	5.22	3.63	2.72
	20000	25,23,12	10.27	14.31	10.19	6.42	6.50	9.32	6.87	4.86	3.81	9.89	12.22	10.00	6.42	6.50	9.32	6.87	4.86	3.81
		19,15,10	10.27	14.30	8.90	4.65	4.59	7.11	5.24	4.00	3.12	9.20	12.21	8.75	4.65	4.59	7.11	5.24	4.00	3.12
	50000	25,23,12	4.84	7.74	7.36	6.36	6.35	9.13	6.99	4.96	3.71	4.72	7.60	7.36	6.36	6.35	9.13	6.99	4.96	3.71
		19,15,10	4.41	6.40	6.15	4.98	4.87	6.92	5.34	3.89	3.01	4.28	6.25	6.15	4.98	4.87	6.92	5.34	3.89	3.01
	100000	25,23,12	3.28	5.60	6.42	6.25	6.24	9.12	6.96	4.85	3.70	3.25	5.53	6.42	6.25	6.24	9.12	6.96	4.85	3.70
		19,15,10	2.85	4.56	5.09	4.87	4.75	6.82	5.32	3.89	3.01	2.84	4.52	5.09	4.87	4.75	6.82	5.32	3.89	3.01
30	1000	25,23,12	310.6	431.5	199.7	9.43	10.30	13.07	17.76	6.34	4.76	272.2	352.7	180.0	8.76	8.68	12.01	13.33	6.31	4.67
		19,15,10	310.6	431.5	199.7	7.12	8.91	10.38	17.76	5.06	3.72	272.2	352.7	180.0	6.53	7.21	9.25	11.94	5.06	3.72
	2000	25,23,12	144.3	215.8	99.87	8.44	8.29	11.57	10.89	6.34	4.70	128.7	176.4	90.01	8.31	7.84	11.16	9.33	6.34	4.70
		19,15,10	144.2	215.8	99.86	6.35	6.24	8.82	9.56	5.01	3.74	128.7	176.4	90.01	6.35	5.93	8.63	7.41	5.01	3.74
	5000	25,23,12	57.72	86.33	39.95	8.14	7.39	11.09	8.55	6.28	4.70	51.51	70.56	38.50	8.14	7.39	11.09	8.27	6.28	4.70
		19,15,10	57.71	86.32	39.95	6.26	5.72	8.38	6.43	4.94	3.62	51.51	70.55	36.01	6.26	5.72	8.38	6.32	4.94	3.62
	10000	25,23,12	31.08	43.18	23.69	8.10	7.39	11.09	8.03	6.24	4.67	27.24	35.29	23.07	8.10	7.39	11.09	8.03	6.24	4.67
		19,15,10	31.07	43.17	21.20	6.21	5.67	8.38	6.22	4.92	3.62	27.23	35.29	20.54	6.21	5.67	8.38	6.22	4.92	3.62
	20000	25,23,12	16.25	21.60	16.88	8.71	8.22	11.93	8.05	6.74	5.21	15.73	19.36	16.64	8.71	8.22	11.93	8.05	6.74	5.21
		19,15,10	15.55	21.60	14.35	6.10	5.66	9.20	6.23	5.52	4.26	14.33	17.65	14.23	6.10	5.66	9.20	6.23	5.52	4.26
	50000	25,23,12	7.72	11.41	12.92	8.61	7.93	11.53	8.29	6.92	5.07	7.54	11.21	12.92	8.61	7.93	11.53	8.29	6.92	5.07
		19,15,10	6.85	10.02	10.27	6.72	6.21	8.85	6.54	5.37	4.11	6.73	9.81	10.27	6.72	6.21	8.85	6.54	5.37	4.11
	100000	25,23,12	5.40	8.83	11.69	8.45	7.76	11.53	8.26	6.75	5.07	5.39	8.76	11.69	8.45	7.76	11.53	8.26	6.75	5.07
		19,15,10	4.59	7.10	9.04	6.55	6.03	8.68	6.45	5.36	4.11	4.59	7.08	9.04	6.55	6.03	8.68	6.45	5.36	4.11

>20% difference   Between 10 and 20% difference

CONCLUSIONS

The paper has described a model that was developed for the City of Cape Town able to estimate the cost of a public transport service and also to provide values that can be used in modeling public transport alternatives being considered for the restructuring of the public transport system in Cape Town.

The model is able to calculate the financial and economic costs of a public transport service using 20 alternative public transport modes. It can also calculate the fare income. The model is driven by the information on situation to be served which is input by the user and a set of mode related operating parameters and capital and operating costs that are provided as default values.

The generalised hourly cost values for the eight public transport alternatives which are given in Table 3 can be used for transport modelling purposes. The parameter values given in Table 2 can be used for a more detailed analysis of public transport costs.

In application the model can be used to determine the effect of operating parallel services along a corridor and the cost implications of changing the public transport route network; i.e. a balance sheet can be prepared to compare the total cost of networks with different routings and modes; costs would need to be calculated for each route in the network and added to determine the total cost. This is affected by route length and passenger peaking.

Furthermore the model can be used to test the effects of changing service standards such as minimum vehicle frequency, minimum passenger / space ratios.

The model provides a useful tool to determine the cost savings that can be derived from restructuring the public transport services in terms of routes, modes and service standards; needing only the input of passenger volume, peaking and route type. Policy decisions may be required in respect of which elements of the capital cost are included and which are not.

Since the model is data sensitive it is important that not only should the data be updated on a regular basis but that similar data be collected in other centres of South Africa so that a bench marking process can be initiated. This is not easy since public transport operations differ significantly in the different centres in terms of topography, speed of operation, the historical management of the services and the proportion of travel that occurs on the different types of routes. Finally, as the model is used areas where it can be upgraded will emerge.

In using the model, the sensitivity of output indicators to a range of values needs to be tested so that the impact of changes in technologies and costs are fully understood.

Finally, it needs to be recognized that this is a cost model and further work needs to be done in developing an income model which is sensitive to modal share changes that result from improved vehicles and services for which commuters are prepared to pay a premium.

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The major contribution of Mr Laurent Hermant of Cape Town office of Stewart Scott Inc in writing the software for the model is acknowledged; as is the contribution of all those who provided data on public transport operations.