Singapore's Public and Private Transport Modes: An Economic Comparison and Policy Implications

by

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ABSTRACT

Frequently, public decisions on transportation are based on cost benefit analyses that do not take into account the costs that private individuals are eventually led to spend in order to use thesesystems, even though these expenditures are sizeable. For FY2006-2007 in Singapore, we estimate that more than 90% of the S$34.4 billion to S$34.9 billion spent on the private automobile system were borne by private individuals. In contrast, only about 65% of the S$1.66 billion spent on the public transport system were borne by private individuals. The inclusion of private expenditures shows that the private automobile transport system costs society at least 20.7 times as much as the public transport system, even though 64% of all morning peak hour trips were made with public transport in 2004.

Excluding time costs, private automobile trips cost S$2.05 per passenger-kilometer, or 14 times as much as public transport trips, which cost S$0.143 per passenger-km. Applying derived economic and time cost functions to each trip from the 2004 home travel survey data, we compared trips made among each of the 82 postal sectors of Singapore, and found that the economic costs to society for private car driver trips far exceed those made with public transport for all of the 1,906 postal sector combinations analyzed. Although the time costs for private car driver trips were substantially lower than those of public transport trips for almost all of the origin-destination pairs, these were not sufficient to offset the far higher economic costs to society.

We have highlighted particular zonal combinations for which differences in economic, time, and total costs between private car driver trips and public transport trips were very pronounced, as these promise the largest potential benefits to society if the differences between public and private modes were bridged. Therefore policies should be pursued to increase the share of variable automobile costs as a percentage of total costs. In parallel, other policy measures should include improvements of Rapid Transit System coverage specially along the corridors identified in this thesis, increases in road pricing, and actions to shift the burden of parking costs to private motorists.

Thesis Advisor: Mikel Murga

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1. INTRODUCTION

1.1 Overview

This research makes a economic comparison between the private automobile transport system and the public transport system (bus and rail services only) in Singapore for the Fiscal Year (FY) 2006 to 2007 (April 1, 2006 to March 31, 2008). We include the expenditures borne by all actors, public and private, to account for the full costs associated with each of these modes. Non-motorized modes have not been included given their insignificant role in the Singapore mobility profile. We will also include an estimation of the monetary value of time costs in our analysis so as to compare how the public and private transport systems compare head-to-head in terms of aggregated costs, for trips between different pairs of origins and destinations within Singapore. Trends of the variables behind these analyses will be identified, conclusions reached, and resulting corresponding recommendations will be made for Singapore to achieve a more economically cost effective overall land transport system.

1.2 Motivation

1.2.1 Complexity of Cost Structures Inhibit Clear Economic Comparisons

The cost structures of the land transport systems are complex and involve many actors and variables. For the private automobile, the government funds the development and maintenance of roadway infrastructure, building developers and owners fund the construction and maintenance of parking facilities and pass on a portion of such costs to motorists, and private motorists themselves shoulder the costs of depreciation, fuel and vehicle maintenance. For public transportation, the government funds the design and construction of rail infrastructure and the purchase of rail vehicles, and public transport operators shoulder the operation and maintenance costs of the system while passing some or all of these costs to commuters and users in general in the form of fares. The costs borne by the users represent the hidden part of the iceberg that is the total cost of transportation. Hence, we have estimated such private costs which are not part of any public estimates. Similarly, external costs while being estimated in some studies very rarely influence transportation policy decisions. The complexity of these cost structures inhibits the accurate comparison of the 'true' economic costs of public versus private transport systems, as often only those costs that are part of economic accounting are considered during planning exercises leading to transport and land use decisions.

1.2.2 It is Essential to Include Private Expenditures in Analyses

Frequently, public decisions as to whether to fund new infrastructural developments involve cost benefit analyses that do not take into account the costs that private individuals are eventually led to spend in order to use these transport systems developments. Numerous studies have shown that most of the costs of the private automobile system outweigh those borne by public agencies responsible for setting transport policy. Kothari and Anthos, in 2005, found that private spending in the case of the automobile outweighed public spending by a factor of over 14 while on the public transport side, public spending outweighed private spending by a ratio of about 2.3[1]. A 2003 report on Parisian transport expenditures stated that private automobile expenditures were about 13 times as much as that funded from public sources[2]. The omission of these enormous private costs from consideration may thus lead to public agencies underestimating the true costs to society of sustaining an automobile transport system, and consequently bias decisions to allocate more resources towards roadway rather than public transport infrastructural developments and operational subsidies.

An unfair allocation of public resources towards the automobile transport system is not necessarily a bad thing for society if the private automobile were indeed more cost effective than public transport, considering the often considerable time cost savings of private car users. However, existing literature has shown that this is not the case. In his studies in 1991 and 1996 of the transport systems in the Greater Toronto Area, Kennedy

[1] Kothari, and Antos, "Public and Private Transportation Costs in Boston, MA."
[2] Authorite Organisatrice des Transports D'Ile-de-France . "Compte Deplacements de Voyageurs en IDF Pour L'annee 2003 – Edition 2005."

estimated that just including the monetary value of time costs, the average cost per person trip was $5.17 and $3.24 for private and public transport respectively[3]. Furthermore, the cost per person-kilometer was $0.55 and $0.33 for private and public transport respectively.

A 2005 study by Kothari determined that when full parking costs were included, the private automobile cost more than public transport for trips made between all zonal combinations (he had divided London into 4 total zones for this analysis) within Greater London, even when time costs were included[4].

The phenomena described above may likely be even more acute in the case of Singapore, where vehicle ownership costs are notoriously high.

If the ultimate objective of all travel is accessibility to goods and services, then travel as a wholly derived demand should encourage a rational society to seek the optimal balance between accessibility and the full costs it has to bear. Given that the planning and direction of transport systems lie almost entirely in the hands of Singapore's public agencies, it becomes imperative that sufficient research be conducted to compare the full costs to society of each mode so that resources can be allocated in a judicious and efficient manner.

1.2.3 The Case for Singapore

With a population of 4.6 million and a land area of only 707 square kilometers, Singapore has one of the highest population densities in the world. With the target population set at 6.5 million over the next 40 to 50 years[5], geometric constraints physically limit the ability of the private automobile to play a major role in the future. Currently, 12% of Singapore's total land area is already dedicated to roads (compared to 15% used for

[3] Kennedy, "A comparison of the sustainability of public and private transportation systems."
[4] Kothari. "A Comparative Financial Analysis of the Automobile and Public Transportation in London."
[5] Channel News Asia. "Govt Re-Looking at Land Use in View of Change in Projected Long-Term Growth."

housing)[6]. Yet, public transport mode share during peak hours has actually dropped from 67% in 1997 to 63% in 2004.

Recognizing that the projected increase in future travel demand will have to be met by public transport rather than the private automobile, the Singapore government is aggressively trying to reverse current trends and has set an ambitious target of raising public transport mode share during morning peak hours to 70% by 2020[6]. Though the Land Transport Master Plan has identified key areas where the attractiveness of public transport can be improved, we believe that a more targeted approach is possible based on the identification of specific trip corridors that can be improved. In order to estimate with a reasonable level of accuracy the full costs to society of each mode into account, this thesis approach involves the creative processing of Singapore's travel survey data to identify specific trips corridors where the maximum cost savings to society can be reaped for each private transport user who switches over to public transport.

1.3 Major Statistics of Singapore

Before we begin our analysis proper, it is important to provide some major numbers on Singapore to frame our discussion. These are as provided in **Table 1.1** below.

Statistic	Number	Date of Information
Total Population	4.589 million	June 2007
Total Number Employed	2.671 million	June 2007
Total Number of Households	1,0247,216	2005
GDP per capita	S$50,026	June 2007
Exchange Rate to USD	US$1 = S$1.507	2007
Total Number of Private Cars	514,694	Dec 2007
Car to Population Ratio	1:8.92	Dec 2007
Total Land Area	707.1 square km	June 2007
Population Density	6489 per square km	June 2007
Total Daily Travel Demand	8.9 million trips	2007
Daily mass public transport ridership	4.5 million	2007
Peak Hour Public Transport Mode Split	63%	2004
Road Network Capacity	8631 lane-km	2007
Average Annual Private Vehicle Mileage	21,075km	2006
Total RTS network length	138 km	2007

Table 1.1: Major Statistics of Singapore[7],[8].

[6] Land Transport Authority. "Land Transport Master Plan."

1.4 Overview of Chapters

In the following chapters, we will seek to address the objectives of this research:

Chapter 2 – In this chapter, we will collect data on all expenditures on the private automobile for Calendar Year (CY) 2007 borne by private actors. The data sources and calculation methodologies and assumptions will be described. The expenditures on the private automobile for CY2007 borne by private actors will then be assumed to be roughly equivalent to that for Fiscal Year (FY) 2006-2007.

Chapter 3 – In this chapter, we will collect data on all expenditures on the public transport system for FY2006-2007, as well as expenditures on the private automobile borne by public actors. The data sources and calculation methodologies and assumptions will be explained. using our results from Chapter 2, we can then compare the aggregate economic costs of the private automobile with that of public transport, on a per trip basis as well as on a and per passenger-kilometer basis.

Chapter 4 – This chapter includes an estimation of the monetary value of time costs in our comparisons. From our results in Chapter 3, we can ascribe generalized costs functions (that include the full economic costs) to each private car and public transportation trip recorded in 2004 travel survey data. Factoring the time costs to travelers, we can then compare the public and private automobile trips between every postal sector of Singapore, so as to identify the specific zones pairs with the greatest disparities in terms of economic, time, and total costs. These will become the zones which should be prioritized for improvement action.

Chapter 5 – This chapter summarizes our findings and proposes several recommendations, based on our specific findings, describing how Singapore can improve

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[7] Singapore Department of Statistics. "Yearbook of Statistics Singapore 2008."
[8] Land Transport Authority. "Land Transport Master Plan."

the cost-efficiency of its expenditures on transportation. The chapter concludes by identifying areas of future research.

2. THE AUTOMOBILE – ECONOMIC COSTS TO PRIVATE ACTORS

In this chapter, we will calculate the total costs of automobile ownership and usage, borne by private actors.

The main components of automobile cost can be broadly classified as fixed costs and variable costs. According to LTA's monthly Car Buyer magazine[9], the main components within these categories are as shown in **Table 2.1** below.

Motoring Costs	
Fixed Costs	Depreciation Financing Road Tax Insurance
Variable Costs	Electronic Road Pricing (ERP) Vehicle maintenance and spare parts Petrol Parking charges

Table 2.1: Elements of Motoring Costs.

We will obtain estimates for each of these subcategories in the following sections.

2.1 Fixed Costs

Unlike many other cities, Singapore's desire to restrict vehicle population growth has led to various price mechanisms that artificially raise car operating prices. Upon the registration of a new car, the following fees and taxes, shown in **Table 2.2**, are levied over and above its import price, or Open Market Value (OMV):

[9] Land Transport Authority. "Car Buyer Issue 6."

Excise Duty	20% of OMV
Goods and Services Tax (GST)	7% of OMV
Registration Fee (RF)	S$140
Additional Registration Fee (ARF)	110% of OMV for cars registered between March 2004 to February 2008 130% of OMV for cars registered between May 2002 and February 2004 140% of OMV for cars registered before May 2002 150% of OMV for cars registered before 1 Nov 1990
Certificate of Entitlement (COE)	Depends on monthly bidding price. Typically around $16,000 in recent years.

Table 2.2: Levies on Vehicle Registration[10]

The Certificate of Entitlement (COE) is another measure used to control the growth of the vehicle population. Every new car registered must possess a COE of the appropriate category, and the LTA controls the number of COEs issued monthly in adherence to the Vehicle Quota Scheme (VQS), which outlines the strategic annual allowable population growth for each category of vehicle. Since there is a limited number of COEs issued monthly by the LTA, prospective car owners undergo an open bidding exercise that determines the eventual prices of the COEs for that month.

2.1.1 Depreciation

In order to encourage vehicle fleet renewal, Singapore has in place, as an adjunct to the Additional Registration Fee (ARF), the Preferential Additional Registration Fee (PARF) scheme. In essence, it is a rebate by the government on the ARF paid for a car when the vehicle is eventually deregistered, either for exporting to another country or to be scrapped. **Table 2.3** shows these PARF rebate rates.

[10]Source: Land Transport Authority website. http://www.lta.gov.sg/motoring_matters/index_motoring_vo.htm.

Age at Deregistration (year)	Graduated PARF Rebate (For cars registered before May 2002)	New PARF Rebate (for cars registered from May 2002)
Not exceeding 5	130% of OMV	75% of ARF paid
Above 5 but not exceeding 6	120% of OMV	70% of ARF paid
Above 6 but not exceeding 7	110% of OMV	65% of ARF paid
Above 7 but not exceeding 8	100% of OMV	60% of ARF paid
Above 8 but not exceeding 9	90% of OMV	55% of ARF paid
Above 9 but not exceeding 10	80% of OMV	50% of ARF paid
Above 10	Nil	Nil

Table 2.3: PARF Rates[10].Until August 2008, this PARF rebate was not cash-refundable and could only be used to offset the taxes and fees for another new car purchase.

In addition to the PARF rebate, when a car is deregistered or scrapped, the owner also receives the linearly pro-rated remaining value of the COE (which is valid for up to 10 years), on top of the remaining market value of the car. As a result, calculation of the depreciations costs of Singapore's automobile fleet through FY2006-2007 is not as simple as obtaining the aggregate drop in market value of all the cars in the fleet. Instead, we have to also estimate the depreciation in possible PARF rebates and COE rebates across the fleet for that year. Accordingly, our total depreciation estimates for the fleet will have to include the following:

- COE rebate depreciation for entire fleet
- PARF rebate depreciation for entire fleet
- Actual depreciation of body (resale) value of entire fleet
- Registration Fee, GST, and Excise Duty for cars bought in FY 2006-2007

COE Rebate Depreciation

To estimate the COE rebate depreciation in FY2006-2007, we have to first obtain the average initial COE prices for cars registered in the previous 11 years. The LTA publishes monthly records of the number of successful bids for each vehicle category and the corresponding prices. From these values, we can then calculate an average initial COE price for all new cars registered for each year of the previous 11 years.

The LTA also publishes annual reports on vehicle fleet age distribution. Layering the vehicle fleet age distribution for 31st December 2007 with our calculated average initial COE prices, we can estimate COE rebate depreciation. Note that these results within this section provide the COE depreciation for CY2007, which we will then assume to be approximately equal to that of FY2006-2007.

For all cars at least one year old on 31 Dec 2007, the proration procedure is straightforward, since the depreciation of the 10-year COE over a year is simply 10% of its initial cost, after factoring in the Consumer Price Index (CPI) change from 2006 to 2007. The CPI change is included in the calculations because it describes fully the cost to motorists had they decided to deregister their vehicle a year ago, instead of today, since the COE rebate is not adjusted for inflation. (For example, if a car owner paid S$60,000 for his COE in 1998, he does so with 1998 Singapore dollars. But when he deregisters his car 9 years later in 2007, he receives $6,000 in 2006 Singapore dollars.)

For cars in the 0-< 1 yrs category, the average age is assumed to be 0.5 years on 31 Dec 2007, so that the COE depreciation for that class is 5% of the initial average COE cost of 2007. The CPI factor need not be considered for this category of cars.

The simplifying assumption in both our estimates is that the proportion of cars in each COE category for all age groups as at 31st Dec 2007 remains the same as the proportion during their initial registration years ago. The results of these calculations are as shown in **Table 2.4** overleaf.

Age as at 31-Dec-07	Age as at 31-Dec-06				Average Initial COE	Consumer Price Index	Average Depreciation per car	Average Depreciation per Car Adjusted for 2006 CPI	Total Depreciation
		Number of Cars	% of fleet	Registered Between	(Registration Year S$)	(2004 = 100)	(Registration Year S$)	(2007 $)	(2007 $)
0-<1 yrs	N.A.	106,502	20.7	Jan 2007 - Dec 2007	14,051	103.5	703	717.1	76,371,590
1-<2 yrs	0-<1 yrs	116,656	22.7	Jan 2006 - Dec 2006	11,623	101.4	1,162	1,186.3	138,393,639
2-<3 yrs	1-<2 yrs	108,606	21.1	Jan 2005 - Dec 2005	21,786	100.4	2,179	2,223.7	241,505,450
3-<4 yrs	2-<3 yrs	81,376	15.8	Jan 2004 - Dec 2004	25,283	100.0	2,528	2,580.6	210,001,231
4-<5 yrs	3-<4 yrs	42,069	8.2	Jan 2003 - Dec 2003	28,879	98.3	2,888	2,947.7	124,007,281
5-<6 yrs	4-<5 yrs	12,678	2.5	Jan 2002 - Dec 2002	31,526	97.8	3,153	3,217.9	40,796,261
6-<7 yrs	5-<6 yrs	10,607	2.1	Jan 2001 - Dec 2001	27,254	98.2	2,725	2,781.8	29,506,697
7-<8 yrs	6-<7 yrs	3,638	0.7	Jan 2000 - Dec 2000	38,016	97.2	3,802	3,880.3	14,116,653
8-<9 yrs	7-<8 yrs	2,024	0.4	Jan 1999 - Dec 1999	40,878	96.0	4,088	4,172.5	8,445,091
9-<10 yrs	8-<9 yrs	2,288	0.4	Jan 1998 - Dec 1998	32,881	95.9	3,288	3,356.2	7,678,976
10-<11 yrs	9-<10 yrs	502	0.1	Jan 1997 - Dec 1997	55,339	96.2	5,534	5,648.5	2,835,564
>= 11 yrs	>=10 yrs	27,739	5.3	Jan 1996 - Dec 1996	Not required	0.0	0	0.0	0

Total Fleet Depreciation (2007 S$)	893,658,433

Table 2.4: COE Depreciation Estimation

PARF Rebate Depreciation

In a similar fashion, we can arrange information for the ARF and PARF schemes onto the car fleet distributed by age. Since the PARF depreciation is non-linear, as shown in **Table 3**, this estimation is somewhat more labor intensive, and is achieved by considering the difference in PARF rebate value if the cars had been deregistered a year before, on 31st Dec 2006 instead of 31st December 2007. Since there were changes in the ARF and PARF rates in May 2002 and March 2004, the rates for these two years were pro-rated according to the proportion of time within the year in which the newer scheme was in place. As an illustration, the derivation of the eventual ARF rates used for these 2 years is as shown in **Figure 2.1** below.

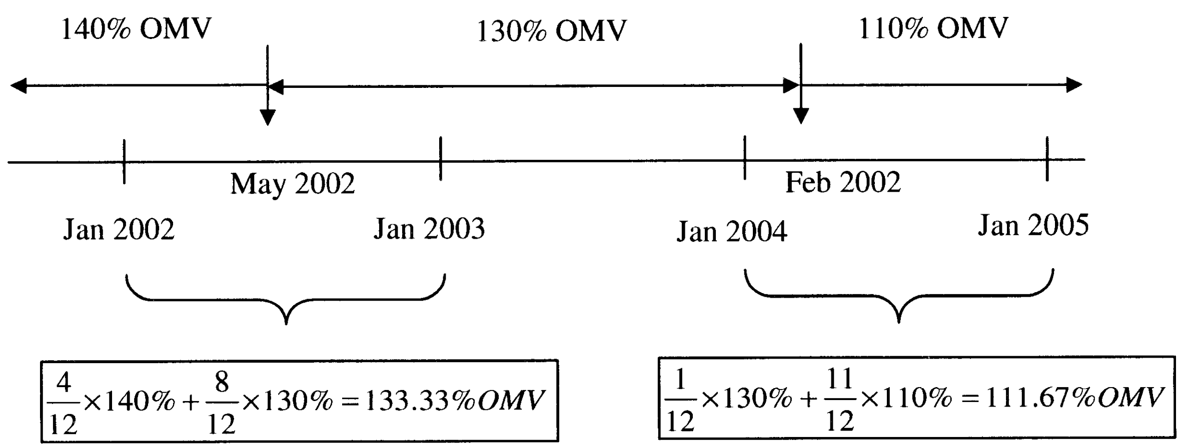

Figure 2.1: Derivation of ARF Rates for the Years 2002 and 2004.

A similar method was used to derive the PARF rebates for cars registered in 2002.

The assumption here is that car registration and possible deregistration occurs at a constant pace in those years, in spite of policy changes. From this step, we can obtain as well the depreciation of the car fleet as a percentage of the OMV of the fleet, as shown in **Table 2.5** overleaf. The total depreciation of the car fleet is thus 161.66% of the average OMV of the entire fleet.

Note that the results of our estimation for this section will give us the PARF rebate depreciation for CY2007, which we will then assume to be approximately equal to that of FY2006-2007.

Fleet Distribution of Private Car Fleet as at 31st December 2007

					ARF Paid	PARF Rebate (% OMV) if deregistered on		PARF Depreciation
Age as at 31-Dec-07	Age as at 31-Dec-06	Number	% of fleet	Registered Between	(% OMV)	31-Dec-07	31-Dec-06	(% OMV)
0-<1 yrs		106,502	20.7	Jan 2007 - Dec 2007	110	75	NA	35
1-<2 yrs	0-<1 yrs	116,656	22.7	Jan 2006 - Dec 2006	110	75	75	0
2-<3 yrs	1-<2 yrs	108,606	21.1	Jan 2005 - Dec 2005	110	75	75	0
3-<4 yrs	2-<3 yrs	81,376	15.8	Jan 2004 - Dec 2004	111.67	75	75	0
4-<5 yrs	3-<4 yrs	42,069	8.2	Jan 2003 - Dec 2003	130.00	75	75	0
5-<6 yrs	4-<5 yrs	12,678	2.5	Jan 2002 - Dec 2002	133.33	86.67	93.33	6.66
6-<7 yrs	5-<6 yrs	10,607	2.1	Jan 2001 - Dec 2001	140	110	120	10
7-<8 yrs	6-<7 yrs	3,638	0.7	Jan 2000 - Dec 2000	140	100	110	10
8-<9 yrs	7-<8 yrs	2,024	0.4	Jan 1999 - Dec 1999	140	90	100	10
9-<10 yrs	8-<9 yrs	2,288	0.4	Jan 1998 - Dec 1998	140	80	90	10
10-<11 yrs	9-<10 yrs	502	0.1	Jan 1997 - Dec 1997	140	0	80	80
11-<12 yrs	10-<11 yrs	1,125	0.2	Jan 1996 - Dec 1996	140	0	0	0
12-<13 yrs	11-<12 yrs	621	0.1	Jan 1995 - Dec 1995	140	0	0	0
13-<14 yrs	12-<13 yrs	698	0.1	Jan 1994 - Dec 1994	140	0	0	0
14-<15 yrs	13-<14 yrs	3,223	0.6	Jan 1993 - Dec 1993	140	0	0	0
15-<16 yrs	14-<15 yrs	9,311	1.8	Jan 1992 - Dec 1992	140	0	0	0
16-<17 yrs	15-<16 yrs	6,982	1.4	Jan 1991 - Dec 1991	140	0	0	0
17-<18 yrs	16-<17 yrs	980	0.2	Jan 1990 - Dec 1990	150	0	0	0
18-<19 yrs	17-<18 yrs	1,380	0.3	Jan 1989 - Dec 1989	150	0	0	0
19-<20 yrs	18-<19 yrs	445	0.1	Jan 1988 - Dec 1988	150	0	0	0
>= 20 yrs	19-<20 yrs	2,974	0.6	Jan 1987 - Dec 1987	150	0	0	0

Table 2.5: PARF Depreciation Estimation

Our next step would be to obtain an average OMV representative of the car fleet as at 31 Dec 2007. There are essentially 2 methods to arrive at this estimate. The first method is to utilize sales data published by the LTA.

In addition to the fleet distribution by age figures that we have already utilized, the LTA also publishes figures on fleet distribution by vehicle cc rating. As at 31 Dec 2007, there were 304,853 CAT A (cc rating <=1,600cc) cars and 209,841 CAT B (>1,600 cc) cars, yielding a ratio of 1.453 Cat A cars to 1 Cat B car.

The LTA also publishes monthly figures reporting the average OMV of new cars registered in the previous month, categorized by make and model. These prices were compiled from surveys of automotive traders across the country. From this extensive list, we can calculate the average OMV values for all CAT A and CAT B models belonging to a certain make. We layer this information with LTA published data on car fleet distribution by make, as shown in **Table 2.6** below, and calculate the average OMV of all vehicles belonging to a certain make according to the total ratio of CAT A to CAT B cars derived in the preceding paragraph. From this, based on the car fleet distribution by make, we can then obtain an average OMV estimate for the entire car fleet.

Total Car Population by Make as at 31 Dec 2007

Make	Total Car Population as at 31 Dec 2007	% of fleet	Average CAT A OMV (S$)	Average CAT B OMV (S$)	Average OMV (S$)	Total OMV (S$)
Alfa Romeo	900	0.17	N.A.	N.A.		
Aston Martin	54	0.01	N.A.	N.A.		
Audi	3,115	0.60	N.A.	59,455	59,455	185,203,741
Austin	155	0.03	N.A.	N.A.		
B.M.W	18,321	3.54	N.A.	58,966	58,966	1,080,321,083
Bentley	138	0.03	N.A.	202,158	202,158	27,897,804
Cadillac	5	0.00	N.A.	N.A.		
Chery	906	0.18	7,235	N.A.	7,235	6,554,910
Chevrolet	8,161	1.58	10,556	19,814	14,330	116,948,388
Chrysler	670	0.13	N.A.	32,374	32,374	21,690,245
Citroen	615	0.12	20,169	31,049	24,604	15,131,572
Daewoo	286	0.06	N.A.	N.A.		
Daihatsu	2,044	0.40	15,802	N.A.	15,802	32,299,288

Daimler	22	0.00	N.A.	N.A.		
Datsun	17	0.00	N.A.	N.A.		
Dodge	39	0.01	N.A.	N.A.		
Dongfeng	33	0.01	6,462	N.A.	6,462	213,246
Ferrari	221	0.04	N.A.	225,570	225,570	49,850,860
Fiat	1,404	0.27	17,884	N.A.	17,884	25,109,136
Ford	4,878	0.94	16,200	24,585	19,618	95,698,551
Geely	523	0.10	6,889	N.A.	6,889	3,602,947
Hafei	168	0.03	5,580	N.A.	5,580	937,440
Holden	7	0.00	N.A.	N.A.		
Honda	67,830	13.12	17,459	26,538	21,161	1,435,321,315
Hyundai	44,798	8.66	11,549	17,859	14,121	632,596,204
Isuzu	18	0.00	N.A.	N.A.		
Jaguar	1,826	0.35	N.A.	77,775	77,775	142,017,759
Jeep	86	0.02	N.A.	23,440	23,440	2,015,840
KIA	16,591	3.21	9,020	14,855	11,399	189,120,874
Lamborghini	110	0.02	N.A.	356,364	356,364	39,200,040
Lancia	6	0.00	N.A.	N.A.		
Land Rover	249	0.05	N.A.	N.A.		
Lotus	75	0.01	N.A.	N.A.		
M.G.	127	0.02	N.A.	N.A.		
Maserati	143	0.03	N.A.	112,586	112,586	16,099,798
Mazda	22,495	4.35	14,407	24,573	18,551	417,308,731
Mercedes Benz	24,999	4.84	N.A.	62,108	62,108	1,552,646,715
MG-F	9	0.00	N.A.	N.A.		
Mini	984	0.19	33,653	N.A.	33,653	33,114,552
Mini Mayfair	5	0.00	N.A.	N.A.		
Mitsubishi	34,542	6.68	15,394	23,638	18,755	647,826,802
Mitsuoka	26	0.01	N.A.	N.A.		
Morgan	6	0.00	N.A.	N.A.		
Morris	99	0.02	N.A.	N.A.		
Nissan	64,507	12.48	14,704	27,348	19,859	1,281,019,509
Opel	2,082	0.40	N.A.	24,337	24,337	50,668,801
Others	62	0.01	N.A.	N.A.		
Panther	7	0.00	N.A.	N.A.		
Perodua	1,905	0.37	5,209	N.A.	5,209	9,923,145
Peugeot	2,387	0.46	22,047	40,864	29,718	70,936,133
Porsche	1,242	0.24	N.A.	108,932	108,932	135,293,958
Proton	4,642	0.90	9,550	N.A.	9,550	44,331,100
Renault	3,019	0.58	17,261	28,431	21,814	65,857,686
Rolls Royce	116	0.02	N.A.	N.A.		
Rover	122	0.02	N.A.	N.A.		
Saab	1,574	0.30	N.A.	38,994	38,994	61,376,950
Sasangyong	196	0.04	N.A.	20,148	20,148	3,948,910
Seat	62	0.01	N.A.	N.A.		
Skoda	323	0.06	N.A.	N.A.		

Subaru	9,949	1.92	11,261	24,118	16,502	164,180,126
Sunbeam	8	0.00	N.A.	N.A.		
Suzuki	11,263	2.18	12,084	16,374	13,833	155,801,383
TD Cars	5	0.00	N.A.	N.A.		
Toyota	146,597	28.35	16,178	46,326	28,468	4,173,373,451
Triumph	33	0.01	N.A.	N.A.		
Volkswagen	3,475	0.67	21,383	33,390	26,278	91,316,200
Volvo	5,759	1.11	N.A.	42,679	42,679	245,788,361
Total	517,041	100			Fleet Average OMV (S$)	25,767

Table 2.6: Total Car Fleet Distribution by Make as at 31 Dec 2007. Highlighted in turquoise are makes which we have cost data for, based on sales in May 2008. These account for 99.44% of the fleet. The reason why the total private car fleet in this distribution list is slightly different from the aggregate reported in the fleet age distribution is due to the fact that this list includes tax-exempted vehicles and VQS-exempted vehicles, which were excluded from the fleet age distribution list.

Several assumptions were used in our above estimation methodology. The most important of these is that all cars bought in years prior to May 2008 cost the same as the do in 2007 Singapore dollars, as long as they are of the same make. The second assumption is that all models within the same CC rating category are sold in equal proportion for each make. This may lead to an overestimation of the CAT B average OMV for Toyota cars, since the large number of models for the more expensive Lexus cars are assumed to be sold in equal proportion to cheaper Camry, of which there are only 2 models, which is probably not true. The third assumption, as afore-mentioned, is that the distribution of CAT A and CAT B cars within each make is assumed to be identical to that of the entire fleet.

Nonetheless, short of delving into historical records for car prices, our estimates give a good ball-park figure sufficiently robust and accurate for our purposes.

The second method of average OMV estimation is to make use of Singapore's trade data as reported on the United Nations Commodity Trade Statistics Database[11]. Data for Singapore's trade in passenger cars other than buses was obtained, showing that

[11] United Nations Statistics Divison. "United Nations Commodity Trade Statistics Database." http://comtrade.un.org/db/dqBasicQuery.aspx

Singapore's total car imports for the year 2006 was 130,305 which roughly corresponds (within 7%) to the 121,963 passenger cars and taxis registered in Singapore in 2006[12]. Also, Singapore's total car exports for the year 2006 was 78,802, which also roughly corresponds to the 64,999 vehicles deregistered in Singapore in 2006[13]. The slight discrepancies with actual deregistration figures are to be expected because not all cars imported in 2006 are expected to be sold within the same year. Similarly, not all vehicles deregistered in 2006 are immediately exported within the same year. Data for the year 2007 is not available yet on the database. From the UN Comtrade Database, the total value of all Singaporean car imports in 2006 was US$1,758,071,360. Divided by the 130,305 cars imported that year, the average OMV cost for the fleet is estimated to be US$13,492 or S$21,422 in 2006 Singapore dollars. Inflated by the CPI, this is actually S$21,866 in 2007 Singapore dollars.

Thus, our 2 separate average OMV estimates are within 18% of each other, and can be considered fairly precise. The reason why our first estimate is higher is probably due to the overrepresentation of Lexus prices, as mentioned before, and also because the OMV's used in our first estimate are the reported selling prices as quoted by dealers, which would be inevitably higher than the actual cost prices used to tally the aggregate import values. Furthermore, since 2007 data is not available in the UN Comtrade Database, we are essentially comparing estimates from two different years.

For our purposes, we will assume that the average OMV of Singapore's car fleet is somewhere within the range established by our 2 estimates, i.e. between S$21,866 and S$25,767. Using our estimated fleet average OMV multiplied by the respective depreciation of PARF rebates for each age category of cars, we estimate that the fleet PARF depreciation for FY2006-2007 is 2007 S$882.89 – 1,040.40 million, as illustrated in **Table 2.7** below. Unlike in the COE depreciation calculations, we do not need to inflate our estimates with the corresponding CPI, because we had already made the assumption that all cars, irrespective of age, are worth about the same in 2007 S$.

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[12] Land Transport Authority. "New Registration of Motor Vehicles by Vehicle Quota Categories."
[13] Land Transport Authority. "De-Registration of Motor Vehicles by Quota Categories."

Age as at 31-Dec-2007	Number	PARF Depreciation (% OMV)	PARF Depreciation (Estimate 1) (2007 S$)	PARF Depreciation (Estimate 2) (2007 S$)
0-<1 yrs	106,502	35	960,482,962	815,070,456
1-<2 yrs	116,656	0	0	0
2-<3 yrs	108,606	0	0	0
3-<4 yrs	81,376	0	0	0
4-<5 yrs	42,069	0	0	0
5-<6 yrs	12,678	6.66	21,756,490	18,462,662
6-<7 yrs	10,607	10	27,331,057	23,193,266
7-<8 yrs	3,638	10	9,374,035	7,954,851
8-<9 yrs	2,024	10	5,215,241	4,425,678
9-<10 yrs	2,288	10	5,895,490	5,002,941
10-<11 yrs	502	80	10,348,027	8,781,386
11-<12 yrs	1,125	0	0	0
12-<13 yrs	621	0	0	0
13-<14 yrs	698	0	0	0
14-<15 yrs	3,223	0	0	0
15-<16 yrs	9,311	0	0	0
16-<17 yrs	6,982	0	0	0
17-<18 yrs	980	0	0	0
18-<19 yrs	1,380	0	0	0
19-<20 yrs	445	0	0	0
>= 20 yrs	2,974	0	0	0
		Total Depreciation (2007 S$)	1,040,403,301	882,891,240

Table 2.7: PARF Depreciation of Car Fleet Based on Our Two Average OMV Estimates.

Actual Depreciation of Body Value

There is a lack of published data on the depreciation of the actual body value of Singaporean cars. However given that the most significant sources of difference between the depreciation curves of Singaporean cars and cars from other countries have already been accounted for, it is reasonable to assume that the depreciation in actual body value of Singapore cars follows closely that of cars in other countries.

For our purposes, we want published body depreciation data that does not include the effects of taxes, since we have already accounted for these separately. Data published by the American Automobile Association (AAA) in Your Driving Costs 2007 for cars with 15,000 annual mileage is as reproduced in **Table 2.8** below.

	Small Sedan	Medium Sedan	Large Sedan
Annual Depreciation 2007 US$	2,461	3,394	4,321
*Annual Depreciation 2007 S$	3,708	5,113	6,510

Table 2.8: Depreciation Costs for American Cars.
Costs in each category are based on average costs for five top-selling models selected by AAA, for the first 5 years of vehicle life. By size category, they are:
- Small sedan — Chevrolet Cobalt, Ford Focus, Honda Civic, Nissan Sentra and Toyota Corolla.
- Medium sedan — Chevrolet Impala, Ford Fusion, Honda Accord, Nissan Altima and Toyota Camry.
- Large sedan — Buick Lucerne, Chrysler 300, Ford Five Hundred, Nissan Maxima and Toyota Avalon.

* Average exchange rate in 2007 was 1 USD to 1.5066 SGD

Depreciation costs for 15,000 annual mileage were chosen over the 10,000 and 20,000 annual mileage options because the average annual distance driven in Singaporean private cars was 21,075 km (13,095 miles) in 2006[14]. Although other fixed and operating costs were published in addition to the body depreciation costs, these were discarded because they were more applicable to the U.S. context and we have more reliable local data sources for these.

The 'small sedans', 'medium sedans' and 'large sedans' used in the AAA samples have a CC rating of about 1,800cc, 2,000cc and upwards of 3,000cc respectively, with the former 2 classes of cars roughly corresponding to the CC ratings of CAT A and CAT B cars under the Singapore classification. With the actual numbers of CAT A and CAT B cars for our fleet at 304,853 and 209,841 respectively, we obtain S$2.203 billion for the total depreciation in body value of the fleet for FY2006-2007.

Admittedly, our above value would be a slight overestimation because the small and medium sedan classifications are both slightly above the CC ratings for CAT A (<=1,600cc) and CAT B (>1,600cc) cars respectively. An alternate method of estimating the annual body depreciation of Singapore's car fleet would be to consider the difference between the average value of Singapore's used cars which were exported, compared to

[14] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2007."

the average value of the new cars arriving, divided by the average age of the exported used car fleet.

Based on the UN Comtrade Database figures for Singapore's passenger car trade in 2006, as tabulated in Table A-3, the average OMV for new cars being imported into Singapore during 2006 was S$21,322 in 2006 Singapore dollars. In addition, the 78,802 used cars exported that year cost $442,988,564 in total. Thus, the average body value of these cars was $5,622. If we assume that the used cars exported in 2006 used to cost the same as the new cars imported in 2006 (in 2007 Singapore dollars) when they themselves were brand new, then on average, a depreciation of S$15,700 has occurred.

From the annual vehicle fleet distribution by age figures published by LTA, we can work out the age distribution of cars deregistered in the year 2006. This is as illustrated in **Table 2.9** below.

Age as at 31 Dec '06	Number of Cars	Age as at 31 Dec '05/ Age when De-registered	Number of Cars	Number De-registered in '06
0-<1 yrs	116,741	0-<1 yrs	109,165	90
1-<2 yrs	109,075	1-<2 yrs	96,518	3,278
2-<3 yrs	93,240	2-<3 yrs	78,754	15,630
3-<4 yrs	63,124	3-<4 yrs	46,496	20,440
4-<5 yrs	26,056	4-<5 yrs	34,396	18,741
5-<6 yrs	15,655	5-<6 yrs	10,562	4,739
6-<7 yrs	5,823	6-<7 yrs	6,644	3,246
7-<8 yrs	3,398	7-<8 yrs	8,462	4,006
8-<9 yrs	4,456	8-<9 yrs	2,284	1,110
9-<10 yrs	1,174	9-<10 yrs	3,250	2,119
10-<11 yrs	1,131	10-<11 yrs	644	10
11-<12 yrs	634	11-<12 yrs	787	41
12-<13 yrs	746	12-<13 yrs	4,003	386
13-<14 yrs	3,617	13-<14 yrs	12,431	1,464
14-<15 yrs	10,967	14-<15 yrs	11,822	2,850
15-<16 yrs	8,972	15-<16 yrs	1,823	528
16-<17 yrs	1,295	16-<17 yrs	2,859	945
17-<18 yrs	1,914	17-<18 yrs	1,113	416
18-<19 yrs	697	18-<19 yrs	879	325
19-<20 yrs	554	19-<20 yrs	844	2,263
>= 20 yrs	3,039	>= 20 yrs	4,458	

Table 2.9: Age Distribution of Cars De-registered in 2006.

From **Table 2.9**, it is evident that the PARF and COE rebate schemes have been working well for the sake of vehicle fleet renewal. If we assume that cars above 10 years of age upon de-registration (11% of total de-registrations in 2006) were scrapped rather than exported, then the average age of cars exported in 2006 would be 4.18 years. [Incidentally, the 73,400 cars deregistered in 2006 correspond pretty well with the 78,800 reported to be exported in 2006.] Combining this information with our depreciation value of S$15,700 calculated before and assuming a linear depreciation function for these 4.18 years, the average annual depreciation of Singapore cars is S$3,756 in 2006 dollars, S$3,834 in 2007 dollars, which corresponds very well with the figures suggested by the AAA.

If we use this estimate of annual depreciation for the Singapore car fleet, then the total annual depreciation in body value for the Singapore car fleet in CY2007 is <u>**S$1.982 billion**</u>, again, agreeing well with our first estimate. Hence we will assume this to be approximately equal to that of FY2006-2007.

<u>*Registration Fee, GST and Excise Duty*</u>

Since the registration fee, GST and excise duties are sunk costs payable only during the purchase of a new car, they can be considered part of the depreciation costs for all cars in their first year. We will assume that all first year cars for FY2006-2007 are cars that were registered in calendar year 2007.

The LTA annually publishes new car registration figures, sorted by car make, as well as engine CC rating categories. For the year 2007, 60,200 CAT A and 46,331 CAT B cars were registered. This yields a ratio of 1.30 CAT A cars to 1 CAT B car.

Adopting a similar method to that used to calculate the average OMV for the entire vehicle fleet, we arrange the information based on average OMV values for all CAT A and CAT B models belonging to a certain CAR make, and calculate the average OMV for each make according to the ratio of CAT A to CAT B cars for new registrations in 2007. Supplementing this with information on the number of cars registered in 2007 for each make, we can calculate the average OMV for all new cars registered in 2007. This whole process is as illustrated in **Table 2.10** below.

New Registrations in 2007 by Car Make

Make	No. of New Cars Registered in 2007	% of fleet	Average CAT A OMV (S$)	Average CAT B OMV (S$)	Average OMV (S$)	Total OMV (S$)
Alfa Romeo	169	0.16	N.A.	N.A.		
Aston Martin	20	0.02	N.A.	N.A.		
Audi	964	0.90	N.A.	59,455	59,455	57,315,058
Austin	0	0.00	N.A.	N.A.		
B.M.W	3,732	3.50	N.A.	58,966	58,966	220,062,130
Bentley	37	0.03	N.A.	202,158	202,158	7,479,846
Cadillac	0	0.00	N.A.	N.A.		
Chery	637	0.60	7,235	N.A.	7,235	4,608,695
Chevrolet	2,134	2.00	10,556	19,814	14,581	31,116,318
Chrysler	140	0.13	N.A.	32,374	32,374	4,532,290
Citroen	247	0.23	20,169	31,049	24,899	6,150,107
Daewoo	0	0.00	N.A.	N.A.		
Daihatsu	694	0.65	15,802	N.A.	15,802	10,966,588
Daimler	0	0.00	N.A.	N.A.		
Datsun	0	0.00	N.A.	N.A.		
Dodge	33	0.03	N.A.	N.A.		
Dongfeng	33	0.03	6,462	N.A.	6,462	213,246
Ferrari	53	0.05	N.A.	225,570	225,570	11,955,184
Fiat	649	0.61	17,884	N.A.	17,884	11,606,716
Ford	334	0.31	16,200	24,585	19,618	6,552,545
Geely	505	0.47	6,889	N.A.	6,889	3,478,945
Hafei	168	0.16	5,580	N.A.	5,580	937,440
Holden	0	0.00	N.A.	N.A.		
Honda	21,215	19.88	17,459	26,538	21,407	454,144,846
Hyundai	5,408	5.07	11,549	17,859	14,292	77,292,233
Isuzu	0	0.00	N.A.	N.A.		
Jaguar	182	0.17	N.A.	77,775	77,775	14,155,111
Jeep	32	0.03	N.A.	23,440	23,440	750,080
KIA	2,451	2.30	9,020	14,855	11,557	28,326,802
Lamborghini	34	0.03	N.A.	356,364	356,364	12,116,376
Lancia	0	0.00	N.A.	N.A.		
Land Rover	41	0.04	N.A.	N.A.		
Lotus	5	0.00	N.A.	N.A.		
M.G.	0	0.00	N.A.	N.A.		
Maserati	45	0.04	N.A.	112,586	112,586	5,066,370
Mazda	4,427	4.15	14,407	24,573	18,827	83,346,487

Mercedes Benz	3,875	3.63	N.A.	62,108	62,108	240,669,868
MG-F	0	0.00	N.A.	N.A.		
Mini	290	0.27	33,653	N.A.	33,653	9,759,370
Mini Mayfair	0	0.00	N.A.	N.A.		
Mitsubishi	8,335	7.81	15,394	23,638	18,978	158,184,131
Mitsuoka	23	0.02	N.A.	N.A.		
Morgan	0	0.00	N.A.	N.A.		
Morris	0	0.00	N.A.	N.A.		
Nissan	9,625	9.02	14,704	27,348	20,201	194,439,380
Opel	309	0.29	N.A.	24,337	24,337	7,520,009
Others	11	0.01	N.A.	N.A.		
Panther	0	0.00	N.A.	N.A.		
Perodua	579	0.54	5,209	N.A.	5,209	3,016,011
Peugeot	494	0.46	22,047	40,864	30,228	14,932,619
Porsche	337	0.32	N.A.	108,932	108,932	36,710,196
Proton	677	0.63	9,550	N.A.	9,550	6,465,350
Renault	456	0.43	17,261	28,431	22,117	10,085,491
Rolls Royce	7	0.01	N.A.	N.A.		
Rover	0	0.00	N.A.	N.A.		
Saab	210	0.20	N.A.	38,994	38,994	8,188,793
Sasangyong	77	0.07	N.A.	20,148	20,148	1,551,358
Seat	0	0.00	N.A.	N.A.		
Skoda	61	0.06	N.A.	N.A.		
Subaru	3,297	3.09	11,261	24,118	16,851	55,557,245
Sunbeam	0	0.00	N.A.	N.A.		
Suzuki	4,158	3.90	12,084	16,374	13,949	58,001,433
TD Cars	0	0.00	N.A.	N.A.		
Toyota	27,574	25.84	16,178	46,326	29,286	807,529,595
Triumph	0	0.00	N.A.	N.A.		
Volkswagen	942	0.88	21,383	33,390	26,604	25,060,644
Volvo	984	0.92	N.A.	42,679	42,679	41,996,136
Total	106,710	100			Average OMV (S$)	25,601

Table 2.10: New Car Registrations by Make for the year 2007. Highlighted in turquoise are makes which we have cost data for, based on sales in May 2008. These account for 99.65% of the fleet.

Since the average OMV for new cars registered in 2007 is S$25,601, the total depreciation in terms of excise duty and GST is simply 27% of the total OMV of these 106,710 cars, or S$737.61 million. Added to the flat rate registration fee of S$140 per car, the total depreciation estimate obtained for this section is S$752.55 million.

Totaling all components of our depreciation estimates, the total car fleet depreciation for FY2006-2007 was between **S$4.512** and **S$4.890 billion**, with about 50% of that depreciation attributable to government surcharges and levies, as shown in **Figure 2.2** below. The average depreciation costs per car and car-kilometer are as tabulated in **Table 2.11**.

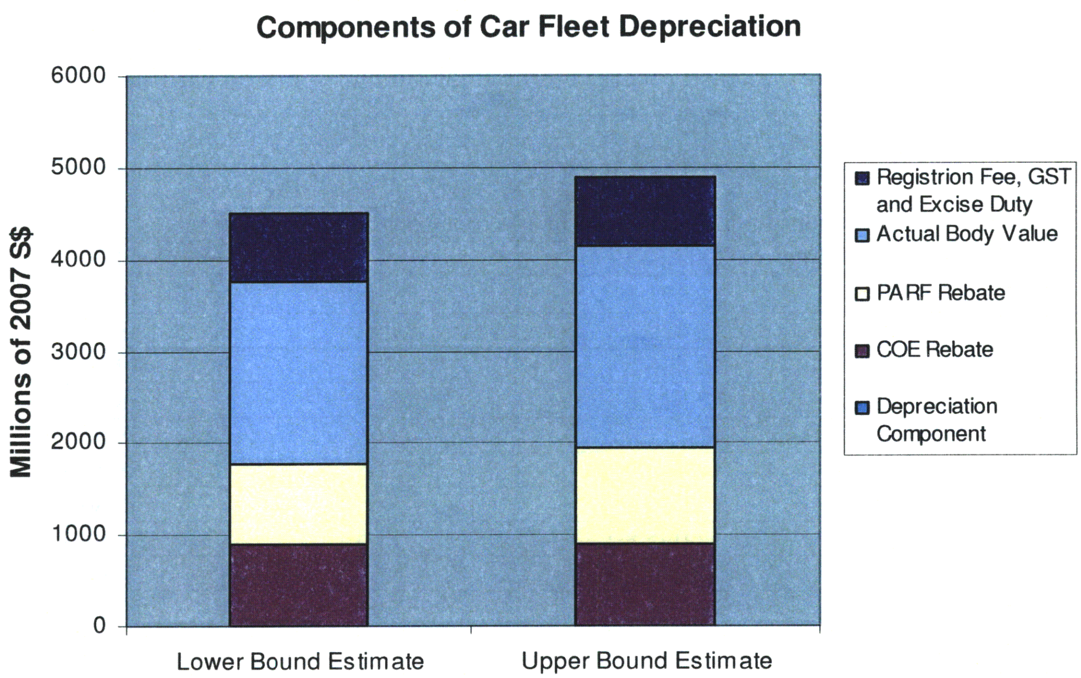

Figure 2.2: Components of Car Fleet Depreciation

	Lower Bound Estimate	Upper Bound Estimate
Depreciation Costs	(2007 S$)	(2007 S$)
Fleet Total	4.512 billion	4.890 billion
Per Car	8,766.37	9,500.79
Per Car-Kilometer	0.42	0.45

Table 2.11: Average Depreciation Costs per Car and Per Car-Kilometer.

2.1.2 Financing

To find out how much is spent financing the car fleet, we look at monthly statistical data published by the Monetary Authority of Singapore (MAS), which is Singapore's central bank. The statistical data published includes the total amount of car loans facilitated by banks in Singapore, as well as the monthly effective interest rates for a typical 3-year car loan. The figures for these are as reproduced in the first 2 columns of **Table 2.12** below. From these figures, we can easily work out the total amount spent on car financing in CY 2007.

End of Period		Amount Loaned	Effective Loan Rate	Interest Paid
		(Millions of 2007 S$)	(%)	(Millions of 2007 S$)
2007	Jan	12,391.5	5.65	58.34
	Feb	12,429.4	5.65	58.52
	Mar	12,536.5	5.65	59.03
	Apr	12,512.8	5.65	58.91
	May	12,511.4	5.65	58.91
	Jun	12,489.9	5.65	58.81
	Jul	12,076.4	5.65	56.86
	Aug	12,095.8	5.65	56.95
	Sep	12,118.8	5.65	57.06
	Oct	12,164.7	5.65	57.28
	Nov	12,176.3	5.65	57.33
	Dec	12,201.0	5.65	57.45
			Total Interest Paid	695.44

Table 2.12: Total Car Fleet Financing Costs[15].

Thus, the total amount spent on financing Singapore's car fleet for CY 2007 is 2007 **S$695.4 million**, and the average financing costs per car and per car-kilometer are as tabulated in **Table 2.13** below.

	Lower Bound Estimate	Upper Bound Estimate
Financing Costs	(2007 S$)	(2007 S$)
Fleet Total	695.40 million	695.40 million
Per Car	1,351.09	1,351.09
Per Car-Kilometer	0.06	0.06

Table 2.13: Average Depreciation Costs per Car and Per Car-Kilometer.

[15] Monetary Authority of Singapore. "Monthly Statistical Bulletin, May 2008."

2.1.3 Road Tax

The road tax structure for Singapore's road vehicles is as shown in **Table 2.14** below.

6-Monthly Road Tax for Vehicles with Conventional Gasoline Engines		
	Before 1st Sep 2007	1st Sep 2007 to 31st June 2008
EC ≤ 600 cc	\$200	\$200 x 0.92
600 cc < EC 1,000 cc	\$200 + 0.125 X (EC -600)	[\$200 + 0.125 x (EC - 600)] x 0.92
1,000 cc < EC ≤ 1,600 cc	\$250 + 0.375 x (EC – 1,000)	[\$250 + 0.375 x (EC - 1,000)] x 0.92
1,600 cc< EC ≤ 3,000 cc	\$475 + 0.75 x (EC – 1,600)	[\$475 + 0.75 x (EC - 1,600)] x 0.92
EC > 3,000 cc	\$1,525 + 1.0 x (EC – 3,000)	[\$1,525 + 1.0 x (EC - 3,000)] x 0.92

Table 2.14: Road Tax Structure for Singapore's Cars.

Unfortunately, we have limited data on the exact fleet distribution according to the tax structure's categories. Our COE registration data for 1999 and later years only differentiate cars at the 1600 cubic centimeter (CC) mark. We have therefore provided estimates on our fleet distribution based on COE registration data from the years 1997 to April 1999, when COE categories were slightly more disaggregate, with four categories rather than two. The car registration by category data for this time period is as shown in **Figure 2.3** below.

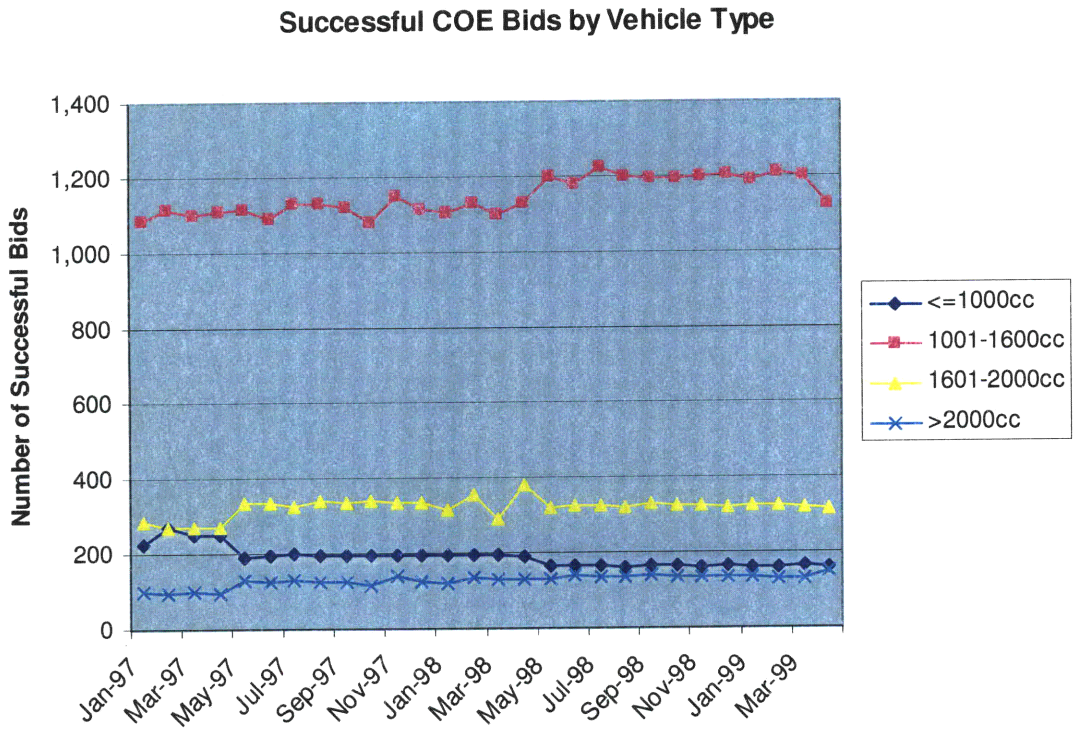

Figure 2.3: Successful COE Bids by Engine CC Rating from Jan 97 to April 99.

As we can see from **Figure 2.3**, the car registration for each engine cc category has remained stable over the entire time period. It is thus reasonable to assume that these same proportions could serve as a guide for the 2007 car fleet. To obtain estimates of these proportions, we once again draw upon the same data used in **Figure 2.3**, as illustrated in **Table 2.15** below.

Successful Bids	Cat 1	Cat 2	Cat 3	Cat 4	Total Successful bids
Quota Month	<=1000cc	1001-1600cc	1601-2000cc	>2000cc	
Jan-97	228	1,085	284	100	1,697
Feb-97	270	1,113	272	97	1,752
Mar-97	249	1,099	272	101	1,721
Apr-97	249	1,109	271	94	1,723
May-97	192	1,116	338	130	1,776
Jun-97	196	1,091	336	124	1,747
Jul-97	199	1,130	326	131	1,786
Aug-97	197	1,128	341	126	1,792

Sep-97	196	1,117	337	127	1,777
Oct-97	195	1,080	339	117	1,731
Nov-97	194	1,151	335	138	1,818
Dec-97	196	1,115	338	123	1,772
Jan-98	194	1,105	314	122	1,735
Feb-98	196	1,129	358	136	1,819
Mar-98	195	1,097	292	132	1,716
Apr-98	193	1,129	380	128	1,830
May-98	166	1,197	321	131	1,815
Jun-98	164	1,181	328	143	1,816
Jul-98	164	1,223	326	137	1,850
Aug-98	163	1,199	319	136	1,817
Sep-98	165	1,196	329	138	1,828
Oct-98	164	1,193	324	137	1,818
Nov-98	163	1,200	324	136	1,823
Dec-98	165	1,203	322	135	1,825
Jan-99	163	1,189	325	135	1,812
Feb-99	163	1,207	324	130	1,824
Mar-99	164	1,198	323	130	1,815
Apr-99	160	1,122	318	150	1,750
Total	5,303	32,102	9,016	3,564	49,985
Average %	10.61	64.22	18.04	7.13	100

Table 2.15: Estimating the Car Fleet Proportions from Historical Data.

Considering the above data with respect to the road tax CC rating categories, we first note that the number of cars below 600cc is probably negligible, since there are practically no car models sold in Singapore below this particular CC rating. Next, we note that 59.2% of the vehicle fleet in 2007 were CAT A cars. We will therefore assume that since 1999, people have become more affluent to the point that the proportion of people owning cars from 600cc to 1,000cc has dropped to about 7.2%. Of the 59.2% CAT A cars, this leaves 52% of the car fleet in 2007 composed of cars between 1,000cc and 1,600cc. Of the 40.7% CAT B share, we will assume that about 4.7% own cars above 3,000cc, leaving 36% of the 2007 fleet composed of cars with engine CC rating between 1,600cc and 3,000cc.

Overlaying our estimates with the information in **Table 2.14**, and further assuming that the average CC rating for cars within each category is exactly half of the category bounds, we have obtained the following estimates as illustrated in **Table 2.16** below.

Road Tax Category	% of 2007 Fleet	Number of Cars	Average EC	8-Month Road Tax Paid Before 1st Sep 2007 Per Car (2007 S$)	4-Month Road Tax Paid After 1st Sep 2007 Per Car (2007 S$)	Total Road Tax Paid for Category (2007 S$)
EC ≤ 600 cc	0	0	300	267	123	0
600 cc< EC 1,000 cc	7.2	37,058	800	300	138	16,231,390
1,000 cc < EC ≤1,600 cc	52.1	268,156	1,300	483	222	189,228,450
1,600 cc< EC ≤3,000 cc	36	185,290	2,300	1,333	613	360,697,555
EC > 3,000 cc	4.7	24,191	4,000	3,367	1,549	118,904,951
Total	100	514,694			Total	685,062,346

Table 2.16: Road Tax Estimates for 2007 Car Fleet.

These estimates, however, do not take into account road tax surcharges which are levied upon older cars in the fleet as per **Table 2.17** below:

Age of Vehicle	Annual Road Tax Surcharge
More than 10 years	10%
More than 11 years	20%
More than 12 years	30%
More than 13 years	40%
More than 14 years	50%

Table 2.17: Road Tax Surcharges

Assuming that all vehicles across the fleet, regardless of age, are distributed in the road tax categories in the exact same proportions as the fleet average, we can estimate the surcharges levied, as illustrated in **Table 2.18** below. Here, we make use of LTA's fleet age distribution figures once again.

Age as at 31-Dec-2007	% of fleet[16]	% Surcharge Levied (%)	Value of Surcharge (2007 S$)
10-<11 yrs	0.1	10	68,506
11-<12 yrs	0.2	20	274,025
12-<13 yrs	0.1	30	205,519
13-<14 yrs	0.1	40	274,025
14-<15 yrs	0.6	50	2,055,187
15-<16 yrs	1.8	50	6,165,561
16-<17 yrs	1.4	50	4,795,436
17-<18 yrs	0.2	50	685,062
18-<19 yrs	0.3	50	1,027,594
19-<20 yrs	0.1	50	342,531
>= 20 yrs	0.6	50	2,055,187
		Total	17,948,633

Table 2.18: Road Tax Surcharges for the Private Automobile Fleet.

Thus, our estimate for the total road tax costs in CY 2007 is **S$703.01 million**.

The average road tax costs per car and per car-kilometer are as shown in **Table 2.19** below.

Road Tax Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	703.01 million	703.01 million
Per Car	1,365.88	1,365.88
Per Car-Kilometer	0.06	0.06

Table 2.19: Average Road Tax Cost per Car and per Car-Kilometer.

The Ministry of Finance (MOF) publishes annual data on the Singapore Government's revenue estimates from various tax sources. According to the FY2008-2009 budget publications, the revised FY2007-2008 estimates for motor vehicle road tax were S$780.8 million[17]. However, this figure includes revenue from road taxes on buses, goods vehicles, motorcycles and scooters. Considering that the road tax charges for each of the approximately 143,000 motorcycles and scooters are only roughly a tenth that of a car,

[16] Land Transport Authority. "Age Distribution of Motor Vehicles as at 31 December 2007."
[17] Ministry of Finance. "Total Estimated Receipts for FY2008 by Object Class."

and that for each of the approximately 153,000 goods vehicles and buses are very roughly about half that of a car, then the private car should account for roughly 85% or so of all road tax charges. Our estimates are within 6% of our rough check, and are thus, considered reasonable.

An alternative method to obtain the road tax estimates would be to calculate the road tax charges for motorcycles and scooters, goods vehicles and buses, and subtract this from the total road tax revenue. However, due to the less-than-ideal nature of the data available, we will still have to end up making estimates for the number of vehicles in each road tax category anyway, rendering it not more superior than our current methodology.

2.1.4 Insurance

The General Insurance Association of Singapore (GIA) reported that in CY 2007, the total Gross Written Premiums in motor vehicle insurance for the entire Singapore vehicular fleet was S$754.8 million[18]. However, this figure is for the entire vehicle fleet, comprising 851,336 vehicles, including 514,694 private cars, 24,096 taxis, 146,889 goods vehicles and buses, 143,524 motorcycles and scooters, and 22,210 others[19]. Since we were unable to obtain further breakdown on how much of the motor insurance was attributable to each type of vehicle, we will make two estimates – a reasonable one, and a more conservative one, for later sensitivity analyses at the end of this chapter.

Singapore's car fleet is very new compared to her motorcycle and scooter fleet, as evidenced from a simple comparison of the fleet age distribution for both vehicle types. Also, as a result of the disproportionately high taxation on private cars driving up the costs compared to other vehicles types, we would reasonably expect the vehicle insurance for private cars to be much more expensive in order to adequately cover these higher values. Goods vehicles and buses, however, may have higher insurance premiums

[18] General Insurance Association of Singapore. "Overview Of Motor Insurance Market In 2007". http://www.gia.org.sg/industry_motor_stats_2007.php
[19] Land Transport Authority. "Motor Vehicle Population by Quota Categories."

because their drivers have to be insured for professional liability, and because accidents involving these vehicle types tend to be result in higher damage and loss. This is assumed the same for vehicles under the 'Others' category, which include vehicles exempted from the VQS and taxes, and which are typically composed of emergency and official vehicles.

Taking into account the above, we assume that goods vehicles and buses, as well as 'Other' vehicles, and taxis, have premiums equal to that of private cars, whilst motorcycles and scooters only have premiums a third of that. This results in an average insurance premium of S$999 for each vehicle, and **S$514.04 million** in total premiums paid.

A much more conservative estimate would be to assume that premiums for each motorcycle and scooter cost the same as that of private cars. This makes for an average insurance premium of S$887 for each vehicle, and **S$456.3 million** in total premiums paid for the private car fleet. This is only 11% less than our first estimate, largely due to the small number of motorcycles and scooters compared to the private car fleet.

The average insurance costs per car and per car-kilometer are as shown in **Table 2.20** below.

Insurance Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	456.30 million	514.04 million
Per Car	886.55	998.73
Per Car-Kilometer	0.04	0.05

Table 2.20: Average Insurance Costs per Car and per Car-Kilometer.

2.2 Variable Costs

2.2.1 Electronic Road Pricing (ERP)

Since its implementation in 1998, the ERP has been a form of congestion pricing predominantly concentrated around the Central Business District (CBD) Area. Though the system has been expanding slightly and toll charges and toll times have been adjusted slightly over the years, the annual revenue from ERP has remained at around S$100 million until major adjustments scheduled for 1st July 2008 are expected to increase this amount by S$70 million[20,21].

We conservatively estimate that at least 60% of the S$100 million revenue is collected from the private car fleet, since 60% of the entire vehicle fleet comprises private cars. This estimate is likely to be conservative because goods vehicles are likely to be more price elastic with respect to ERP since their deliveries are likely less restricted to the morning and evening peak commute hours when the ERP is in operation. Furthermore, the bulk of cargo transportation in Singapore occurs outside of the CBD areas, near the airport in the east, and seaport in the southwest and industrial areas on the island's periphery. Also, we do not expect the 2.6% or so tax-exempt and emergency vehicles to make regular morning commutes or be charged for it, even if they do happen to. As such, ERP revenue collected from private cars is likely to be a greater proportion than their share of the entire vehicle fleet. However, due to the lack of data availability, we will stay with our conservative estimate of **S$60 million** charged to the private car fleet.

[20] The Business Times. "ERP Helps Business, Says LTA."
[21] Luk. "Electronic Road Pricing in Singapore."

Table 2.21 below shows the average ERP costs per car and per car-kilometer.

ERP Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	60.0 million	60.0 million
Per Car	116.57	116.57
Per Car-Kilometer	0.01	0.01

Table 2.21: Average ERP Costs per Car and per Car-Kilometer.

2.2.2 Vehicle Maintenance and Spare Parts

In order to estimate the amount spent on car maintenance and spare parts, we first take a look at the Singapore General Household Survey 2003/2004. This is the only source of published data on vehicle maintenance costs that could be found in the public domain. Relevant data of interest to us are put into **Table 2.22** and presented below.

Monthly Household Income (S$)	Monthly Expenditure (S$)			% Households Owning a Car	% Households Owning a Motorcycle/ Scooter	Repair, Maintenance and Spare Parts Cost as a % of Vehicle Fixed Costs
	Purchase of Vehicle (Fixed Costs)	Repair, Maintenance, and Spare Parts	Other Running Costs			
<1,000	0	0	3.6	1.8	5.4	N.A.
1,000 - 1,499	1.3	0.2	15.1	5.9	9.4	15.4
1,500 - 1,999	8.5	1.7	26.6	10.6	9.7	20.0
2,000 - 2,499	48.9	0.5	51.8	23.5	11.5	1.0
2,500 - 2,999	113.7	4.4	85.6	34.6	11.2	3.9
3,000 - 3,999	248.8	11.8	151.6	46.7	10	4.7
4,000 - 4,999	380.7	21.4	246.9	63.9	7.9	5.6
5,000-5,999	528	53.2	290.7	74	7.3	10.1
6,000-6,999	627.3	48.6	363.6	81.3	4.5	7.7
7,000-9,999	803.6	66.8	425.1	81.2	5.2	8.3
> 10,000	1372.4	186.6	604.8	91.1	5.3	13.6

Table 2.22: Private Transport Expenditure by Expenditure Category and Household Income. 'Other Running Costs' include parking, ERP, and taxi charges. 'Purchase of Vehicle Costs' include taxes, registration fees, COE, insurance and etc, essentially all fixed costs.

From **Table 2.22**, we can see that the ratio of repair, maintenance and spare parts to vehicle fixed costs are roughly stable, around 4% to 10%, for the household income groups between $2,500 and $9,999. Below $2,500, the proportion of households with motorcycles and scooters to households with cars is still rapidly changing, resulting in *vehicular* repair and maintenance costs that do not accurately reflect *car* repair and maintenance costs. For households with incomes above $10,000, income variability is too great and the likely existence of many outliers undermines the reliability of our estimates.

The next step is to estimate the monthly household expenditure on car fixed costs. We already have estimates on the road tax, insurance, and interest costs from **Section 2.1**. However, we cannot use our depreciation estimates to complete the fixed costs calculations, because, even though these are the true costs to motorists, since we are utilizing household monthly expenditures for this estimate, we need an estimate for the actual monthly installments paid towards the financing of the car. The term 'Purchase of Vehicle' thus includes costs of road tax, insurance, annual interest on bank loans, and annual installments that actually reduce the loan amount, the first three of which we have already obtained estimates for in the previous section.

To determine the portion of annual installments that actually go towards reducing the loan amount, we look at **Table 2.12**, and see that the average amount loaned for car financing is S$12,308.7 million. These loans are typically used to finance the excise duty, registration fee, ARF and COE charges. Given that the typical length of a car loan in Singapore is 7 years, this means that on average, Singaporean private car owners pay S$1758.4 million annually towards debt reduction.

The annual out-of-pocket fixed costs for car ownership are therefore the sum of the following:

Debt reduction: S$1,758.4 million
Interest: S$695.4 million
Road Tax: $703.0 million - 764.8 million
Insurance: S$456.3 million - 514.0 million

Above figures yield a range of S$3,613.1 – 3,732.6 million. If we further assume that the car fleet maintenance costs are the average of 4% and 10% of the total out-of-pocket fixed costs, as found before, then 7% of this gives an annual expenditure of **S$252.9 - 261.3 million** in CY 2007 on car fleet maintenance.

The average maintenance and spare parts costs per car and per car-kilometer are as shown in **Table 2.23** below.

Spare Parts and Maintenance Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	252.90 million	261.30 million
Per Car	491.36	507.68
Per Car-Kilometer	0.02	0.02

Table 2.23: Average Spare Pars and Maintenance Costs per Car and per Car-Kilometer.

The methodology described above might seem convoluted, and some might argue that a much simpler and more straightforward method might be to use the average household expenditure in 2003 on vehicle maintenance multiplied by the number of households today, and inflate the prices using the CPI. However, this would involve us making assumptions on car ownership levels based on 2003 data, household distributions based on 2005 data, and vehicle maintenance costs based on 2003 data. We argue that it is more reliable to make the single assumption used in our methodology: that vehicle maintenance and repair costs are relatively stable with respect to the fixed costs of cars, since all components of fixed costs and maintenance costs are likely to be highly correlated with the actual OMV of the cars themselves.

2.2.3 Petrol Costs

To compute the petrol costs of private cars in Singapore in CY2007, we rely on LTA published data car fleet average fuel consumption rate, average distance travelled by cars in Singapore, as well as the average petrol price in Singapore for CY2007.

The latest available published data from the LTA stated that the average fuel efficiency for CAT A cars was 10 liters/100km and 12.9 liters/100km for CAT B cars in 2004[22] (as compared to 8.5 liters/100km and 12.5 liters/100km respectively in the year 2003[23]). We will assume the 2004 averages for the 2007 private car fleet. The implicit assumption is that vehicle fuel efficiency technologies had not changed vastly over the span of 3 years.

According to LTA published data, private cars in Singapore travelled an average of 21,075km in the year 2006[24]. Thus, if we assume conservatively that private cars in Singapore travelled the same average distance in CY2007 regardless of engine cc rating, and recall that there were 304,853 CAT A cars and 209,841 CAT B cars in CY2007, the total volume of petrol consumed in CY2007 by the private car fleet was 1.213 billion liters.

According to the Monthly Digest of Statistics published by the Singapore Department of Statistics, the average price of intermediate and premium petrol was S$1.50 and S$1.67 per liter respectively[25]. Included in these prices are an excise duty of 44 cents per litre and a 7% GST. Assuming all car owners opted to use intermediate petrol, the total expenditure by the private car fleet was **<u>S$1.820 billion</u>** in CY2007.

Table 2.24 below shows the average petrol costs per car and per car-kilometer.

Petrol Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	1.82 billion	1.82 billion
Per Car	3,536.08	3,536.08
Per Car-Kilometer	0.17	0.17

Table 2.24: Average Petrol Costs per Car and per Car-Kilometer.

[22] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2005."
[23] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2004."
[24] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2007."
[25] Singapore Department of Statistics. "Monthly Digest of Statistics, Singapore. March 2008."

2.2.4 Parking Charges

The estimation of parking charges for Singapore's car fleet is undertaken using two different methods. The first method involves estimating the out-of-pocket costs to private car motorists. This method, however, does not reflect the full expense to society in the provision of parking facilities, and is thus only applicable if we want to consider costs borne by private car motorists themselves. This is because parking costs are frequently subsidized by retail businesses as a way to attract customers and by large employment centers as an employee benefit. The second method, thus, is to estimate the full costs required to provide all the existing private car parking facilities in Singapore. In summary, this second method involves estimating the number of parking lots in each geographic region of Singapore, followed by a computation of the land and constructions costs involved in providing these car parking lots, based on the average land prices in each of these geographic regions. The costs are then amortized for their average building lifetime.

Step 1: Geographic Distribution of Car Parking Lots in Singapore

One good way for us to geographically divide up Singapore would be to use the urban planning areas used by the Singapore government in 2000. These planning areas are as shown in **Figure 2.4**.

The Central Business District of Singapore lies in the south, within the 'Central Area' planning area, and comprises the planning sub-areas of Outram, Museum, Singapore River, Downtown Core and most of River Valley. A blow-up of the CBD is as shown in **Figure 2.5**. In 2008, the LTA reported that there were **49,000** car parking lots within the CBD[26].

[26] Land Transport Authority. "Land Transport Master Plan".

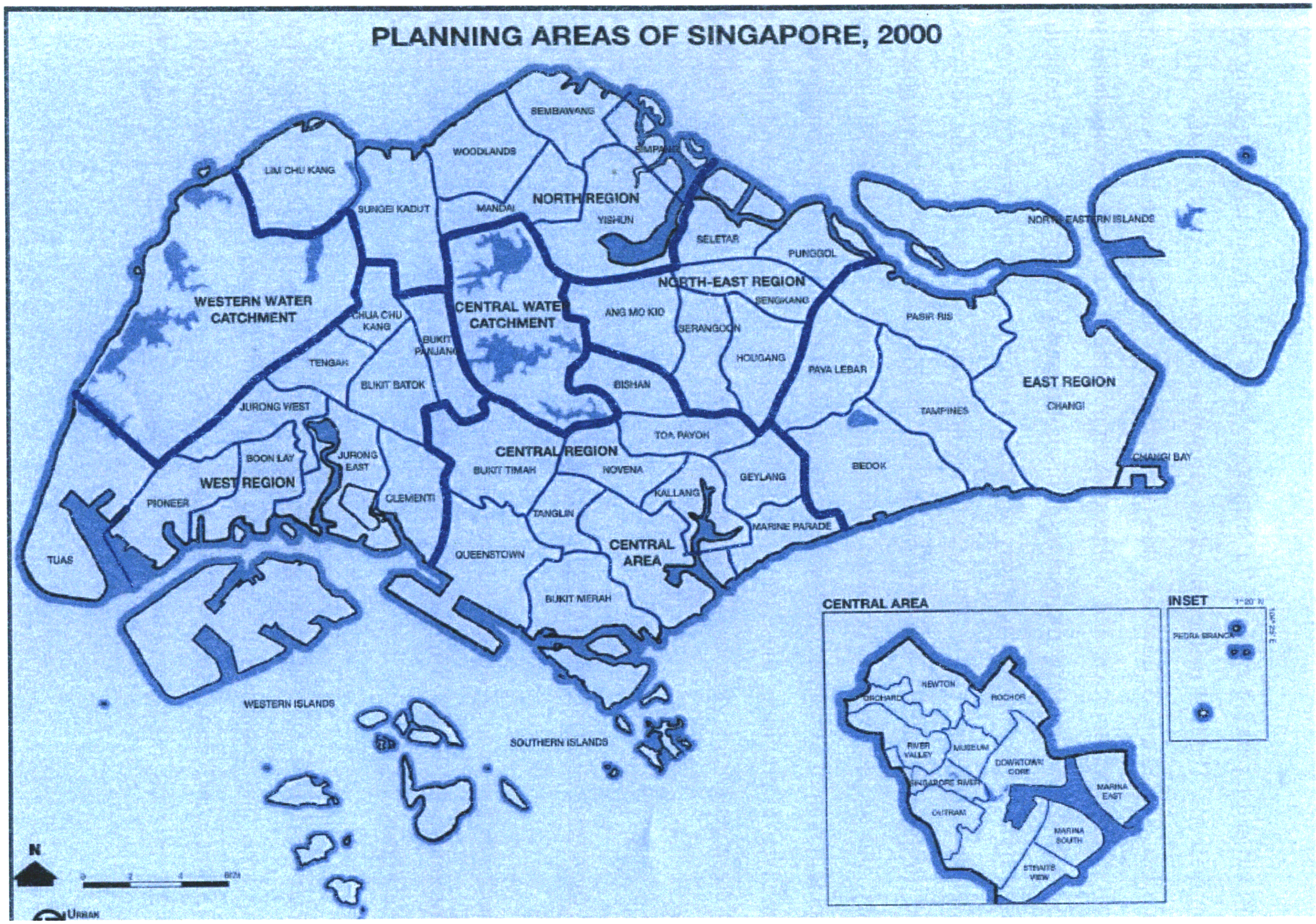

Figure 2.4: Planning Areas of Singapore. Source: Singapore Census of Population 2000.

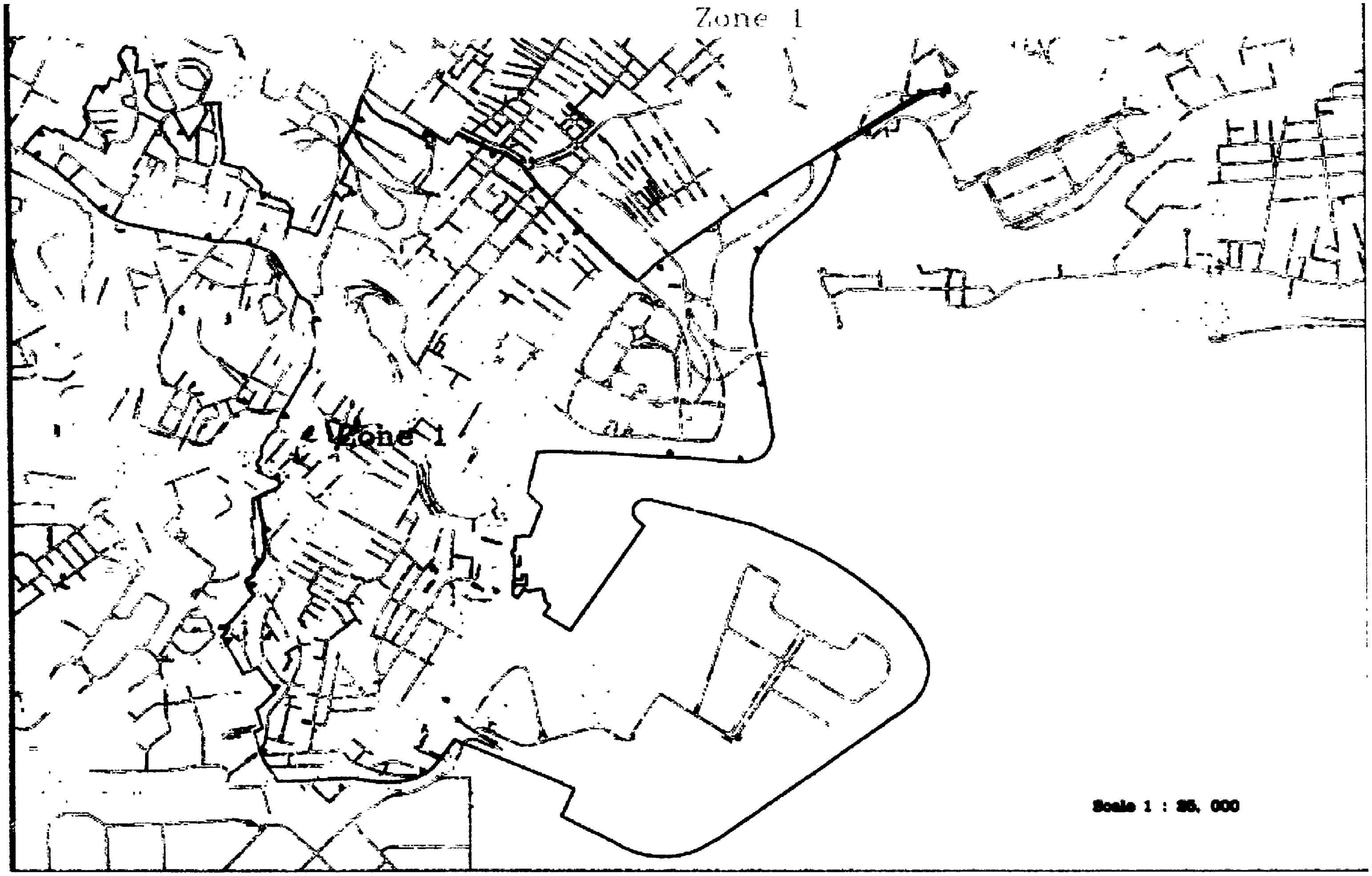

Figure 2.5: The CBD is also referred to as Zone 1 in the LTA parking guidelines. Note that Zone 1 roughly corresponds to the planning areas Outram, Museum, Singapore River, Downtown Core and most of River Valley of "Central Area", as illustrated in **Figure 2.4**. Source: Handbook of Vehicle Parking Provision in Development Proposals. 2005 Edition.

Outside of the CBD, a large part of Singapore's land has been developed into new towns and public housing estates managed by the Housing Development Board (HDB) of Singapore. These towns and estates house 84% of Singapore's population today[27], and their relative locations are as shown in **Figure 2.6**. Not surprisingly, the geographical boundaries of the HDB estates correspond closely with the similarly named planning areas of Singapore. According to the HDB 06/07 Annual Report, the total number of car parking lots within all HDB estates was **552,789**[28].

Figure 2.6: Singapore's HDB Public Housing Towns and Estates. Source: HDB Infoweb Website. www.hdb.gov.sg

There are no published figures for the number of car parking lots provided outside of the CBD and HDB estates, so these will have to be obtained from our own estimations.

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[27] Housing Development Board. HDB Website. http://www.hdb.gov.sg/fi10/fi10296p.nsf/WPDis/About%20UsA%20Brief%20Background%20-%20HDB's%20Beginnings?OpenDocument&SubMenu=A_Brief_Background

[28] Housing Development Board. "HDB Annual Report 06/07."

The LTA publishes guidelines on minimum standards of parking provisions for various kinds of property developments in order to ensure adequate parking supply for Singapore's vehicles. Relevant sections of these are reproduced in **Table 2.25** below.

Property Type	**Parking Provision Requirements**
Residential Properties	1 car space per residential unit
Office Space	Zone 1: 1 car space per 450 sq. m
	Zone 2: 1 car space per 250 sq. m
	Zone 3: 1 car space per 200 sq. m
Shop Space	Zone 1: 1 car space per 400 sq. m
	Zone 2: 1 car space per 200 sq. m
	Zone 3: 1 car space per 150 sq. m
Markets and Food Centers	For 1st 150 Sq. m: All zones: 1 car space per 150 sq.m
	Exceeding 1st 150 sq. m: Zone 1 & 2: 1 car space per 60 sq. m
	Zone 3: 1 car space per 50 sq. m
Factory Space	
Terrace Workshops	About 1 car space per 325 sq. m
Industrial Workshops	1 car space per 600 sq. m
Flatted/Ramp-up Factories	1 car space per 350 sq. m
Canteens/Eating Houses	1 car park per 150 sq. m for 1st 150 sq. m
	1 car park per 50 sq. m exceeding 150 sq. m
Warehouse Space	Nil.
Recreational	
Swimming Complexes	1 car park per 40 sq. m of pool area
Sports Complexes	About 1 car park per 200 sq. m
Indoor Stadiums, Training Halls and Sports Halls	1 car park per 300 sq. m
Town Gardens and Parks	12.7 car parks per hectare
Community Centers/Clubs	1 car park per 200 sq. m

Table 2.25: Summary of LTA's Car Park Provision Standards[29]. Zone 1 refers to areas within the CBD. A figure depicting the boundaries of Zone 1 is as shown in **Figure 2.5**. Zone 2 refers to areas outside of Zone 1 that are within 400m of Rapid Transit Service (RTS) stops. Zone 3 refers to all other areas.

[29] Land Transport Authority. "Handbook on Vehicle Parking Provision in Development Proposals. 2005 Edition."

Using the above information, we can estimate the minimum number of car parking lots that have to be provided in the areas outside of the CBD and the HDB housing estates, provided we know the average land use mixes within these regions.

The Urban Redevelopment Authority (URA) publishes statistics on aggregate land use patterns in Singapore, and the land use statistics as at the end of the 4th quarter, 2007 are as reproduced in **Table 2.26** below.

Property Type	Quantity	Units
Residential Properties		
Public	878,813	Number
Private	234.812	Number
Office Space	6,524	Thousands of Sq metres
Shop Space	3,218	Thousands of Sq metres
Factory Space	28,058	Thousands of Sq metres
Warehouse Space	6,260	Thousands of Sq metres

Table 2.26: Aggregate Land Use Statistics in Singapore at the end of Q4 2007[30].

Unfortunately, there are no comprehensive published details on how these land uses are geographically distributed within Singapore. In order to estimate how much of these developments are located outside the CBD and HDB estates, we first have to estimate the developments *within* the CBD and HDB estates using published data.

According to the LTA, if those parking provision guidelines were followed strictly, the minimum number of parking lots to be provided in the CBD (interchangeably known as Zone 1 in the vehicle parking provision guidelines) in 2007 would be 29,000[31]. This includes parking lots for residential dwelling units within the CBD, as well as for the commercial establishments. From the Census of Population 2000, the total number of occupied dwelling units in the Outram, Museum, Singapore River, Downtown Core, and River Valley planning areas (see **Figure 2.5** for the location of these areas within the 'Central Region') was 17,514[32]. However, this number is for occupied dwellings only,

[30] Singapore Department of Statistics. "Monthly Digest of Statistics, Singapore, March 2008."
[31] Land Transport Authority. "Land Transport Master Plan."
[32] Singapore Department of Statistics. "Census of Population 2000."

and does not include vacant dwellings for which parking lots have to be provided for as well.

To work out the total number of dwelling units for which car parking spaces have to be provided for, we first estimate that the total number of public and private dwelling units available in Singapore in 2000 was 843,656 and 187,899 respectively (average of 1999[33] and 2001[34] figures). Together with the fact that only a total of 964,138[35] out of these 1,031,555 available units were occupied, the average residential dwelling unit occupancy rate for the year 2000 was about 93.5%. If we assume that the same average dwelling unit occupancy applied for the CBD region in 2000, and that the total number of dwelling units in the CBD region was fairly stable through 2007, then the number of parking lots attributable to Office and Shop uses was about 10,261 (29,000 – 17,514/0.9346). Working backwards from the parking provision standards, and assuming that office and shop spaces in Zone 1 require the same ratio throughout the country (about 2.027 unit office space to 1 unit shop space), the Gross Floor Area (GFA) of office and shop spaces in the CBD (Zone 1) was about 2.969 million and 1.465 million square meters respectively, representing a total of 4.434 million square meters of commercial space*. This compares relatively well with the 3.8 million square meters of office and shop space GFA in 2003[36], taking into account strong economic and real estate growth in the 4 years in between. This leaves about 3.555 million square meters of office space and 1.753 million square meters of shop space outside of the CBD. We assume that there is no factory space in the CBD.

To estimate the land use mix in HDB estates, we combine data from the 06/07 HDB annual report, which provides the raw numbers of offices, shops and factories etc with the

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* Although the LTA introduced the Ranged-Based Car Parking Standard (RCPS) in 2005 to allow developers to provide 20% less parking lots than as stipulated in minimum standard in Zones 1 and 2, this measure has obviously not taken flight yet. Strong demand for car parking lots in the CBD has actually resulted in 49,000 parking lots being provided in Zone 1 instead of the 29,000 suggested by the parking standards.

[33] Singapore Department of Statistics. "Yearbook of Statistics Singapore 2005."

[34] Singapore Department of Statistics. "Yearbook of Statistics Singapore 2007."

[35] Singapore Department of Statistics. "Census of Population 2000."

[36] Ministry of National Development. "Large Site Planned for Release Next Year for an Integrated Business and Financial Development in the New Downtown." http://www.ura.gov.sg/pr/text/pr02-48.html

town planning guidelines, which provides the typical sizes of offices and shops in HDB estates, and average factory floor areas from the Jurong Town Council (JTC). The data is as presented in **Table 2.27** below.

Establishments Managed by HDB	Number	Typical Floor Area	Total Floor Area
		(Square Meters)	(Square Meters)
Shops	13,112	100[a]	1,311,200
Kiosks and Shoplets	747	50[a]	37,350
Eating Establishments	842	100[a]	84,200
Supermarkets and Emporiums	150	350[a]	52,500
		Sub-Total	**1,485,250**
Offices	2,129	60	127,740
Industrial			
Terrace Workshops	2,813	325[b]	914,225
Industrial Workshops	4,883	325[b]	1,586,975
Flatted/Ramp-up Factories	2,706	325[c]	879,450
Prototype Factories	201	2,800[d]	562,800
		Sub-Total	**3,943,450**

Table 2.27: Properties Managed by HDB as at 31st Dec 2007.
a-the typical floor area for shops was listed as 30-400m^2. However, most actual retail shops generally belong in the lower range, with kiosks and shoplets being even smaller. The higher ends of the range are generally due to supermarkets and emporiums being counted as 'Shops' as well.
b-average of the range 100-550m^2 provided by the JTC[37].
c-assumed to have the same floor are as typical workshops, in lieu of data
d-average floor size of standard factories built by the JTC[38].

Hence, the total remaining office, shop and factory space in regions outside of the CBD and HDB estates is about 3.427, 0.268, and 24.115 million square meters, respectively. This is in addition to the 234,812 private dwelling units not found in the HDB towns/estates.

Figure 2.7 below shows Singapore's RTS network as at 31st Dec 2007. Comparing this with **Figure 2.6**, we note that there are hardly any RTS stops which do not serve either

[37] Jurong Town Council. JTC Website. http://www.jtc.gov.sg/products/readybuilt/workshops/pages/index.aspx
[38] Jurong Town Council. JTC Website. http://www.jtc.gov.sg/products/readybuilt/lowrise/pages/index.aspx

HDB estates or the CBD. Hence, for the remaining office, shop and factory spaces we had calculated for regions outside of the CBD and HDB estates, we can safely apply the LTA vehicle parking provision guidelines for Zone 3 (see **Table 2.25**). The contribution of parking for recreational facilities is considered comparatively insignificant because most of these are located within the HDB estates.

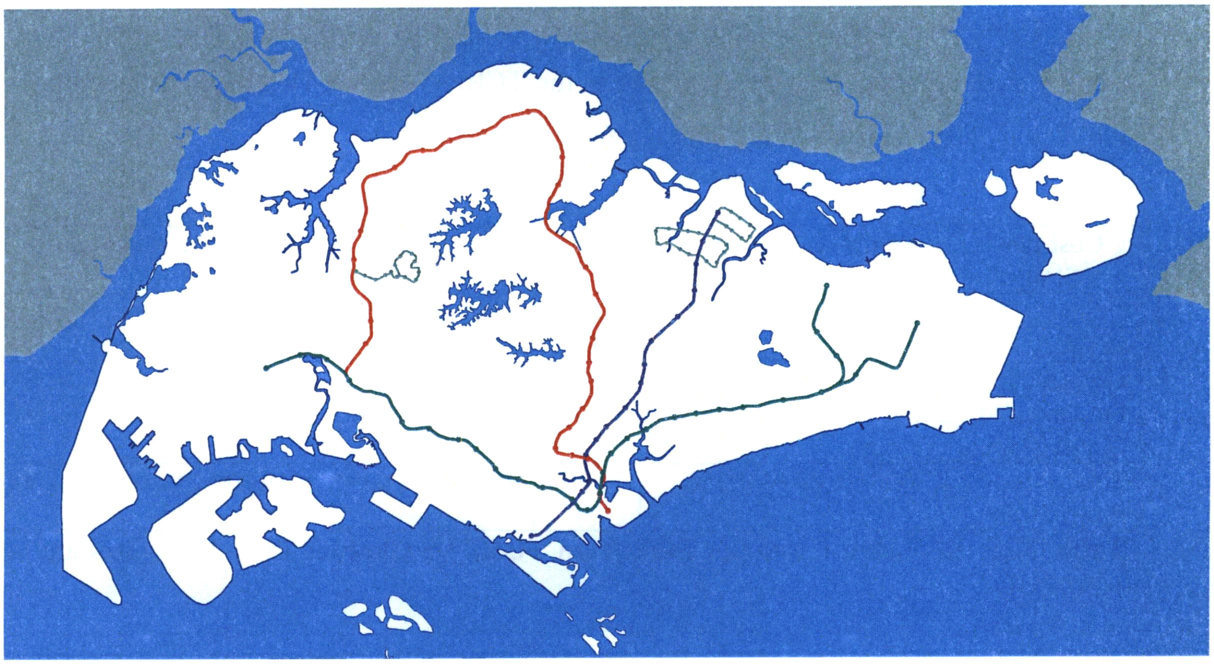

Figure 2.7: Singapore's RTS network. In red is the North-South Mass Rapid Transit (MRT) line, in purple, the North-East MRT Line, in teal, the East-West MRT line, and in grey, the Light Rapid Transit (LRT) lines serving local neighborhoods.

Assuming further that terrace, flatted and industrial factories are in equal proportion, then the minimum total number of car parking lots to be provided in areas outside of the HDB new towns/estates and the CBD is estimated at about **<u>310,475</u>**, 234,812 of which are residential car park lots.

Step 2: Estimating the Cost per Parking Space

In order to estimate the cost incurred to provide each parking space, we draw from two sources: Transit Cooperative Research Program (TCRP) 95 Chapter 18, and from the Victoria Transport Planning Institute (VTPI). Though these figures are based on studies conducted in the United States, they are the best current published sources on parking costs. **Table 2.28** shows the land, construction, design and contingency costs per parking stall by parking structure type published in the TCRP95 report. These figures essentially tell how much it costs to build a parking facility from scratch.

Cost per Stall	Surface Lot ($)			Above-Ground Multi-Level Structure ($)			Below Ground ($)		
	Low	High	Average	Low	High	Average	Low	High	Average
Land	600	12,000	6,300	500	1,000	750	0	0	0
Construction	1,500	4,000	2,750	8,800	20,000	14,400	16,000	40,000	28,000
Design and Contingency	200	800	500	1,800	5,000	3,400	3,200	10,000	6,600
Total Project Cost	2,300	16,800	9.550	12,100	26,000	19,050	19,200	50,000	34,600

Table 2.28: Reported Costs per Stall from TCRP 95 Chapter 15[39]. All figures are in 1997 USD.

To adapt these figures, we will first assume that construction costs and design and contingency costs are roughly the same for the US and Singapore, since both involve a high level of local labor input. We will convert the average costs for these components into equivalent 2007 Singapore dollars by first converting the 1997 USD into 1997 SGD, before inflating it with the Singapore CPI. Land costs, however, will obviously differ between the two countries.

To obtain the average land costs for the CBD area, each individual HDB estate, and for areas outside the CBD and HDB estates, we refer to the vacant land sale records

[39] Transit Cooperative Research Program. "TCRP Report 95 Chapter 18."

published by the URA[40]. These records contain information on the sale of government land plots since 1993, sorted by time, lease length, site area, and development type.

Since the average age of Singapore's car parking lots is likely to be more than 15 years, we need to include cost information for all the years since 1993 to determine the average land value. To do this, we consider only historical sales with lease periods of 99 years, and with sales completed before the end of 2007. All development types were included in our analysis because car park provision is required for almost all land use types. The average per unit land price for each sale was calculated by dividing the successful tender price with the site area, and then inflated to 2007 SGD. Also, each of the 453 sales were manually sorted into the following localities: CBD, any one of the respective HDB estates, and others. The average land values computed from this procedure is as listed in the second column of **Table 2.29** below. The average land prices in HDB estates in which no land sales occurred for the past 15 years was assumed to be the average of all the other HDB estates for which we have data.

Location Zone	Average Land Price (2007 S$) per m^2
CBD	33,083
Ang Mo Kio	2,229
Bedok	21,895
Bishan	31,917
Bukit Batok	8,386
Bukit Merah	33,607
Bukit Panjang	14,453[a]
Bukit Timah	14,453[a]
Central	14,453[a]
Choa Chu Kang	14,453[a]
Clementi	2,713
Geylang	14,970
Hougang	9,282
Jurong East	14,453[a]
Jurong West	12,824
Kallang/Whampoa	13,667
Marine Parade	12,443
Pasir Ris	14,453[a]
Punggol	14,453[a]

[40] Urban Redevelopment Authority. "Vacant Sites Sold since 1993." www.ura.gov.sg/sales/residential/vacantsites.xls

Queenstown	14,453 [a]
Sembawang	10,862
Seng Kang	14,453 [a]
Serangoon	26,389
Tampines	14,453 [a]
Toa Payoh	14,453 [a]
Woodlands	5,112
Yishun	14,453 [a]
Others	10,493

Table 2.29: Average Land Costs in Different Regions of Singapore.
a-HDB Estates for which there was no data.

Based on the Handbook on Vehicle Parking Provision in Development Proposals, the minimum dimensions of a car parking stall are 2.4m wide by 4.8m long. The area of a typical parking lot is thus 11.52m^2. However, if we were to include the areas necessary for corridors, exits, service and HVAC rooms, etc, we assume that the area of a typical parking lot becomes 22 m^2. Using this figure, we can thus easily compute the land costs per parking lot from our figures in **Table 2.29**, depending on whether our parking facility is an above-ground structure or a simple open surface lot. The next logical step would thus be to estimate the proportion of the total number of parking lots within each geographical zone that belong to each parking facility type.

Step 4: Car Parking Lots in the CBD

In order to determine the ratio of surface lots to above-ground-structures and of underground parking structures to street lots in the CBD region, we refer to the online street directory, www.streetdirectory.com, which contains an extensive list of all the car parks in Singapore sorted by districts, and arranged into the following categories: Open Space Public Car Parks (Surface Lot), Street Car Parks, Multi-storey Public Car Parks (Above-Ground Multi Level Structures), Building Public Car Parks (includes underground car parks, but in essence, car parks that are housed within existing structures and do not require their own land), and Season/Authorized Parking. The following districts that make up the CBD were chosen: Beach Road, Boat Quay, Chinatown, City Hall, Clarke Quay, Dhoby Gaut, Mohammed Sultan Road, Orchard Road, Raffles Place, River Valley, Rochor, Somerset and Tanjong Pagar, and the total number of each type of parking facility in these CBD districts was tallied. Parking facilities which were listed as Season/Authorized parking facilities were further individually researched and classified into the 3 former categories. The results of this tabulation are as presented in **Table 2.23** below.

CBD District	Multi-Storey Car Parks (MSCPs) (Number of)	Open Space Car Parks (Number of)	Building / Underground Car Parks (Number of)	Street Car Parks (Number of)
Beach Road	1	8	6	0
Boat Quay	0	0	0	4
Chinatown	1	4	9	8
City Hall	0	9	19	3
Clarke Quay	0	2	12	1
Dhoby Gaut	0	4	8	4
Mohammed Sultan	0	0	4	2
Orchard Road	0	10	24	2
River Valley	0	8	6	5
Raffles Place	0	3	51	10
Rochor	0	1	7	5
Somerset	0	5	13	5
Tanjong Pagar	1	1	8	9
Total	3	55	167	58

Table 2.30: Estimated Number of Parking Facilities by CBD District.

We will proceed to make some further assumptions. Firstly, most of the on-street parking in the CBD are located on the shorter, minor streets, and therefore have lower capacity. For simplicity's sake, we will assume that each side-street parking facility thus has only half the number of parking lots as an open space surface car park. We will also assume that each deck of a multi-storey car park or building/underground has the same capacity as an open space car park and that there is an average of 4 decks for each of these facilities. The land costs for multi-storey car parks and street-side parking are thus about 4 times and half of that of open space car parks respectively. Distributing the 49,000 car park lots in the CBD according to our assumptions, we estimate that there are about 770, 3,527, 42,843 and 1,860 stalls in MSCPs, surface car parks, building/underground car parks and street-side parking respectively.

Using the 2007 Singapore average housing loan interest rate of 5.73% per annum compounded monthly[41] and assuming an average development life span of 26 years[42], the land and development costs for each type of CBD parking stall can be amortized over the 26 year life span, and the developmental costs for CY2007 are about 0.17 times of the total upfront developmental costs.

In addition to the development costs allocated to CY 2007, there are also annual operation and maintenance costs to be included. **Table 2.31** below shows the annual operating costs per parking stall published by the Victoria Transport Policy Institute (VTPI). We will be using 'CBD', 'Urban' and 'Suburban' O & M costs for parking lots in the CBD, HDB estates, and other regions respectively.

Type of Facility	Annual O & M Costs per Stall
Suburban, On-street	$300
Suburban, Surface, Free Land	$300
Suburban, Surface	$300
Suburban, 2-Level Structure	$300
Urban, On-Street	$300
Urban, Surface	$500
Urban, 3-Level Structure	$500
Urban, Underground	$500
CBD, On-Street	$400
CBD, Surface	$400
CBD, 4-Level Structure	$500

Table 2.31: Reported Annual Operation and Maintenance Costs per Stall from VTPI[43]. All figures are in 2004 USD.

Overlaying the O & M costs with the development costs, and bearing in mind that each car parking stall is about $22m^2$ in surface area, our results are for CBD parking stalls are as presented in **Table 2.32**. We will make the further assumption here that the construction and design and contingency costs for street parking lots are negligible, since they are accounted for under road development expenses. The land costs of the street

[41] Monetary Authority of Singapore. "Monthly Statistical Bulletin, May 2008."
[42] Channel News Asia. "Average Age of Developments in Collective Sales is 25.9 Years." http://www.channelnewsasia.com/stories/singaporelocalnews/view/300378/1/.html.
[43] Victoria Transport Policy Institute. "Transportation Cost and Benefit Analysis – Parking Costs."

parking lot, however, have to be taken into account for since these represent an opportunity cost of possible development on the land taken up.

From the Table, we can see that the total cost of providing car parking facilities in the CBD are **S$1.142 billion**.

Cost per Stall (2007 S$)	Surface	Street	MSCP	Building / Underground
Land	727,826	727,826	181,957	0
Construction	4,397	0	23,022	44,765
Design and Contingency	799	0	5,436	10,552
Total Development Cost	733,022	727,826	210,414	55,317
Amortized 2007 Development Cost	124,614	123,730	35,770	9,404
Annual O & M Costs	700	700	875	875
Total 2007 Costs per Stall	125,314	124,430	36,645	10,279
Number of Stalls	3,527	1,860	770	42,843
Total Costs (2007 S$)	441,981,518	231,440,565	28,216,997	440,379,467

Table 2.32: CBD Car Park Stall Costs Calculations. Not surprisingly, the cheapest costs per stall belong to car parks located within buildings, even though construction costs are higher, due largely to the prohibitively high land costs within the CBD. This is also why this form of parking facility is the most popular within the CBD.

Step 5: Car Parking Lots in HDB Estates

In order to determine the ratio of surface lots to above-ground-structures to underground parking structures to street lots in the HBD estates, we utilize the HDB website's car park locator e-service, http://www.hdb.gov.sg/bn22/bn22004p.nsf/SingaporeMap?OpenForm, which provides basic info on car park type and number of decks for all car parks managed by HDB under each HDB estate.

Since the total number of car parking facilities managed by the HDB is too numerous for us to go through manually, we choose a representative HDB town/estate, and assume that the distribution of the types of car parking facilities are the same in the other similarly designed HDB estates as well. The HDB estate that we choose is the Woodlands Estate. It is well served by 3 MRT stations and is far away enough from the CBD to exclude distortionary effects. It also comprises some industrial estates that make it more 'typical'.

In total, of the 120 car park facilities in Woodlands HDB estate that were sifted through, there was 1 building/underground car parking lot (assumed to comprise 4 decks), 84 MSCPs with an average of 11 decks, and 35 surface parking lots. The relative capacities of these however, are slightly different from what we assumed for the CBD. Firstly, the surface parking lots tend to be larger, and secondly, the building/underground car parking lot belongs to a central shopping complex and thus has a very large car parking capacity than do regular office buildings with authorized/season access. As such, we will assume that each deck of a typical MSCP has about 1/3 the capacity of a surface parking lot, and each deck of the building/underground car parking lot has the same capacity of a surface parking lot. The ratio of car parking lots in a typical HDB estate is thus assumed to be 1 building/underground lot to 77 MSCP lots to 21 surface lots.

If we assume that the total number of car parking lots that HDB manages is distributed among all the HDB estates in proportion to the number of dwelling units, then the total number of car parking lots of each type is as tabulated in **Table 2.33** below.

HDB Estate	Number of Dwelling Units	% of Total Dwelling Units	Total Number of Car Parking Lots	Number of Building/ Underground Lots	Number of MSCP Lots	Number of Surface Lots
Ang Mo Kio	48,071	5.47	30,279	306	23,550	6,423
Bedok	58,973	6.71	37,146	375	28,891	7,879
Bishan	19,367	2.20	12,199	123	9,488	2,588
Bukit Batok	31,731	3.61	19,987	202	15,545	4,240
Bukit Merah	49,567	5.64	31,221	315	24,283	6,623
Bukit Panjang	29,498	3.36	18,580	188	14,451	3,941
Bukit Timah	2,423	0.28	1,526	15	1,187	324
Central	10,750	1.22	6,771	68	5,267	1,436
Choa Chu Kang	39,173	4.46	24,674	249	19,191	5,234
Clementi	23,877	2.72	15,040	152	11,698	3,190
Geylang	30,421	3.46	19,162	194	14,903	4,065
Hougang	48,474	5.52	30,533	308	23,748	6,477
Jurong East	22,300	2.54	14,046	142	10,925	2,980
Jurong West	69,222	7.88	43,602	440	33,912	9,249
Kallang/Whampoa	34,291	3.90	21,599	218	16,799	4,582
Marine Parade	7,866	0.90	4,955	50	3,854	1,051
Pasir Ris	27,515	3.13	17,331	175	13,480	3,676
Punggol	16,309	1.86	10,273	104	7,990	2,179
Queenstown	28,873	3.29	18,187	184	14,145	3,858
Sembawang	17,664	2.01	11,126	112	8,654	2,360
Sengkang	39,982	4.55	25,184	254	19,587	5,342
Serangoon	21,293	2.42	13,412	135	10,432	2,845
Tampines	61,484	7.00	38,728	391	30,121	8,215
Toa	35,123	4.00	22,123	223	17,207	4,693
Woodlands	57,953	6.59	36,504	369	28,392	7,743
Yishun	46,613	5.30	29,361	297	22,836	6,228
Total	878,813	100	553,548	5,591	430,537	117,419

Table 2.33: Estimated Parking Lot Distribution within HDB Estates.

Accordingly, keeping the rest of the assumptions the same as in the case for car parking lots in the CBD, we can compute the costs per lot for each parking facility type for each HDB estate, taking into account the estimated average land prices. Our results are as tabulated in **Table 2.34** below.

HDB Estate		Surface	MSCP	Building / Underground
Ang Mo Kio	Total 2007 Costs per Stall (2007 S$)	9,920	7,797	10,279
	Number of Lots	6,423	23,550	306
	Total Cost of Lots (2007 S$)	63,712,930	183,621,213	3,143,793
Bedok	Total 2007 Costs per Stall (2007 S$)	83,471	26,185	10,279
	Number of Lots	7,879	28,891	375
	Total Cost of Lots (2007 S$)	657,702,830	756,510,018	3,856,773
Bishan	Total 2007 Costs per Stall (2007 S$)	120,953	35,555	10,279
	Number of Lots	2,588	9,488	123
	Total Cost of Lots (2007 S$)	312,983,547	337,349,694	1,266,582
Bukit Batok	Total 2007 Costs per Stall (2007 S$)	32,947	13,554	10,279
	Number of Lots	4,240	15,545	202
	Total Cost of Lots (2007 S$)	139,682,455	210,696,713	2,075,174
Bukit Merah	Total 2007 Costs per Stall (2007 S$)	127,273	37,135	10,279
	Number of Lots	6,623	24,283	315
	Total Cost of Lots (2007 S$)	842,895,030	901,768,326	3,241,630
Clementi	Total 2007 Costs per Stall (2007 S$)	11,730	8,250	10,279
	Number of Lots	3,190	11,698	152
	Total Cost of Lots (2007 S$)	37,421,226	96,498,769	1,561,531
Geylang	Total 2007 Costs per Stall (2007 S$)	57,571	19,710	10,279
	Number of Lots	4,065	14,903	194
	Total Cost of Lots (2007 S$)	234,002,763	293,744,643	1,989,502
Hougang	Total 2007 Costs per Stall (2007 S$)	36,298	14,392	10,279
	Number of Lots	6,477	23,748	308
	Total Cost of Lots (2007 S$)	235,090,090	341,766,697	3,170,149
Jurong West	Total 2007 Costs per Stall (2007 S$)	49,545	17,703	10,279
	Number of Lots	9,249	33,912	440
	Total Cost of Lots (2007 S$)	458,234,183	600,360,856	4,527,046
Kallang/ Whampoa	Total 2007 Costs per Stall (2007 S$)	52,698	18,491	10,279
	Number of Lots	4,582	16,799	218
	Total Cost of Lots (2007 S$)	241,443,919	310,646,468	2,242,596
Marine Parade	Total 2007 Costs per Stall (2007 S$)	48,120	17,347	10,279
	Number of Lots	1,051	3,854	50
	Total Cost of Lots (2007 S$)	50,573,572	66,848,849	514,428
Sembawang	Total 2007 Costs per Stall (2007 S$)	42,207	15,869	10,279
	Number of Lots	2,360	8,654	112
	Total Cost of Lots (2007 S$)	99,613,543	137,324,466	1,155,207
Serangoon	Total 2007 Costs per Stall (2007 S$)	100,278	30,387	10,279
	Number of Lots	2,845	10,432	135
	Total Cost of Lots (2007 S$)	285,289,743	316,980,647	1,392,540
Woodlands	Total 2007 Costs per Stall (2007 S$)	20,702	10,493	10,279

	Number of Lots	7,743	28,392	369
	Total Cost of Lots (2007 S$)	160,300,575	297,901,005	3,790,066
Other HDB Estates	Total 2007 Costs per Stall (2007 S$)	55,638	19,226	10,279
	Number of Lots	48,106	176,387	2,291
	Total Cost of Lots (2007 S$)	2,676,471,646	3,391,284,660	23,548,990

Table 2.34: Car Parking Lot Costs for the Year 2007, by HDB Estates.

Altogether, car parking lots in the HDB estates cost **S$14.796 billion** in CY2007.

Step 6: Car Parking Lots Outside CBD and HDB Estates

Outside of HDB estates and the CBD, land area is somewhat cheaper as these are mostly more on the periphery of the island. However, some areas outside of the CBD and HDB estates actually belong to private condominium developments which favor the development of MSCPs to minimize land costs. Hence, we will assume that for these areas, two thirds of the lots belong to surface car park lots and one third of them, to MSCPs. **Table 2.35** below lists the figures for these areas.

Cost per Stall (2007 S$)	Surface	MSCP
Land	230,846	57,712
Construction	4,397	23,022
Design and Contingency	799	5,436
Total Development Cost	236,042	86,169
Amortized 2007 Development Cost	40,127	14,649
Annual O & M Costs	525	525
Total 2007 Costs per Stall	40,652	15,174
Number of Stalls	206,983	103,492
Total Costs (2007 S$)	8,414,299,814	1,570,367,450

Table 2.35: Car Parking Lot Costs for the Year 2007 for Areas outside of CBD and HDB Estates.

From **Table 2.34**, we see that the total car parking lots costs for CY2007 for areas outside of the CBD and HDB estates were **S$9.984 billion**.

Combining our values, the annual cost of car parking provision in Singapore for CY2007 was **S$25.922 billion**.

The reader should be aware of the following figures:

Total number of cars:		514,694
Total number of parking lots in:	CBD	49,000
	HDB Estates	552,789
	Other Areas	310,475
	Total	912,264

Thus, the average annual cost per parking lot is about S$28,415.

The high parking costs can be largely attributable to the very high land prices in Singapore.

The average parking costs per car and per car-kilometer are as shown in **Table 2.36** below.

Parking Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	25.92 billion	25.92 billion
Per Car	50,363.91	50,363.91
Per Car-Kilometer	2.39	2.39

Table 2.36: Average Parking Costs per Car and per Car-Kilometer.

2.3 Summary of Key Findings

In summary, our cost estimates are as tabulated in **Table 2.37** below. It is important to note that all of these estimates are for CY2007, which we then assume to approximate that of FY2006-2007. All of these costs are borne by private actors.

Cost Component	Lower Bound Estimate (2007 million S$)	Upper Bound Estimate (2007 million S$)
COE Rebate Depreciation	894	894
PARF Rebate Depreciation	883	1,040
Actual Body Value Depreciation	1,982	2,203
Registration Fee, GST and Excise Duty	753	753
Financing	695	695
Road Tax	703	703
Insurance	456	514
ERP	60	60
Spare Parts and Maintenance	253	261
Petrol	1,820	1,820
Parking	25,922	25,922
Total	34,422	34,866

Table 2.37: Cost Components of the Economic Costs to Private Actors.

Note that the parking costs form about 73% of all costs of the automobile borne by private actors. In comparison, in his study of the transport costs in London, Kothari found that parking costs constitute about 38% of all costs borne by private actors for FY2004-2005.

The average total cost of each car and car-kilometer are as shown in **Table 2.38** below.

Total Costs	Lower Bound Estimate (2007 S$)	Upper Bound Estimate (2007 S$)
Fleet Total	34.42 billion	34.87 billion
Per Car	66,877.81	67,740.74
Per Car-Kilometer	3.17	3.21

Table 2.38: Average Total Costs per Car and per Car-Kilometer.

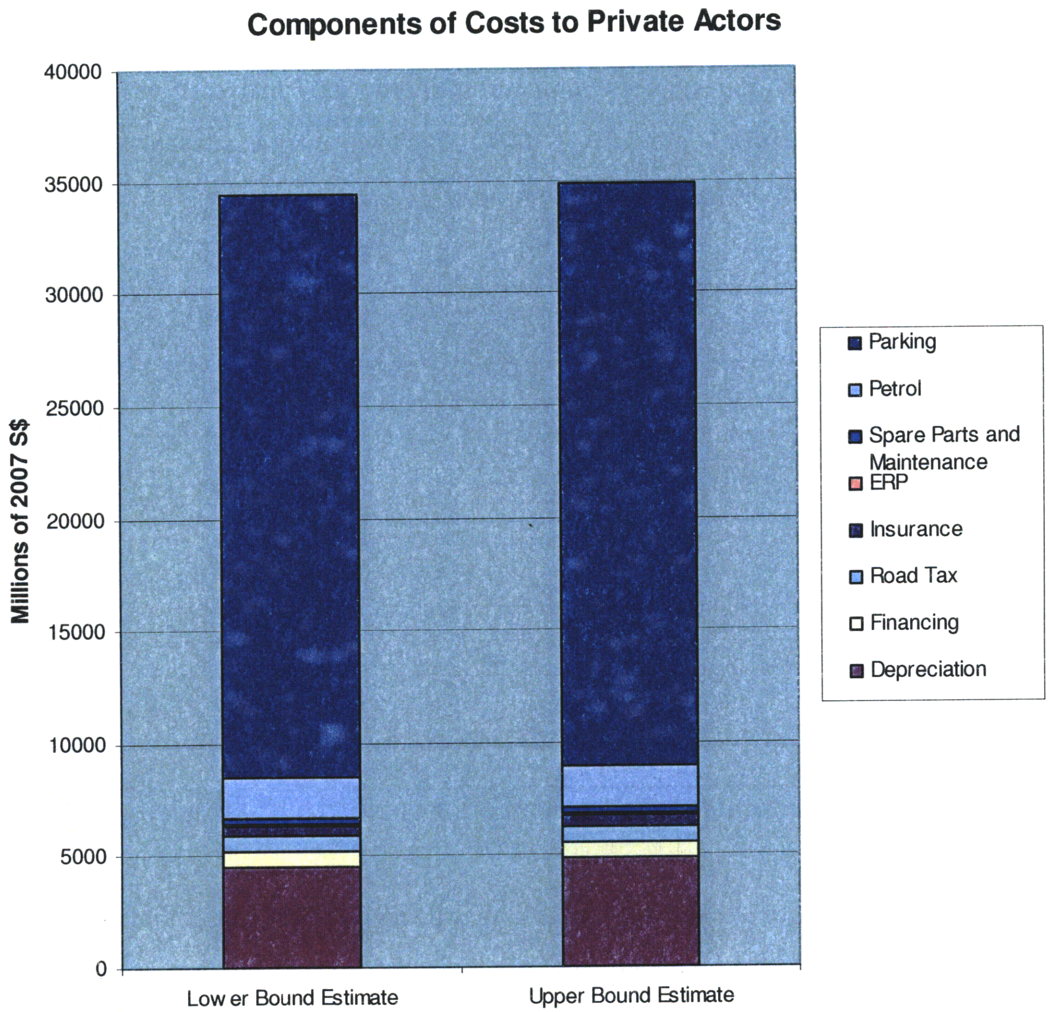

Figure 2.8: Parking costs as the key cost component to private actors in land-scarce Singapore.

3. PUBLIC TRANSPORT – ECONOMIC COSTS TO PUBLIC AND PRIVATE ACTORS

Since we are only interested in the total expenditures on the existing transportation system, we will only consider the yearly operating or running expenditures. We have included the depreciation of current assets as the amortized costs of capital expenditures undertaken in the past.

3.1 Private Actors

Singapore's two main bus and rail public transport operators are SMRT (Singapore Mass Rapid Transit) Corporation Ltd (SMRT) and SBS (Singapore Bus Service) Transit. SMRT operates the North-South and East-West Lines and the Bukit Panjang LRT line, as well as a fleet of 800 buses on 78 route services. SBS Transit operates the Northeast Line, the connecting Seng Kang and Punggol LRT lines, as well as a fleet of 2,830 buses on 234 route services (or about 75% of the scheduled bus market in Singapore). Though majority-owned by Government-Linked Companies such as Temasek Holdings Ltd and DBS Nominees Pte Ltd, both SMRT Corporation Ltd and SBS Transit are publicly listed and are thus considered private companies.

SMRT Corporation

In SMRT's annual report for FY2007, SMRT's operations were segmented into MRT operations, LRT operations, bus operations, taxi operations, rental, advertizing, engineering and other services. Since we are only concerned with expenditures directly associated with transportation, we will include the operating expenditures for MRT, LRT and bus operations only. Data for SMRT's performance is as included in **Table 3.1** below.

SMRT Operation Category	Operating Expenses (2007 S$)	Fare Revenue (2007 S$)
MRT Operations	300.9 million	404.4 million
LRT Operations	9.1 million	8.1 million
Bus Operations	184.8 million	190.4 million

Table 3.1: Direct Operating Expenditure on MRT, LRT and Bus Operations by SMRT[44].

As can be seen from Table, SMRT's fare revenue exceeds their operating expenses for the MRT, LRT and bus segments. In essence, the operating expenses have been passed on entirely to commuters as SMRT's operating expenses is funded solely from fares, without any subsidy from public sources. The total amount spent by Singaporeans through SMRT on public transportation amounts to **$494.8 million**.

For a more detailed look at how the operating expenditures were allocated, we refer to **Tables 3.2** and **3.3**, where relevant sections from different parts of SMRT's annual report are reproduced.

SMRT Operating Outlays (All Operations)	FY2007 S$m
Staff and Related Costs	263.1
Depreciation of property, plant and equipment	132
Amortisation of asset-related grant	-22.3
Repair and Maintenance costs	60.5
Electricity and diesel costs	75.9
Other Operating Expenses	116.4
Total Operating Expenses	625.6

Table 3.2: SMRT Operating Expenses for all Segments, Including Bus, Rail, Taxi, Rental, Advertising, Engineering, and Others[45].

	MRT (S$'000)	LRT (S$'000)	Bus (S$'000)
Operating Expenses	237,474	8,934	167,530
Depreciation, impairment losses and amortization	63,428	86	17,567

Table 3.3: SMRT Breakdown of Operating Costs for MRT, LRT and Bus Services[45].

[44] SMRT Corporation Ltd. "Annual Report 2007."

Disregarding the 'amortization of asset-related grant' (this is not a direct expense) and 'depreciation' (we have more detailed information for this in **Table 3.3**) items in **Table 3.2**, we will assume the 'operating expenses' in **Table 3.3** are distributed according to the same proportions as the remaining items in **Table 3.2**, so that the estimated distribution of operating expenditure for MRT, LRT and Bus operations are as according to **Table 3.4**.

SMRT Operating Outlays (MRT, LRT, Bus only)	MRT (S$m)	LRT (S$m)	Bus (S$m)	Total (S$m)
Staff and Related Costs	121.1	4.6	85.4	211.1
Depreciation of property, plant and equipment*	63.4	0.1	17.6	81.1
Repair and Maintenance costs	27.8	1.0	19.6	48.5
Electricity and diesel costs	34.9	1.3	24.6	60.9
Other Operating Expenses	53.6	2.0	37.8	93.4
Total Operating Expenses	300.9	9.0	185.1	495.0

Table 3.4: Estimated breakdown of Operating Costs for MRT, LRT and Bus Operations for SMRT.

*Minor discrepancies in total figures with **Table 3.1** exist due to figure rounding.

*Delving further into the report, on pages 126-127, a further breakdown of the components of depreciation is given. Of the depreciation costs borne by the MRT and LRT operations, S$42.34 million is due to depreciations in rolling stock, while the remainder is due to depreciation in fare collecting systems, plants and machinery, power generating equipment, computers, leasehold properties, etc. We are unable to breakdown the proportions of the latter few components further due to the aggregate nature of the information published. Similarly, the depreciation costs borne by bus operations, includes S$9.91 million ~~is~~ due to depreciations in buses, while the remainder is split among fare collecting systems, leasehold properties, computers etc.

SBS Transit

From their 2007 Annual Report, SBS Transit's operating expenses for bus operations were S$507.9 million, while their operating expenses for rail operations were S$78.1 million. Once again, rental and advertising revenue or expenses were not included. This meant that a total of **S$586 million** was spent on bus and rail operations. If we discount the S$30 million in revenue from advertising, farebox revenue was still about S$640 million, which clearly exceeds the operating expenses. Hence, like SMRT, the operating expenses have been passed on entirely to commuters and SBS Transit's funds for expenditure comes solely from private actors, without any subsidy from public sources.

The second column of **Table 3.5** below shows the breakdown of the SBS Transit's operating expenses, as reproduced from its 2007 Annual Report. In order to estimate the rough breakdown according to these categories for the bus, rail and other segments, we first assume that the 'Others' category is composed largely of rental and advertising expenditures, and these will have negligible 'Repairs and Maintenance', 'Energy and Fuel Costs', 'Premises Cost' (since most of premise costs go to the leasing of sprawling bus depots and rail stations for bus and rail operations), and 'Depreciation Expense' (since negligible capital equipment is required for rental and advertising). The costs in these aforementioned categories are thus split proportionately between bus and rail operations, according to the total stated operating expenses for these two segments, which were stated as S$507.9 million and 78.1 million respectively. The operating expenses for operations other than bus and rail will thus be composed entirely of 'Staff Costs' and 'Other Operating Expenses'. These are then distributed proportionately according to the ratio of the 'Staff Costs' and 'Other Operating Expenses' for all operating segments, which were stated as S$280.8 million and S$53.77 million respectively. The remainder of 'Staff Costs' and 'Other Operating Expenses' applicable to bus and rail operations will finally be distributed~~,~~ according to the ratio of the total operating expenses of these two segments, which are, again, S$507.9 million and 78.1 million respectively. The results of this methodology are as illustrated in **Table 3.5**.

	All Operating Segments[a]	Bus[b]	Rail[b]	Others[b]
Operating Expenditure Category	S$'000	S$'000	S$'000	S$'000
Staff Costs	280,819	221,070	33,994	25,755
Repairs and Maintenance	91,097	78,956	12,141	0
Energy and Fuel Costs	129,005	111,812	17,193	0
Premises Cost	27,393	23,742	3,651	0
Depreciation Expense	34,605	29,993	4,612	0
Other Operating Expenses	53,767	42,327	6,509	4,931
Total Operating Expenses	616,686	507,900	78,100	30,686

Table 3.5: Breakdown of SBS Transit Operating Expenditure into Categories[45].
a-as reproduced from the 2007 Annual Report for all operating segments.
b-our own estimates, using assumptions as stated before.

As with the case for SMRT, the $34.6 million 'Depreciation Expense' can be further broken down into smaller components given the availability of information in the Annual Report. The components of the total depreciation expense are as tabulated in **Table 3.6** below.

Depreciation Components	Millions of 2007 S$
Buses	17.6
Leasehold Land	0.59
Leasehold Buildings	2.64
Computers and Automated Equipment	11.6
Workshop Machinery, Tools and Equipment	0.99
Motor Vehicles	0.13
Furniture, Fittings and Equipment	1.04
Total	34.59*

Table 3.6: Depreciation Expense Components. All components attributable to bus and rail operations only.
*Slight discrepancy with total from **Table 3.5** due to rounding.

[45] SBS Transit Ltd. "Annual Report 2007."

3.2 Public Actors

The Ministry of Transport (MOT) oversees the development and regulation of the land transport sector, in addition to the civil aviation and maritime transport sectors. The day-to-day operations and regulatory works, however, are carried out by the statutory boards under its responsibility. In particular, all land transport developments in Singapore are carried out under the purview of the Land Transport Authority (LTA). In addition to the LTA, the Public Transport Council (PTC) is another board under the MOT established to approve and regulate bus services, public transport fares and ticket payment services. We will begin by analyzing LTA's financial statements for the financial year that ended IN 31st March 2007.

LTA

The LTA is the overall authority responsible for the development and maintenance of transport infrastructure and public roadways in Singapore. It builds the Rapid Transit System (RTS) infrastructure and leases these under licensing agreements to SMRT and SBS for operation, including as well in its leasing package trains and operating equipment. Hence, the LTA bears the depreciation costs that accrue to the public transit infrastructure, as well as some of the trains used in the RTS networks. **Table 3.7** below lists the breakdown of the operating expenditures of LTA for the FY ending on 31st March 2007. Since we are interested in determining the amount spent on private and public transport, and no further breakdown of this information is available in published sources, we will have to make several assumptions:

a. Firstly, we note that almost all depreciation charges in the financial statements refer to public transport infrastructure or equipment. This does not mean that public roadway infrastructure does not suffer from depreciation, but rather, suggests that they are regularly maintained. Since public transport operators are required to upkeep and maintain the infrastructure leased to them, we can assume that none of the 'Maintenance and Upkeep' costs borne by the LTA are spent on the public transport infrastructure, and that all of it is spent maintaining the roadway infrastructure.

b. Secondly, since public transport operators are required to pay their own utility bills for their operations, we can assume that all 'Utilities' costs accrue to the operation of public roadways, for example, the powering of streetlamps, road tunnel ventilation systems, traffic signals etc.

c. All other costs are distributed proportionately according to how much have been determined to be spent on roadways and public transport thus far. These columns are shaded in grey in **Table 3.7**.

Operating Expenditure	Total[46]	Assumed Public Transport Share	Assumed Private Transport Share
	2007 S$'000	2007 S$'000	2007 S$'000
Depreciation of Property, Plant and Equipment	267,324	267,065	259
Land[a]	12,763	12,763	0
Viaducts and Tunnels[a]	28,936	28,936	0
Railway Tracks[a]	5,442	5,442	0
Buildings and Structures[a]	89,727	89,727	0
Train Fleet[a]	28,529	28,529	0
Operating Equipment[a]	88,222	88,222	0
Computers[a]	11,651	11,651	0
Motor Vehicles[a]	347	347	0
Furniture, Fittings and Office Equipment[c]	1,707	1,448	259
Employee Benefits[c]	160,043	135,795	24,248
Maintenance and Upkeep[a]	69,871	0	69,871
Utilities[b]	25,076	0	25,076
Agency Fees[c]	16,287	13,819	2,468
Rental on Operating Leases[c]	6,693	5,679	1,014
Bond Interest*[c]	91,697	77,804	13,893
Loss on Disposal of Property, Plant and Equipment[a]	488	488	0
Board Members' allowances[c]	130	110	20
Information Technology Service Charges[c]	17,526	14,871	2,655
Construction-in-progress Written off[c]	10,331	8,766	1,565
Purchase of Inventories#[c]	16,283	13,816	2,467
Changes in Inventories[c]	691	586	105
Reversal of Inventory Write-Down (net) [c]	-2,138	-1,814	-324
Other[c]	42,753	36,275	6,478
Total Operating Expenditure	723,055	573,261	149,794

Table 3.7: Operating Expenditures on Private and Public Transport Borne by the LTA.

a-Applying assumption a) as aforementioned.

b-Applying assumption b) as aforementioned.

c-Applying assumption c) as aforementioned.

*- LTA issues public bonds some years to raise capital for the financing of projects.

#-Inventory includes in-vehicle units to be installed in all private automobiles for ERP purposes, as well as EZ-link stored value tickets for public transport.

[46] Land Transport Authority. "The Choices We Make - Annual Report FY06/07."

From **Table 3.7**, we estimate that roughly **S$573.3 million** and **S$149.8 million** were spent on public transport and private transport respectively.

In the earlier sections of this chapter, we determined that all of SMRT's and SBS's operating expenditure came from private actors. To estimate how much of LTA's operating expenditure came from private actors, we take a look at the LTA's operating income as stated in their financial report, which is as reproduced in **Table 3.8** below.

Operating Income	**Total**	**Remarks**
	2007 S$'000	
Management Fees from Government	266,283	Public
Vehicle Transit Licensing Fees	37,717	Private. Already Counted
Composition Fines	21,583	Private
New Motor Vehicle Registration Fees	20,311	Private. Already Counted
Rapid Transit System Lease and Licensing Fees	5,734	Private. Already Counted
Administration Fees	8,389	Private
Advertising License Fees	17,165	Private
Others	11,897	Assumed Private
Total	389,079	

Table 3.8: LTA Operating Income for FY ending 31st March 2007[47]. Note that vehicle transit licensing fees and RTS lease and licensing fees are paid for by the public transport operators. Similarly, the new motor vehicle registration fees have also been included in our costs estimates for the private automobile in Chapter 1. Hence, in calculating the total amount spent by private actors, we have to be careful to exclude these components so as to avoid double counting (see **Table 3.9**).

Note that a simple comparison of **Tables 3.7** and 3.**8** show that LTA had an operating deficit of about S$333.98 million. However, this operating deficit was offset by further governmental grants. In the fiscal year ending on 31st March 2007, a total of S$364.05 million in government grants was provided to the LTA, the bulk of which were in the form of deferred capital grants amortized to offset the huge depreciation costs of the public transit infrastructure. Taking into account the additional government grants, LTA actually ended up with a surplus for FY2007. However, since we are only interested in what was actually spent, S$333.98 million in additional public funds was provided to LTA above the operating income stated in **Table 3.8**.

[47] LTA 2007 Financial Statement

In summary, of the S$723.06 million of operating expenses incurred by the LTA, roughly **S$573.3 million** and **S$149.8 million** were spent on public transport and private transport respectively. **S$596.26 million** of this came from public actors, while **S$126.80 million** of this came from private actors (some of which will have to be discounted to avoid double-counting later). We will also assume that all revenue that comes from the private transport system is spent first on private transport, and the remaining shortfall in operating expenditure is topped up by public funds.

PTC

For the fiscal year ending on 31st March 2007, the Public Transport Council received a total of S$699,505 in government grants and spent a total of **S$700,763**, all of which is for public transport[48].

MOT HQ

For the Budget for FY2008, MOT and PTC together were supposed to receive S$26.76 million to cover their running costs[49]. If we assume that this figure is roughly stable for FY that ended on 31st March 2007, then MOT HQ received about S$26.06 million from Government funds. However, since MOT HQ oversees air and sea transportation in addition to land transportation, we will assume that roughly a third of this figure, or about S$8.69 million, was attributed to land transport. Further assuming this expenditure was split equally among public and private transport, each of these sectors received an expenditure of **S$4.34 million** from public actors.

[48] PTC annual report 2006/2007
[49] Ministry of Transport Expenditure

3.3 Summary of Key Findings

Table 3.9 below lists the main actors and their contributions to expenditures on public and private transport respectively.

	Public Transport (Millions of 2007 S$)		Private Transport (Millions of 2007 S$)	
Actor	Funds from Public Actors	Funds from Private Actors	Funds from Public Actors	Funds from Private Actors
SMRT		494.8		
SBS Transit		586		
LTA	573.3		23	126.8
PTC	0.7			
MOT HQ	4.34		4.34	
Automobile Private Actors				34,421.61
Duplicated Items				
LTA Vehicle Transit Licensing Fees		-37.72		
LTA Motor Vehicle Registration Fees				-20.31
LTA RTS Lease and Licensing Fee		-5.73		
Total	578.34	1,080.80	27.34	34,548.41

Table 3.9: Main Actors and Their Contributions to Public and Private Transport. Here, the lower bound estimates for private automobile transport costs are used.

Figure 3.1 overleaf shows the sharp contrast between expenditures on private and public transport in Singapore for FY2006-2007.

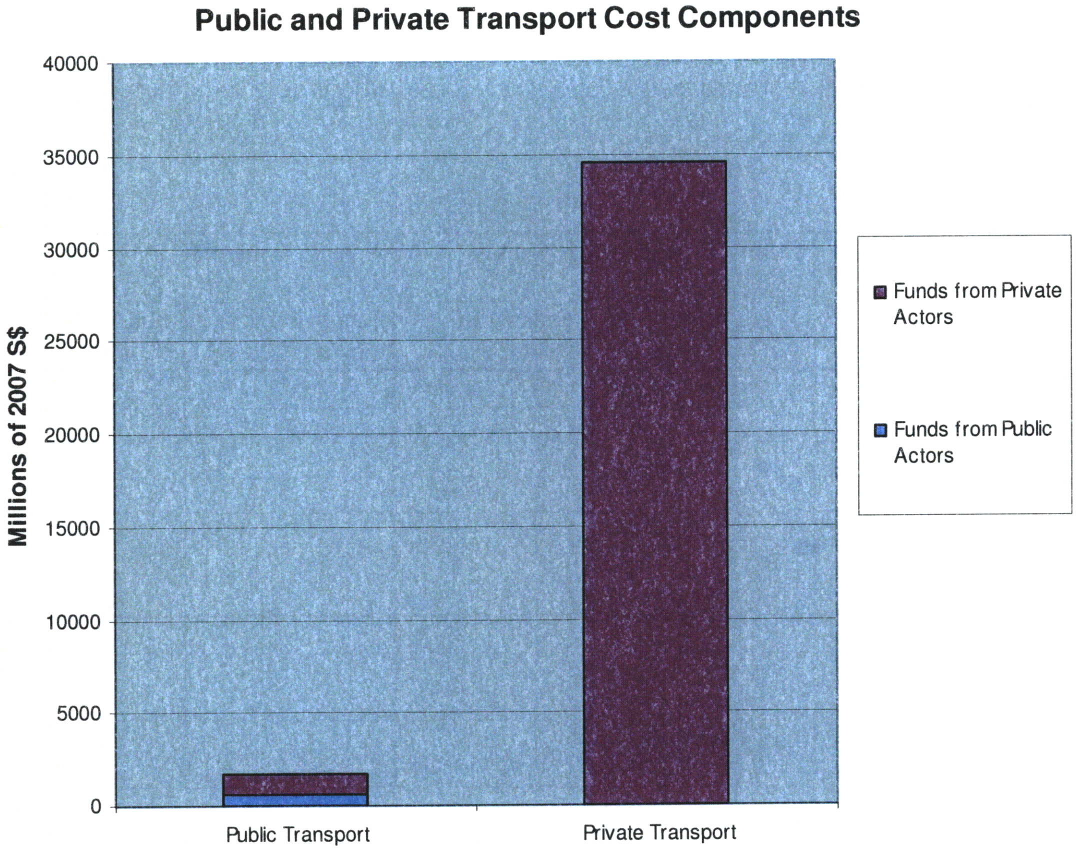

Figure 3.1: The Contrast between Expenditures on Public and Private Transport in Singapore. The disparity in expenditures is noteworthy because in 2004, as much as 64% of all morning peak hour trips were made by public transport[50]. Yet, the aggregated economic cost of private transport is more than 20 times that of public transport. Almost all funds for private transport came from private actors.

We can ascribe an aggregated economic cost per trip and cost per distance borne by society for each public or private transport journey taken. Based on LTA's Statistics in Brief 2007, in CY2006, an average of 1.435 million MRT trips, 0.075 million LRT trips and 2.853 million bus trips were taken daily[51]. Dividing the S$1.66 billion spent on public transport by the total number of public transport trips, the average cost per public transport trip for FY2006-2007 was roughly **S$1.042/trip**. The average trip distance traveled on the MRT and buses was 11.3 and 5.3 km/passenger-trip respectively[9]. Assuming that the average trip distance on LRT trips was the same as that for buses

[50] Land Transport Authority. "Land Transport Master Plan."
[51] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2007." 2007.

(since it plays more of a feeder role, and it's share of the total public transport market is negligibly low for it to adversely affect our results), the total distance travelled on public transport for the year 2006 was 11.583 billion km. Thus, the cost per distance of public transport trips for FY 2006-2007 was **S$0.143/passenger-km**.

Our cost estimates for private automobile trips apply for CY2007. Hence, we will have to use the private automobile fleet population for CY2007 in order not to overestimate the costs, since the private automobile fleet grew significantly from 472,308 to 514,694 from 2006 to 2007[52]. But since we only have CY2006 data on annual private vehicle mileage, we will assume that this stays constant in 2007 at 21,075 km travelled annually per private automobile. Given that the private automobile's total economic cost to society in CY2007 is S$34.58 billion, the cost per distance of private automobile trips for CY2007 was **S$3.03/vehicle-km**. Assuming further that the average vehicle occupancy for CY2007 remained the same as that for CY2004 at 1.48[53], the cost per distance of private automobile trips for CY2007 was **S$2.05/passenger-km**, or about 14 times as much as that of public transport trips. The essential assumption here is that our cost estimates for CY2007 approximate those for FY2006-2007 closely enough. We could not estimate a cost per trip for the private automobile due to a lack of data on the total number of trips made in 2007 (The latest data available was for 2004).

Table 3.10 below summarizes the cost comparisons between expenditures on public and private transport.

	Public Transport	**Private Transport**
Total Expenditure	S$1.66 Billion	S$34.58 Billion
Total Passenger Miles Travelled	11.583 billion passenger-km	11.42 billion car-km Or 16.90 billion passenger-km
Normalized Cost per Distance	S$0.143 per passenger-km	S$3.03 per car-km Or S$2.05 per passenger-km

Table 3.10: Summary of Cost Comparisons.

[52] Land Transport Authority. "Age Distribution of Motor Vehicles as at 31 December 2007."
[53] MVA Singapore Pte. Ltd. "2004 Household Interview Survey and Stated Preference Survey Final Report."

4. GEOGRAPHIC ANALYSIS AND TIME COSTS

In this chapter, we will take into account the difference in times costs between trips made with public and private transport modes. In order to do this, we make use of self-reported travel time data from the Singapore Household Interview Survey (HIS) and Stated Preference Survey conducted in 2004. This survey involved interviews of 35,000 people in 9,500 Singaporean households (about 1% of Singapore's total population). Interviewees were required to recall details of the last trip they had made, including the mode, fare, waiting time, and actual travelling time of each stage of the journey. The data obtained was then expanded using appropriate factors to reflect the actual household, household composition, and trip make-up representative of the whole Singapore.

4.1 Limiting the Data Set

Since the HIS data includes all types of trips, including non-motorized trips, private chartered bus trips and taxi trips etc, we limit our scope to only trips involving public bus, MRT/LRT and private car driver/passenger modes in at least one leg of the trip.

Within this set, we wish to compare the costs of trips where the main mode is public transport, versus trips where the main mode is private automobile transport. The main mode of all trips containing at least one stage with MRT is defined to be MRT, whilst the main mode of all other trips would be the mode which has the longest stage duration for the entire trip. Limiting our data set to just trips with main modes being either public bus, MRT/LRT, or car driver/passenger, eliminates trips which may involve these modes, but when walking or cycling represent for instance the longest stages of the trip.

We will also only analyze entries within the HIS that have valid postal sectors recorded for both origin and destination. We exclude military facilities in our analysis because the postal codes assigned to them are not necessarily based on geographical location. For example, most military facilities in Singapore have postal codes beginning with "91" or "99", even though "91" and "99" do not refer to any specific geographic location in

Singapore. In fact, two military facilities belonging to postal sector "99" can actually be on opposite ends of the island.

4.2 Developing a Usable Generalized Average Cost Function for Each Mode

In the previous chapter, we obtained a generalized cost estimate for public and private transport per passenger-kilometer travelled. This generalized cost includes all economic costs that are normally hidden, and hence omitted from previous studies. With the per passenger-kilometer costs, we can, in theory, calculate the full economic cost associated with each trip made with public or private transport modes, provided we know the distance travelled for each trip. Unfortunately, trip distance is not recorded in the HIS. Since we do not have access to a network model, it would be difficult for us to derive the distances for each trip and hence work out a full economic cost for each trip recorded in the HIS.

We can circumvent this problem, however, by making a key assumption. It can be argued that if the highly variable wait time for public transport in each trip is excluded, the in-vehicle phases of bus and train journeys actually occur at relatively constant average speeds. For example, during off-peak periods, the capacity of the public transport system is reduced due to the increase in headways, and not through the deliberate reduction in travel speeds of the operating vehicles. If we assume a relatively constant average operating speed for public buses and a relatively constant average operating speed for the RTS, we can translate our generalized cost per passenger-km into a generalized cost per in-vehicle passenger-hour for each of these modes. This will be useful for our purposes because the HIS data splits the time duration of each leg of each trip into the waiting and in-vehicle components.

According to statistics published by the LTA, the average trip distances for MRT and bus trips were 11.5 and 5.2 passenger-km respectively, while the average daily ridership for MRT, LRT, and Bus were 1,276,000, 57,000 and 2,788,000 respectively[54]. Assuming that

[54] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2006."

the average trip distance for each LRT trip was the same as that for bus trips, then the total passenger-kilometers travelled on a typical day on the MRT, LRT and bus systems were 14.674, 0.2964, and 14.4976 million respectively. From the HIS data, the total number of passenger-hours spent on each of these systems on a typical day were 527,576 hours, 13,839 hours, and 1,024,700 hours respectively. Thus, the average in-vehicle speed for the MRT, LRT and bus systems in 2004 were <u>27.81 km/h</u>, <u>21.42 km/h</u> and <u>14.15 km/h</u> respectively.

Our results above show that travelling on the MRT is almost twice as fast as travelling on the public bus. Hence, it is crucial for us to derive separate generalized costs per in-vehicle passenger-hours for each main public transport mode. To do this, we have to refer back to our data and estimates in **Chapter 3**, and estimate the total economic expenditures spent individually on the bus and rail systems. For simplification's sake, we note that the average daily ridership on the LRT in 2004 is less than 4.5% of that of the MRT. Hence, we will assume that the generalized economic cost for the LRT to be the same as that of the MRT, since it has similar infrastructure needs such as tunnels, viaducts, tracks, and operating systems. The very low relative mode split of the LRT suggests that our end results will not be sensitive to this particular assumption.

From **Chapter 3**, SMRT and SBS Transit spent a total of S$388.1 million and S$692.7 million on rail and bus operations respectively. Since LTA's primary mission of directing strategic growth with key infrastructural developments is essentially biased toward rail operations, we will assume that 90% of LTA's operating expenses on public transport correspond to rail operations and only 10% to bus operations. We will assume that MOT's and PTC's public transport expenditures are similarly split between bus and rail operations. Our end results will not be sensitive to the amounts that MOT and PTC are assumed to spend on each mode, given the very low contribution (less than 0.5%) that these two organizations represent within the public transport scene. Thus, in total, <u>S$906.55 million</u> and <u>S$752.55 million</u> were estimated to be spent on rail and bus operations respectively in FY2006-2007.

As aforementioned in **Chapter 3**, in CY2006, an average of 1.435 million MRT trips, 0.075 million LRT trips and 2.853 million bus trips were taken daily, while the average trip distance traveled on the MRT and buses was 11.3 and 5.3 km/passenger-trip respectively[55]. Assuming that the average trip distance on LRT trips was the same as that for buses, the total distance travelled on rail and bus systems in 2006 was 6.064 billion km and 5.519 billion km respectively. The average cost per passenger-distance travelled was thus S$0.15/passenger-km and S$0.14/passenger-km for rail and bus trips in 2006 respectively. The proximity of the two values obtained makes intuitive sense because even though rail operations command much higher capital investment, they also have a much higher operating capacity per unit of input labor cost. Multiplying our per distance cost estimates with the average speeds that we obtained earlier on in this chapter, the cost per passenger in-vehicle hour is <u>**S$4.16/passenger-hour**</u> and <u>**S$1.93/passenger-hour**</u> for rail and bus trips in CY2006 respectively.

In a similar fashion, we can develop a generalized economic cost per unit of in-vehicle time for private vehicles. From LTA's Statistics in Brief 2006, the average annual distance travelled by private cars in 2004 was 20,298 km, while the total number of private cars was 389,282. Thus, private cars travelled a total of 7.902 billion km in 2004. From the HIS survey, the total in-vehicle time spent by car drivers on an average day was 710,447 hours. Hence, the average in-vehicle speed of private automobiles in 2004 was <u>30.47 km/h</u>. It should be noted, however, that parking costs, which form a key component of the total cost of private automobile usage, should be tallied on a per-trip basis rather than a per-distance or per-time basis. All other components of private automobile costs can be argued to be spread approximately evenly over the distance travelled by the vehicles. Hence, discounting the total parking costs of S$25.92 billion from our total of S$34.58 billion spent on the private automobile in CY2007, the cost per distance of private automobile trips for CY2007 was S$0.80/vehicle-km. Assuming further that in-vehicle average speeds did not change much from 2004 to 2007, then the cost per driver hour was <u>**S$24.31/driver-hour**</u>. Here, we will assume that passengers in private cars are not responsible for any of the economic costs arising from the use of the automobiles.

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[55] Land Transport Authority. "Singapore Land Transport Statistics in Brief, 2007".

This is necessary because the vehicle occupancy rate will differ from trip to trip, and using an averaged cost per passenger-hour for all trips will underestimate the costs for single-occupancy vehicle trips.

Although our economic cost estimates apply for FY2006-2007 or CY2007, we will assume that the derived generalized economic costs do not differ much for the year of the HIS survey, 2004. From the HIS survey, the total number of car-driver trips made daily in 2004 was 1,899,637. If we assume the total parking costs to be spread equally across all trips, then the total parking cost per trip, in addition to the in-vehicle car user hour economic costs, is **S$35.94 per trip**.

Table 4.1 below shows a summary of the figures used in our analysis.

	MRT Trips	**LRT Trips**	**Bus Trips**	**Private Car Trips**
Total Daily Passenger-Kilometers Travelled (2006/2007)	14.674 million	0.296 million	14.498 million	29.72 million
Annual Passenger-Kilometers Travelled (2006/2007)	6.064 billion passenger-km		5.519 billion passenger-km	10.847 billion passenger-km
Total Expenditure (FY2006-2007)	S$906.55 million		S$752.55 million	S$34.58 billion (S$25.9 billion of which is for parking)
Average In-Vehicle Speed (2004)	27.81 km/h	21.42 km/h	14.15 km/h	30.47 km/h
Cost per Passenger In-Vehicle hour	S$4.158 per passenger-hour		S$1.93 per passenger-hour	S$24.3 per driver-hour
Cost per Passenger-Kilometer	S$0.15 per passenger-km		S$0.14 per passenger-km	S$0.80 per passenger-km
Fixed Cost per Trip	S$0		S$0	S$35.90

Table 4.1: Summary of Economic Cost Estimation Parameters.

4.3 Application of In-vehicle Cost Functions to HIS Trips

We apply the average in-vehicle and per trip cost functions to all the trips recorded in the HIS 2004, and do a quick check by summing up the resultant costs totals for all public and private transport trips. Using our generalized cost per unit in-vehicle time functions, the total cost of public transport trips in 2004 was S$1.544 billion, and the cost of all private car transport trips in 2004 was S$31.22 billion. This compares well with our actual estimates for FY2006-2007 (in which all public transport expenses total S$1.659 billion) and our CY2007 estimates (in which all private automobile expenses total S$34.55 billion) The direction and magnitude of the rise in total spending from 2004 for both public and private transport trips seems reasonable given the rise in public transport ridership as well as the increase in private automobile fleet and annual average mileage.

4.4 Application of Time Costs to HIS Trips

We cannot meaningfully compare the economic efficiency of public and private transportation modes if we do not take into account the time savings typically associated with private modes of transport. In general, the monetary value of time (VOT) of commuters is taken to be a certain percentage of their wage rate. Intuitively, the results of our analysis are dependent on what VOT we ascribe to commuters – the higher the value of time, the more economically effective society's expenditure on private transport modes will seem.

A literature review conducted to determine a fair VOT for use in this study reveals the following: Wilson (1988) estimated that the value of travel time in Singapore ranged between 47% - 49% of the wage rate[56]. Png (1994) found that the value of time for private car owners in Singapore was about 67% of the average wage rate[57]. Elsewhere, Hensher (1989) found that the VOT of car commuters in Sydney is about 68% of the

[56] Wilson. "Scheduling Costs and the Value of Travel Time."
[57] Png et al. "Estimation of the Value of Travel Time of Motorists."

wage rate[58]. Kothari (2005), in his comparison of public and private modal costs in Greater London, used a VOT of two-thirds of the UK national average wage rate for all travelling commuters[59]. Given the somewhat diverse range of VOT with respect to wage rate, we conducted our analysis twice – once assuming that the VOT was 45% of the wage rate of each travelling commuter, and once assuming that it was 70% of the wage rate.

It is essential to note, however, that while some of these past studies tend to ascribe a uniform VOT to *all* travelling commuters, the reality remains that private automobile users tend to have higher wages and correspondingly higher VOT than do public transport users, especially in Singapore where car ownership costs are high. It would be difficult to convince private motorists that switching to public transport is rational if we constantly underestimate their VOT by assuming it to be the same as the nationwide average. Hence, as aforementioned, we have been careful to calculate a separate VOT for each travelling commuter in the HIS based on his/her self-reported monthly income (we further assume that the average number of working hours in a month was 150). It is crucial to note that for this segment of our research, we have chosen to use the VOTs of the individual commuters simply to explain observed behavior, and not to imply that policy should differentiate among citizens based on their income. A uniform VOT would be more appropriate for our direct comparisons for the purposes of policy recommendations, as will be elaborated in **Section 4.6**.

When calculating the time cost for any single trip, we simply multiply the VOT by the trip duration. We argue that this is valid for our purposes since the total trip durations of all recorded trips in the HIS are as perceived by the interviewees, given the self-reported nature of the survey. Thus, even though it is true that commuters perceive waiting time and in-vehicle times differently, they report what they recall and perceive the previous day's trips in such a way that any difference between wait times and in-vehicles times may be masked. For example, the actual time spent waiting for the train might be only 5

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[58] Hensher. "Behavioral and Resource Values of Travel Time Savings: a Bicentennial Update.".
[59] Kothari. "A Comparative Financial Analysis of the Automobile and Public Transportation in London."

minutes, but since the commuter perceives wait times as being longer than in-vehicle time, he reports a perceived waiting time of 10 minutes relative to in-vehicle waiting time, essentially expressing his wait time in in-vehicle time units. Hence, we can assume that the entire trip, including waiting, walking and in-vehicle phases, is basically reported in the same perceived in-vehicle time units and can be simply added so that the time cost of the entire trip is simply the entire perceived trip duration multiplied by the VOT we ascribe.

4.5 Aggregate Results of Survey Processing

Applying our generalized in-vehicle cost functions as described in **Sections 4.2** and **4.3** and applying our VOT calculations as described in **Section 4.4**, we obtain respectively the economic and time costs associated with each trip recorded in the HIS. Summing up the total costs of all trips for public and private transport within our refined dataset, our results are as shown in **Table 4.1** below. Note that the total economic costs of all trips are only about two-thirds of that mentioned in **Section 4.3**. This is because the figures below only pertain to trips which satisfy our dataset-refining criteria described in **Section 4.1**.

	Public Transport as Main Mode	Private Transport as Main Mode
Daily Trips	S$	S$
total monthly wages of users	2,824,999,613	5,024,082,185
average monthly wages of users	997.29	2,483.83
Total duration of all trips	2,053,371	736,406
Average trip duration of all trips	0.72	0.36
total no. of daily trips	2,832,683	2,022,712
Total economic costs of all trips	3,407,777	57,922,856
Average economic costs of all trips	1.20	28.64
Total time cost of all trips (VOT=45% wage rate)	6,724,502	5,940,926
Average time cost of all trips (VOT=45% wage rate)	2.37	2.94
Total time cost of all trips (VOT=70% wage rate)	10,460,336	9,241,440
Average time cost of all trips (VOT=70% wage rate)	3.69	4.57
Total cost of all trips (VOT = 45% wage rate)	10,132,279	63,863,782
Average total cost of all trips (VOT=45% wage rate)	3.58	31.58
Total cost of all trips (VOT = 70% wage rate)	13,868,113	67,164,296
Average total cost of all trips (VOT=70%)	4.90	33.21

Table 4.2: Aggregate and Average Costs for Public and Private Transport Daily Trips which are in the Desired Range of Our Dataset. Note that the average wages of private transport users is indeed more than twice as high as that of public transport users. As such, even though the average trip duration of trips with private transport as the main mode is only about half that of trips with public transport as the main mode, the average time costs to private transport users is almost as high in absolute terms.

Figure 4.1 below shows the relative contributions of time and economic costs to the total average costs of trips with public and private modes as the main modes, respectively.

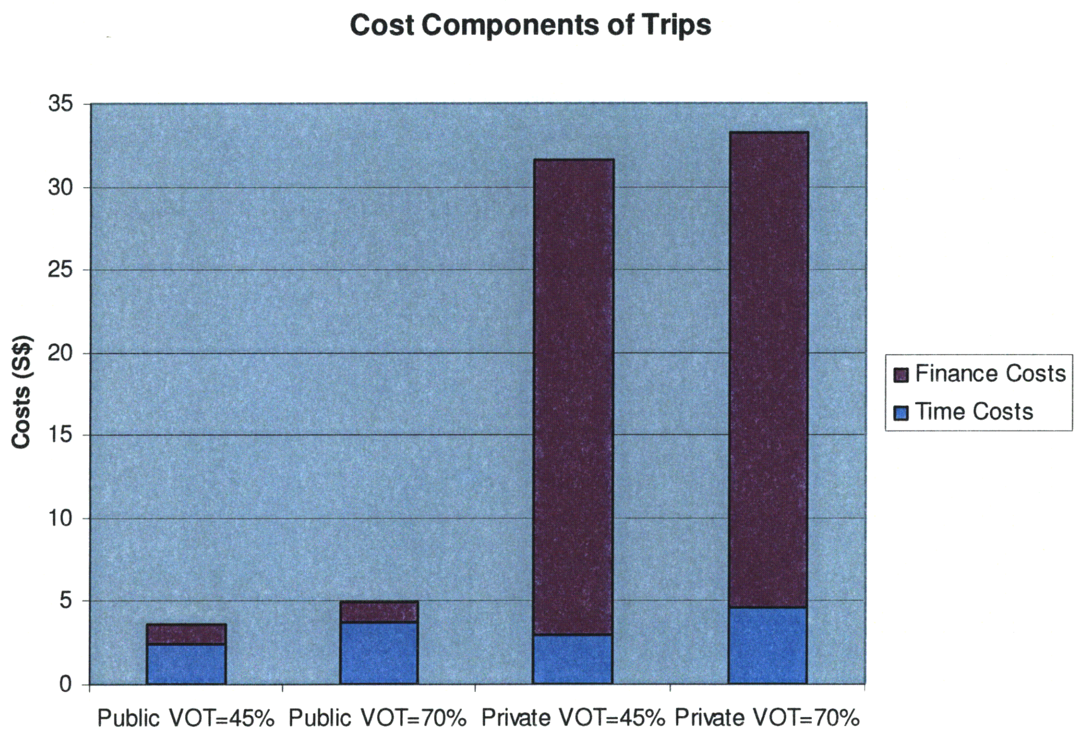

Figure 4.1: Cost Components of Trips with Either Public or Private Modes as the Main Mode. Note that the average absolute time costs of private transport trips were almost similar to that of public transport trips, even though the average trip duration of private transport modes was much lower, due to the general higher wages of private transport users.

4.6 Spatial Disaggregate Analysis of HIS Data: Postal Sector to Postal Sector

In this section, we focus our investigation on the 'economic efficiency' of public and private transport modes in Singapore. More specifically, we are interested in finding out how public transportation measures up against private car transportation in trips made to and from various geographic sectors of Singapore.

Singapore is divided geographically into 82 postal sectors in 28 postal districts. In order to obtain a good comparison of private and public transport modes in bringing people from a suitably disaggregated origin-destination level, we will analyze the public and private transport costs from postal sector to postal sector as recorded in the HIS survey. Such an analysis at a sufficiently small zonal level is necessary because the level of service for public transportation can vary quite substantially even within a chosen sector if its size is too large. There are thus 6,724 possible origin-destination pairs, though not all possible pairs had recorded trips made between them.

Figure 4.2 shows the geographic distribution of the postal sectors in Singapore, while **Figures 4.3** thru **4.6** show visual representations of the desire lines for daily public and private transport trips.

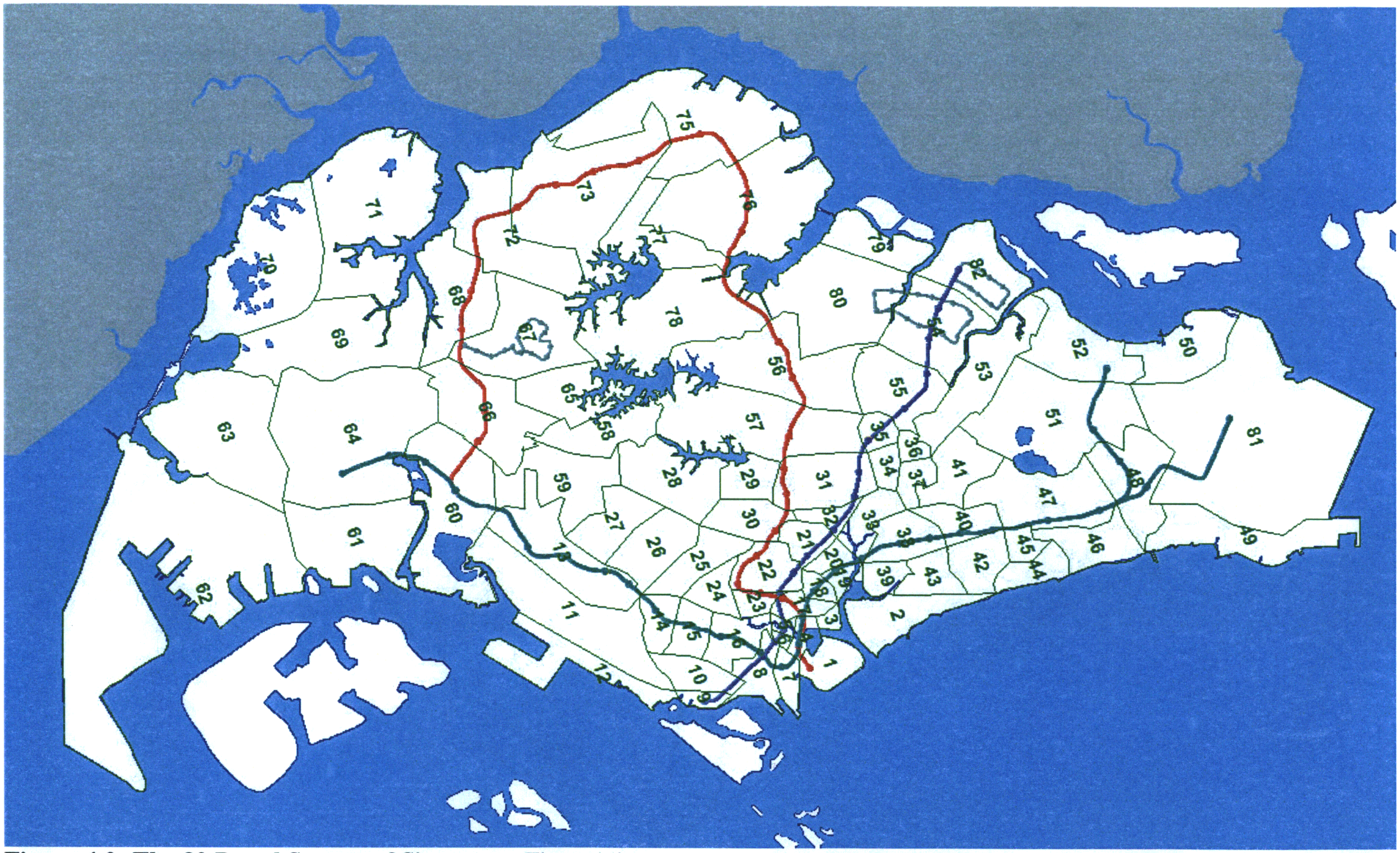

Figure 4.2: The 82 Postal Sectors of Singapore. The red line represents the North-South MRT line. The teal line represents the East-West MRT line. The purple line represents the North-East MRT line and the dark green lines represent the LRT lines.

Figure 4.3: Daily Trips with MRT/LRT or Bus as Main Modes. Zonal combinations with less than 1,500 daily trips are not shown to reduce clutter. We can see that many daily trips are made to and from the CBD region. This is manifested in many finer bands rather than a handful of thick bands because the CBD region is divided into many postal sectors that are much smaller in size, thus in essence creating multiple destinations within the CBD and disaggregating the bands. We also see many short-distance trips made between regional employment and population centers outside of the CBD.

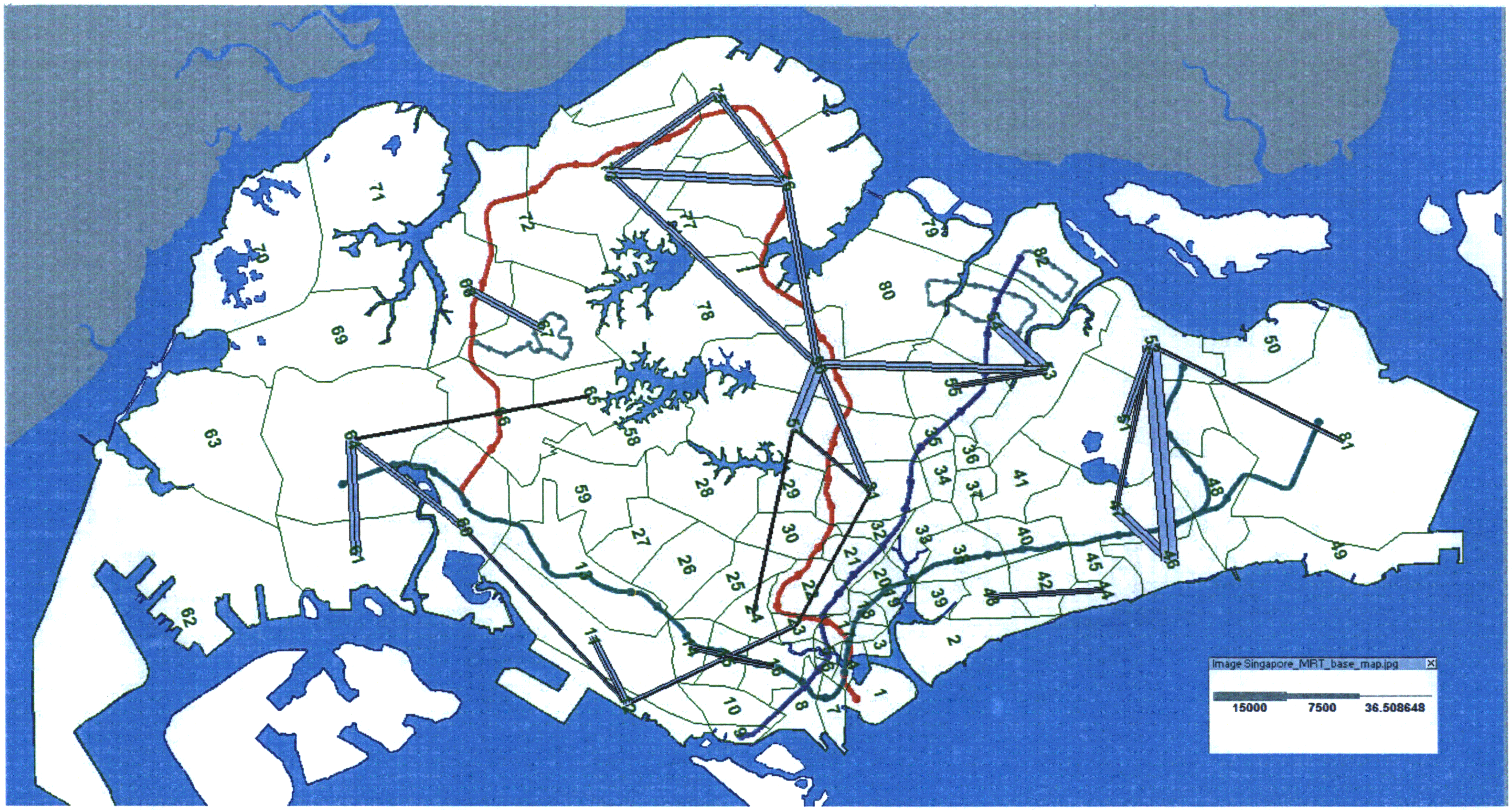

Figure 4.4: Daily Trips with MRT/LRT or Bus as Main Modes. Zonal combinations with less than 5,000 daily trips are not shown to further distill the image presented in **Figure 4.3**. This image shows once again that many public transport trips are made amongst town centers in the north (between Woodlands, Admiralty, Yishun, Bishan, Ang Mo Kio and Toa Payoh), West (within the Jurong residential and industrial estates), and eastern (between Bedok and the Loyang Industrial Estate) regions.

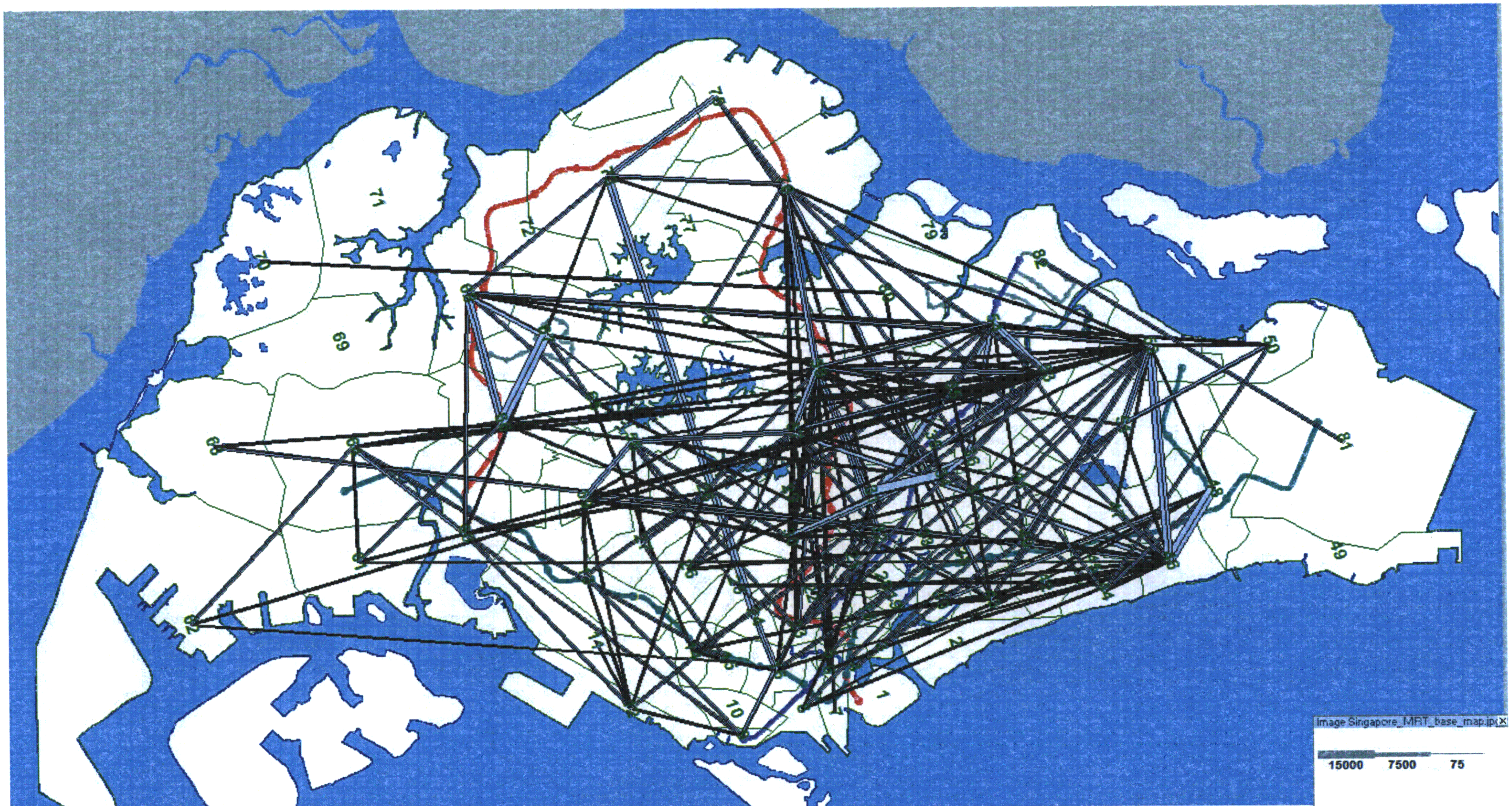

Figure 4.5: Daily Trips with Car Driver or Car Passenger as Main Modes. Zonal combinations with less than 1,500 daily trips are not shown to reduce clutter. Car trips to and from the CBD region seem to originate and end more from the eastern regions than the western and northern regions. We also see more long distance cross-island journeys for private modes than we saw for public transport trips. Journeys into the CBD region via car modes also seem significantly less than that via public modes.

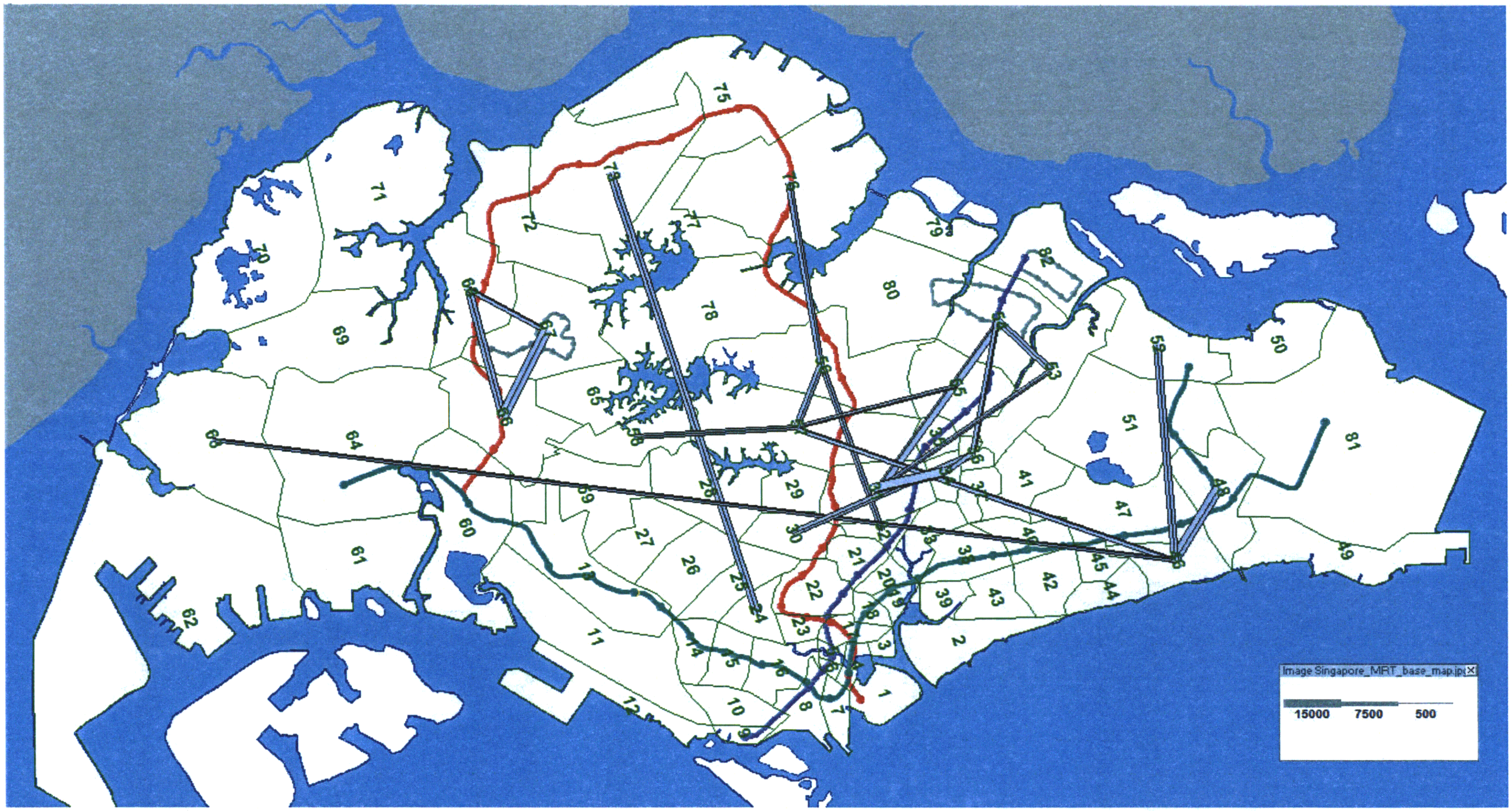

Figure 4.6: Daily Trips with Car Driver or Passenger as Main Modes. Zonal combinations with less than 5,000 daily trips are not shown to further distill the image presented in **Figure 4.5**.

Since we already have the economic and time costs associated with each trip in the HIS that is within our refined dataset, it is a relatively simple task to aggregate these for each O-D pair of postal sectors. However, as identified before, the comparison between public and private transport is complicated by the fact that private transport users have a much higher monetary value of time. In order to compare the social benefits if one person switches from private transport to public transport, we need to evaluate the costs of trips made with these two modes using a constant value of time for each o-d pair. This is also necessary given that policy decisions cannot be formulated to accommodate the higher VOT of private transport users, as this is not socially equitable.

Thus, additional operations were performed to our HIS data. For all trips made between each possible pair of postal sectors, the following were calculated (Items in **bold** and <u>underlined</u> are our desired end figures for analysis. Other items are necessary intermediaries):

<u>Economic Cost Differences</u>

1. Item 1 – average economic cost of trips when public transport modes is the main mode.
2. Item 2 – average economic cost of trips when private transport modes is the main mode.
3. **<u>Item 3</u>** – difference in average economic costs between trips when public transport as main mode and trips with private transport as main mode. (Item 2 – Item 1).
4. **<u>Item 4</u>** – total savings in total economic costs to society if all trips currently made with private transport as the main mode were to switch to public transport instead. (Item 3 multiplied by total number of trips with private transport as main mode).

<u>Time Cost Differences</u>

5. Item 5 – average trip duration of trips with public transport modes as main mode.
6. Item 6 – average trip duration of trips with private transport modes as main mode.

7. Item 7 – difference in average trip durations between trips with public transport as main mode and trips with private transport as main mode. (Item 3 minus Item 4).
8. Item 8 – average wage rate of travelers with private transport as main mode.
9. **Item 9** – average additional time cost to private transport users if they were to switch to public transport of that particular trip. (Item 7 multiplied by Item 8 multiplied by either 45% or 70%).
10. **Item 10** – total additional time costs that would be incurred if all trips currently made with private transport as main mode were switched to public transport. (Item 9 multiplied by total number of trips with private transport as main mode).

Total Cost Differences

11. **Item 11** – savings in average total cost to society if any given trip with private transport as the main mode switched to public transport. (Item 3 minus Item 9).
12. **Item 12** – total savings in total costs to society if all trips currently made with private transport as the main mode were to switch to public transport. (Item 11 multiplied by total number of trips with private transport as main mode).

For this part of the analysis, because we have defined car passengers as not contributing to the economic costs of automobile usage at all, we will exclude car passenger journeys from this part of the analysis to prevent the appearance of private car trips that do not cost anything at all, and hence, are dominantly superior to public transport modes in all respects.

4.7 Results of Analysis

4.7.1 Economic Costs

As expected, trips among all postal sector combinations cost much more if the main mode was private transport. The minimum average economic cost difference was S$27.70. If we had not excluded car passenger trips from this part of the analysis, there would actually be sector combinations for which trips with private automobile as the main mode actually cost less than trips with public transport as the main mode.

Figure 4.7 below shows zonal combinations for which the differences in average economic costs to society are the greatest. Not surprisingly, many of these combinations are long journeys that accentuate the difference between the in-vehicle costs of public and private transport modes.

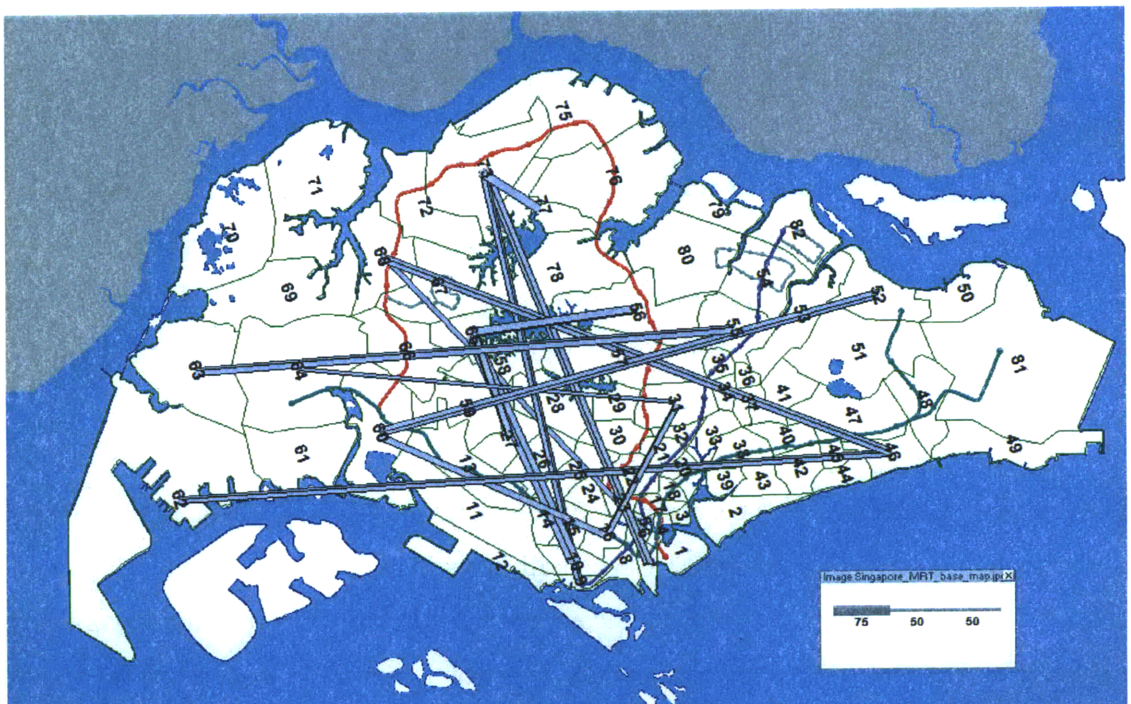

Figure 4.7: Zonal Combinations for which Average Economic Cost Differences are Greater than S$55 per Trip.

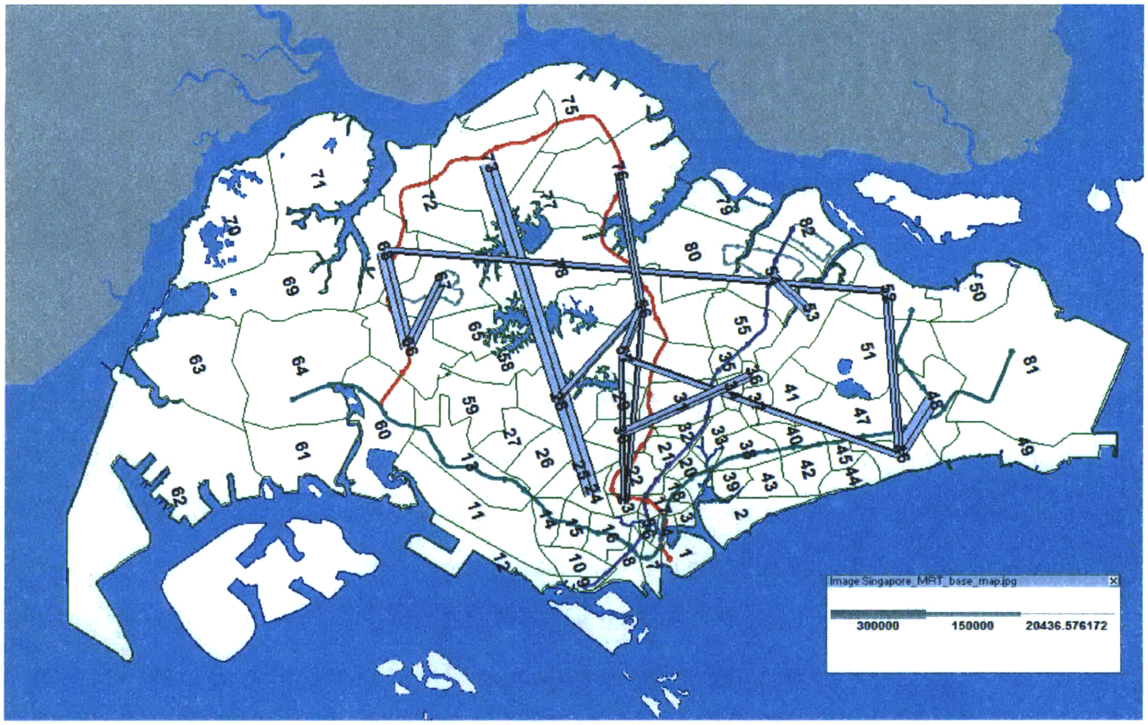

Figure 4.8: Zonal combinations for which the total possible economic costs savings to society are greater than S$150,000 daily if all private car drivers switched to public transport as their main mode.

4.7.2 Time Costs

Comparison of the difference in time costs can serve two functions. Firstly, by using the lower bound VOT of 45% of the wage rate of private car drivers making those particular trips, we can identify the zonal combinations for which public transportation fares badly relative to private modes even given the conservative VOT.

Figure 4.9 below shows the zonal combinations for which the difference in average time costs of trips with public transport as the main mode exceed S$17 that of trips made with private transport as the main mode, even with the conservative estimate of VOT as 45% of the wage rate of the private car drivers making those trips. Not surprisingly, many of these trips are long, cross-island trips that accentuate the difference in average in-vehicle speeds between private and public transport modes. The zones highlighted in this figure also tend to lack access to the RTS network. Also noteworthy are the zonal pairs 54-45, 48-56 and 51-56, which have RTS access, but are served by different lines of the RTS system with interchanges only far away in the CBD. This essentially forces commuters to either extend their RTS journeys plus incur the extra cost and inconvenience associated to a transfer, or to rely on buses with lower travelling speeds and generally higher headways.

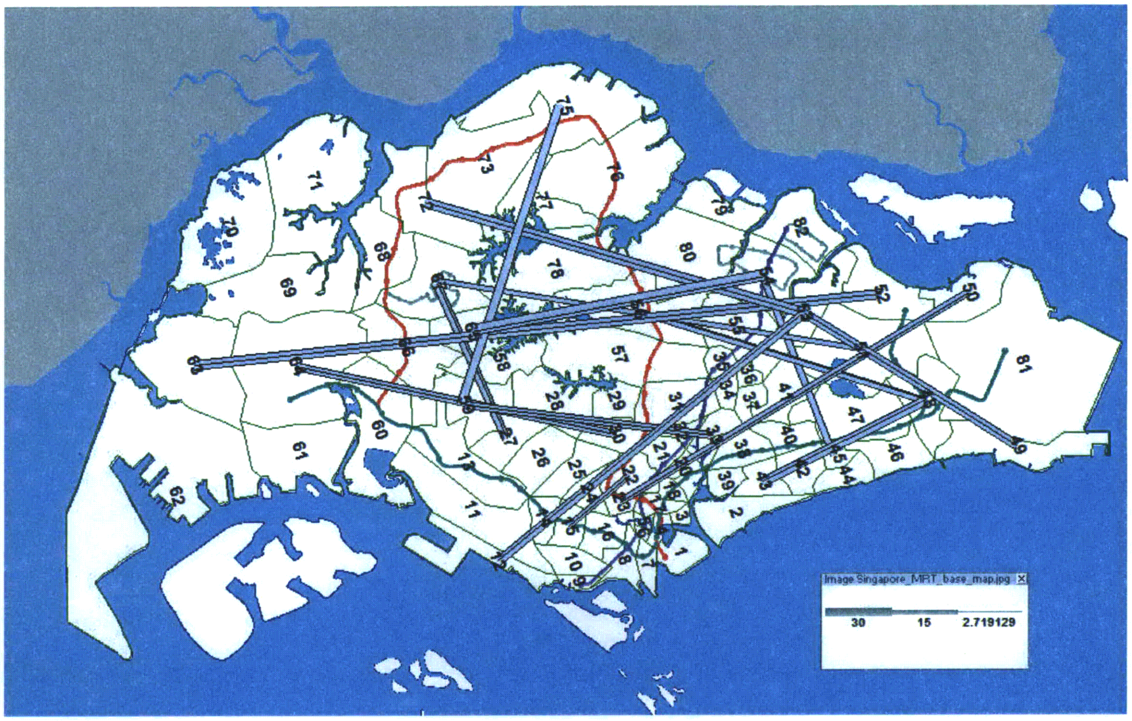

Figure 4.9: Zonal combinations for which the difference in average time costs of trips with public transport as the main mode exceed S$17 that of trips made with private transport as the main mode, from the perspective of private car drivers making those trips. (VOT = 45% of average wage rate of private car drivers making the respective trips).

Extending our comparison to differences in total time costs, we can identify zonal combinations for which an increase in transit level-of-service (LOS) would provide a significant reduction of the social costs incurred currently by auto users if they switched to public transport. **Figure 4.10** below shows zonal combinations for which the collective time difference for all drivers making those indicated trips is greater than S$20,000 on a daily basis.

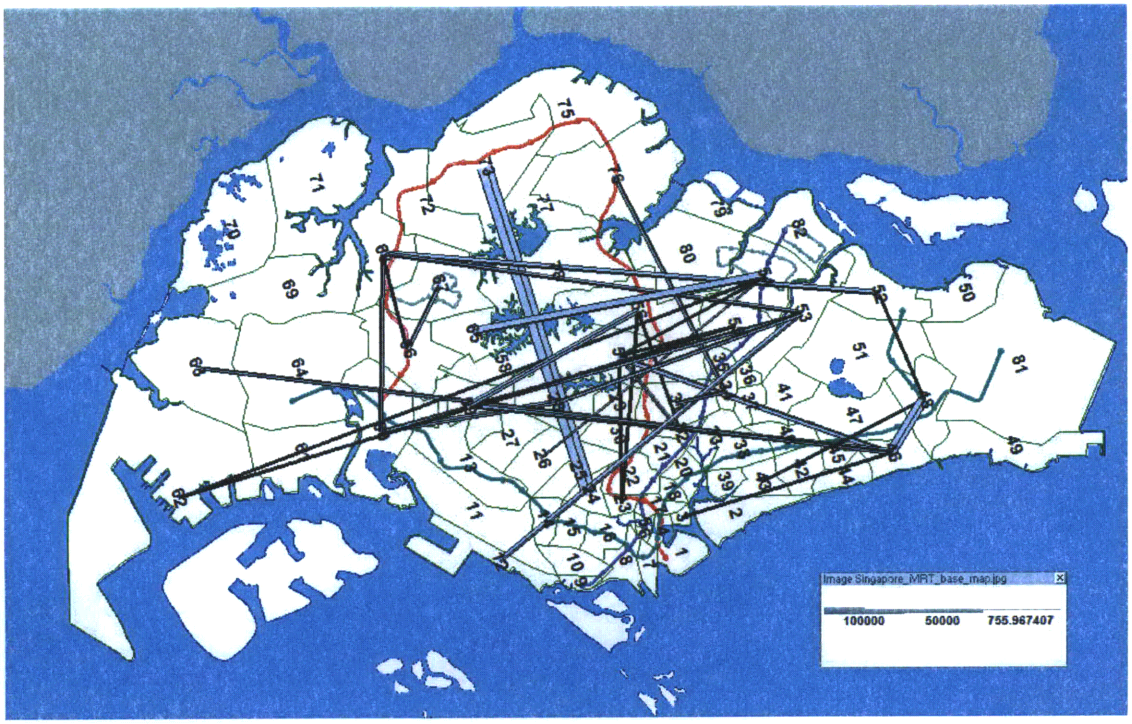

Figure 4.10: Zonal combinations for which the total additional time costs associated with switching to public transport exceed S$20,000 that of all trips made with private transport as the main mode, from the perspective of the private car drivers making these trips. (VOT = 45% of average wage rate of private car drivers making the respective trips).

From **Figure 4.10**, we note, as expected, that regions not well served by RTS infrastructure tend to fare badly in long-haul, cross-island trips. In addition, we also make 3 observations:

1. Even zonal combinations which seem well linked by RTS infrastructure appear to fall significantly short of the speed offered by private transport modes (e.g. 68-60, 48-52, 46-48, 68-66). A short check with **Figure 4.9** reveals that these zonal combinations do not necessarily fare very badly in terms of average time difference. However, the sheer volume of private car drivers making these specific trips renders the collective time difference sizeable. This presents the unique opportunity for public transport to bridge considerable time differences and become a lot more attractive to private car drivers with just a slight increase in LOS or decrease in headways, especially since RTS infrastructure is already in place for these O-D pairs.

2. Several of the zonal combinations can be seen to cross the multiple radial lines of the existing RTS network (e.g. 46-57, 52-68, 53-68). The fact that the interchanges for these separate RTS lines exists far away from the periphery of the island, in the CBD, suggests that the Circle Line currently being built to link these lines outside of the CBD can significantly alleviate the time cost disincentives perceived by many private car drivers.

3. The geographical features of the island, most notably the reservoirs in the central catchment area, physically limit the ability of RTS networks to compete with the private car (note zonal combinations 76-34, 73-24, 54-65, 56-59). Depending on the size of the market (perhaps large enough only for combination 76-34), premier direct bus services making use of the same roadway infrastructure as private cars may be the only viable option to significantly improve the attractiveness of public transport to motorists.

The second function of our comparison of time cost differences would be to reveal areas where the LOS of public transport has already rendered private automobile transport technically redundant. **Figure 4.11** below shows the zonal combinations for which private transport users will actually save between S$1-S$15 in average time costs if they switched to public modes.

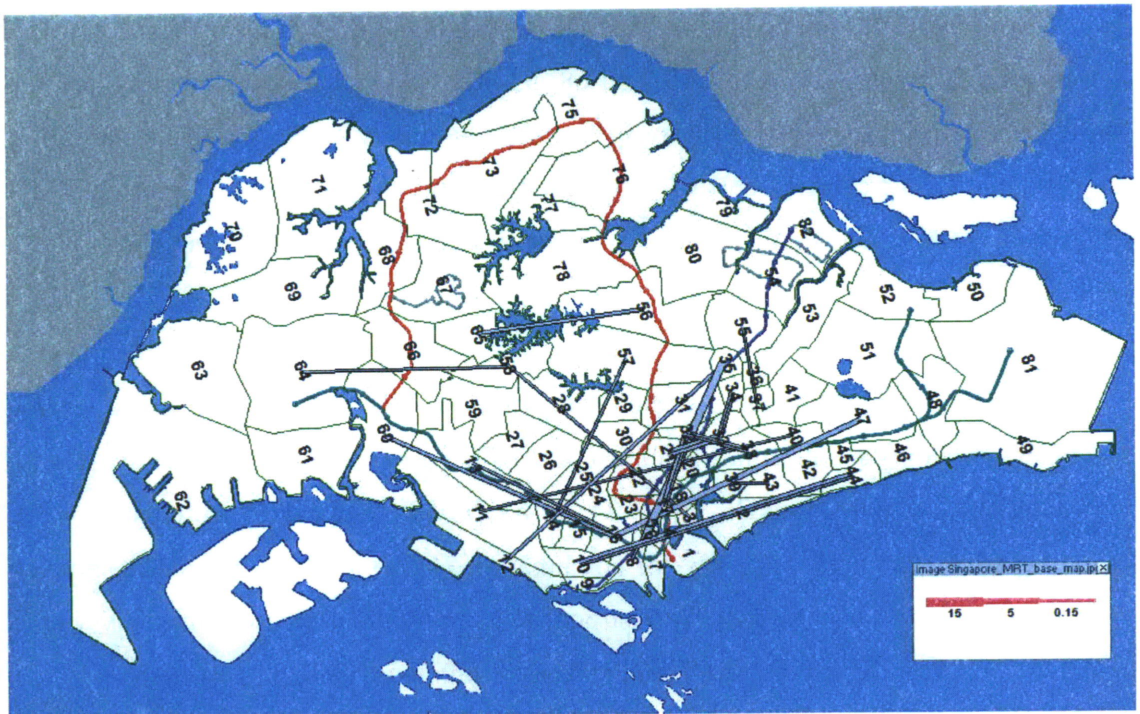

Figure 4.11: Zonal combinations for which average time costs savings are S$1 or more for private car drivers if they switched to public transport.

As expected, most of the zonal combinations for which public transport presents time savings over private transport involve the CBD area and are due to the radial RTS lines leading into the CBD. The direct routes and exclusive rights-of-way offered by the RTS network into the CBD region allow public transport users to avoid roadway congestion effects typically characteristic of CBD areas.

Zonal combination 65-56 stands out as an unexpected anomaly. Tracing back to the raw survey data, we find out that this is because the sole contribution to private automobile trip data for this particular combination came from just one interviewee who reported an exceedingly long automobile journey of 75 minutes. This anomaly highlights the possible inaccuracies when relying on self-reported travel times for our analysis.

Figure 4.12 below shows the zonal combinations with the greatest time savings if we consider the collective possible time savings to all private car drivers making those particular trips instead. As expected, trips to the CBD along the existing RTS lines stand out to potentially save private motorists the most time. However, note the difference in scale between **Figures 4.12** and **4.10**. The time savings associated with switching to public transport modes for these trips are much less than the additional time costs associated with those indicated in **Figure 4.10**.

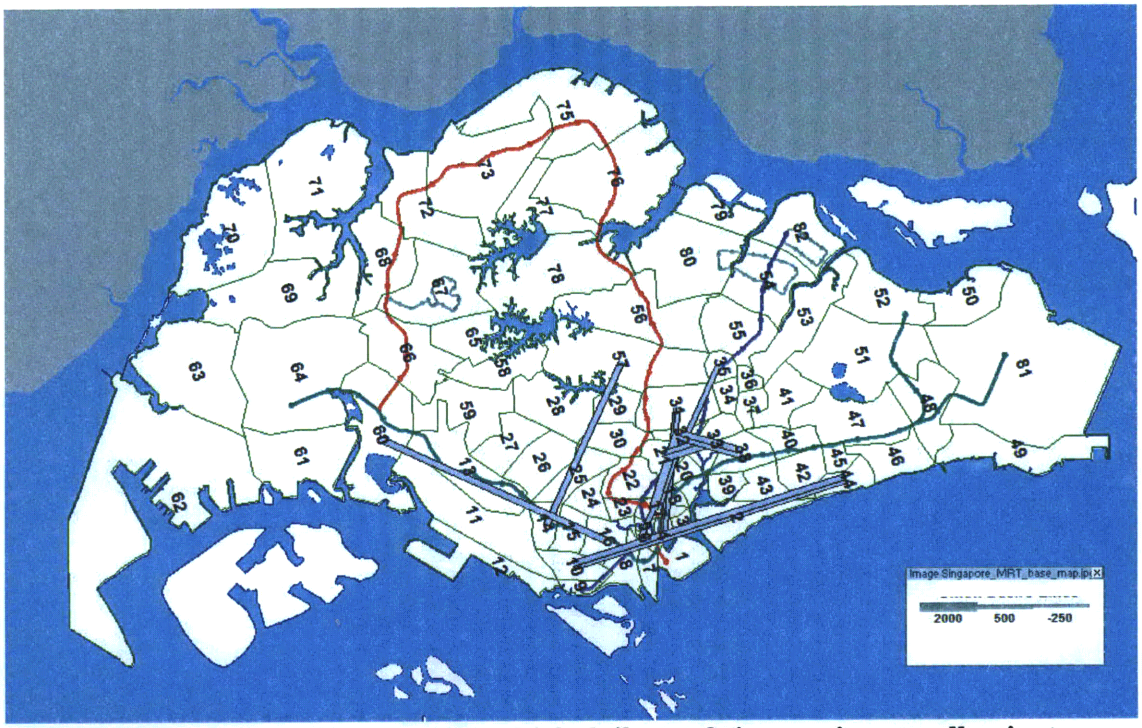

Figure 4.12: Zonal combinations for which daily total time savings to all private car drivers are greater than S$800 if all of them switch to public transport while making that particular trip.

4.7.3 <u>Total Costs</u>

Thus far, we have shown that trips with private car as the main mode are much more costly to society than trips with public transport as the main mode. We have also shown that however, the former are faster and saves time for private car drivers. However, how do the time savings brought about by private transport modes compare with the increased economic costs that society has to bear?

The figures in our calculated matrices show that despite the purported time savings brought about by driving a private vehicle, the additional economic costs to society far outweigh these time savings for the overwhelming majority of zone-to-zone trips.

Figure 4.13 below shows zonal combinations for which the average total cost savings to society is greater than S$40 should he or she switch to using public transport as the main mode; while **Figure 4.14** shows zonal combinations for which the total cost savings to society is greater than S$40,000 should all private car drivers making that trip switch to using public transport as the main mode. These results are obtained with the conservative assumption that the VOT of private car drivers is 70% of their average wage rate.

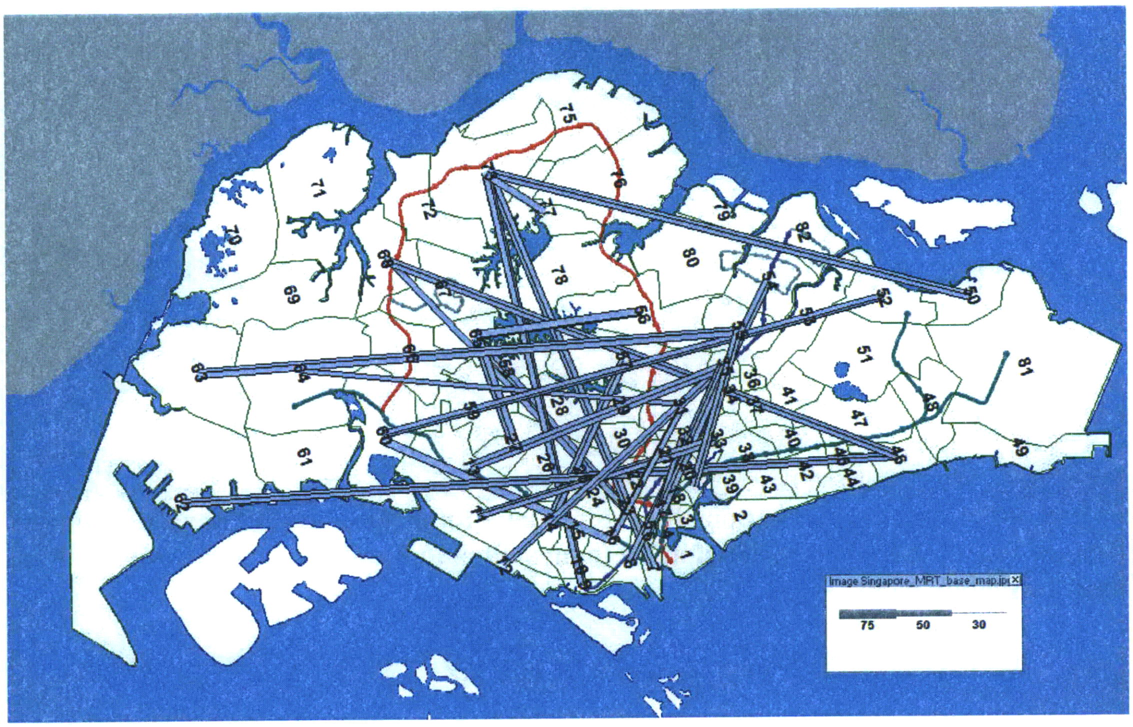

Figure 4.13: Zonal combinations for which the average total cost savings to each private car driver is greater than S$53 should he or she switch to using public transport as the main mode.

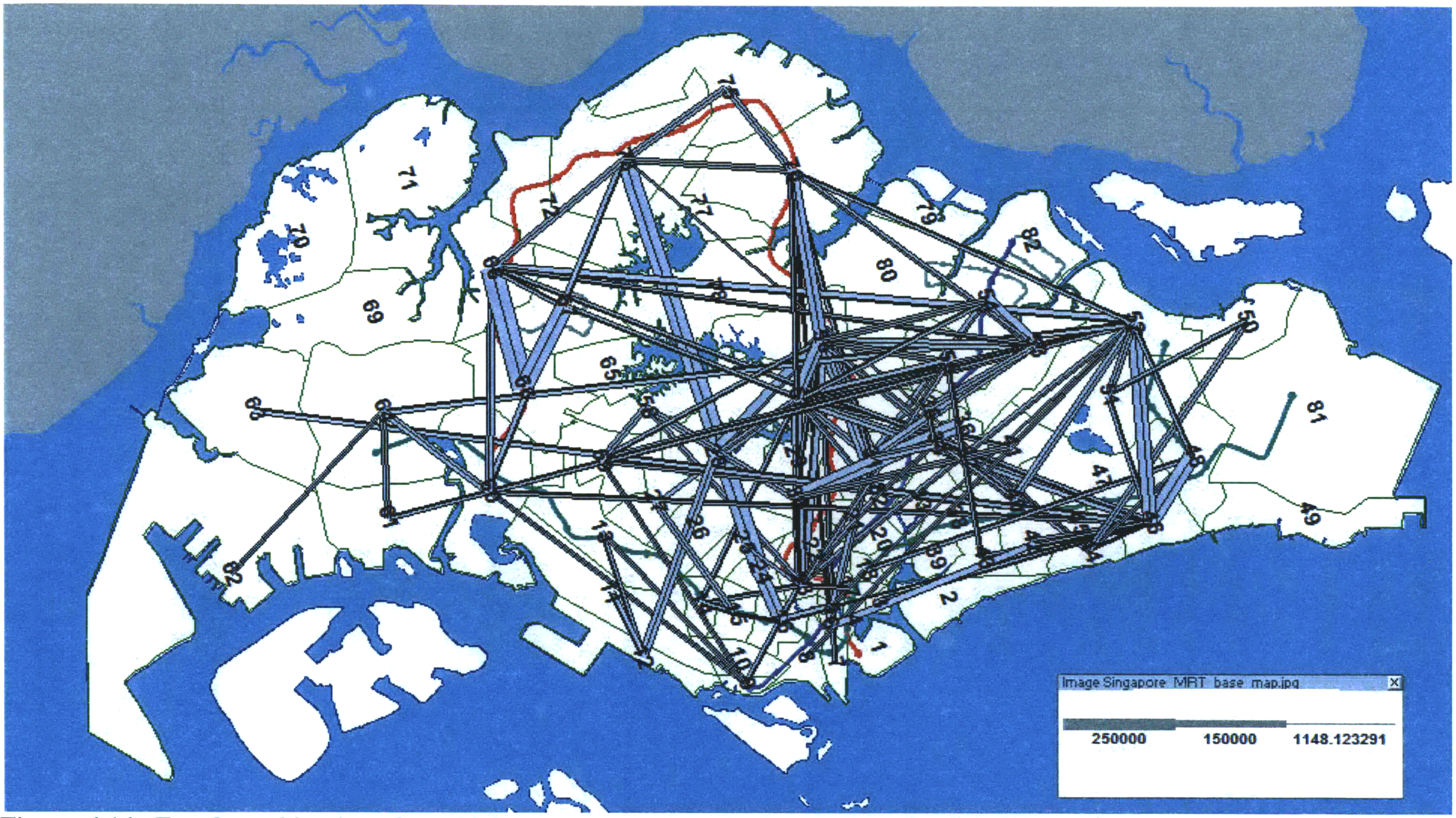

Figure 4.14: Zonal combinations for which the total cost savings to society is greater than S$40,000 should all private car drivers switch to using public transport as the main mode for each specific trip. Note that some zonal combinations which appeared in **Figure 4.13**, such as 73-50, become relatively less important and do not show up here due to the relative lack of private car drivers making those trips daily.

From **Figure 4.14**, we see the zonal combinations which would benefit society the most should private car drivers switch to using public transport as the main mode of their trips instead. Some key observations are as follows:

- As expected, many of these trips follow the existing radial RTS lines into the CBD region closely, as private car drivers stand to gain the least in terms of time savings for these zonal combinations.
- We also see many short trips that are much more costly to society when made using the private automobile. Many of these short trips also follow closely the RTS infrastructure, especially in the northern postal sectors, and the appearance of these short trips suggest that the local public transport systems serving those particular regions are competitive alternatives to private car driving, from society's point of view.
- The prevalence of these short trips also highlight the fact that short private automobile trips are inherently much more costly to society due to the fixed parking costs associated with each automobile trip.
- Several long-haul, cross-island trips (e.g. 63-46, 64-52, 68-52, 73-16) are still better made with public transport, from society's perspective, probably because the geographical barriers between these zones convolute even automobile journeys and decrease their comparative speed advantage over public transport. The appearance of these trips as some of the most beneficial to society if public transport was used instead, highlights the fact that even though private car drivers may perceive their choice of the private automobile as rational given the time cost savings, these decisions can actually be more costly to society than perceived by the drivers themselves.

From the results of this section, we can also theoretically identify zonal combinations in which public transport is lacking when time costs and economic costs are aggregated. However, the results of our calculations show that in none of the 1,906 zonal combinations for which we have data does public transport fare worse than private transport.

4.8 Summary of Key Findings and Conclusions

In this chapter, we have used our results from **Chapter 3** to derive generalized cost functions for bus, rail, and private automobile modes of travel. These cost functions were necessary for us to ascribe costs to each trip recorded in the HIS and disaggregate the total economic costs down to the trip level.

By assuming that all costs for bus and rail are spread evenly over the total passenger distances travelled, and by further assuming that the operating speed for bus and rail vehicles is approximately constant, we found that the economic cost per passenger in-vehicle hour is **S$4.16/passenger-hour** and **S$1.93/passenger-hour** for rail and bus trips in CY2006 respectively. The economic cost per passenger-kilometer is **S$0.15** and **S$0.14** for rail and bus trips respectively.

Since parking costs form a large component of the total economic costs of automobile and are clearly not spread evenly over passenger distance (short trips and long trips alike have the same average parking costs regardless of the in-vehicle distance travelled), these were assigned on a per trip basis, and found to be **S$35.9 per trip.** For the remaining economic costs of private automobile travel, we made the same assumptions as we did for bus and rail, and found that the cost per driver hour was **S$24.3/driver-hour**. The economic cost per passenger-kilometer is **S$0.80**. Here, we assume that passengers in private cars are not responsible for any of the economic costs arising from the use of the automobiles. This is necessary because the vehicle occupancy rate will differ from trip to trip, and using an averaged cost per passenger-hour for all trips will underestimate the costs for single-occupancy vehicle trips typical of work trips.

We assumed that the value of time of travelers ranged between 45% and 70% of their average wage rate.

Applying our economic cost and time cost functions to each trip in the HIS survey that had either bus, rail or private car driver as their main mode, we compared the trips made to and from each of the 82 postal sectors of Singapore, from the perspective of current private car drivers making those trips.

We found that the average and total economic costs to society for trips with private car driver as the main mode far exceed those of trips with public transport as the main mode for all of the 1,906 postal sector combinations for which we had available data. Although the average and total time costs for trips with private car driver as the main mode was substantially lower than those of trips with public transport as the main mode, for almost all of the postal sector combinations, these were not sufficient to offset the far higher economic costs to society. As such, the total cost to society (both economic and time) for all of the 1,906 postal sector combinations were substantially higher for trips with private car driver as the main mode.

For each of the above cost categories for which comparisons were made, we highlighted particular zonal combinations exhibit the highest differences between trips with private car driver as the main mode and trips with public transport as the main mode. These zonal combinations are of interest for future studies because they promise the largest potential benefits to society if the differences between public and private modes were bridged. The methodology described in this chapter thus offers a tool for policy makers to target very specific areas for the improvement of public transport services.

5. RECOMMENDATIONS AND CONCLUSION

5.1 Key Findings from Research

In this thesis, we have compared the direct costs involved in sustaining Singapore's private automobile system (excluding motorcycles, scooters, and taxis) against that for the public transport system. These costs involve the aggregate economic costs from all public and private actors, as well as the time costs to the travelers, but exclude externality costs.

We have found that in CY2007, a total of S$34.87 billion was spent on the private automobile transport system, about S$25.92 billion of which was spent on parking. A breakdown of automobile spending borne by private actors is as shown in **Table 5.1** and **Figure 5.1** below.

Cost Component	Lower Bound Estimate (2007 million S$)	Upper Bound Estimate (2007 million S$)
COE Rebate Depreciation	894	894
PARF Rebate Depreciation	883	1,040
Actual Body Value Depreciation	1,982	2,203
Registration Fee, GST and Excise Duty	753	753
Financing	695	695
Road Tax	703	703
Insurance	456	514
ERP	60	60
Spare Parts and Maintenance	253	261
Petrol	1,820	1,820
Parking	25,922	25,922
Total	34,422	34,866

Table 5.1: Cost Components of the Economic Costs to Private Actors.

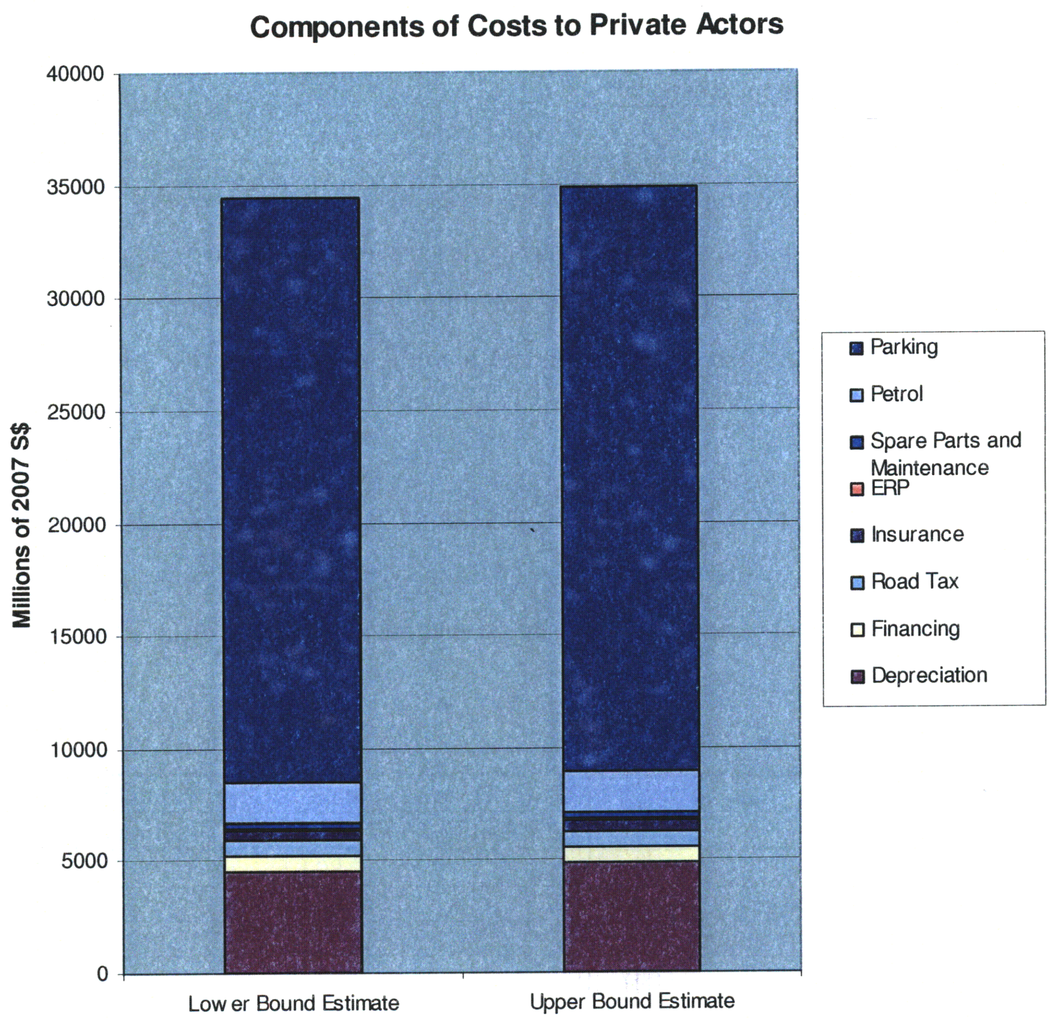

Figure 5.1: Cost Components of the Economic Costs to Private Actors.

In contrast, only S$1.66 billion was spent on the public transport system in FY2006-2007. The private automobile system thus cost at least 20 times as much as the public transport system, even though as recently as 2004, about 64% of all morning peak hour trips were made via public transport. A comparison of the sharp contrasts between private and public expenditures on the public and private transport modes is as shown in **Tables 5.2, 5.3** and **Figure 5.2** below.

Actor	Public Transport (Millions of 2007 S$)		Private Transport (Millions of 2007 S$)	
	Funds from Public Actors	Funds from Private Actors	Funds from Public Actors	Funds from Private Actors
SMRT		494.8		
SBS Transit		586		
LTA	573.3		23	126.8
PTC	0.7			
MOT HQ	4.34		4.34	
Automobile Private Actors				34,421.61
Duplicated Items				
LTA Vehicle Transit Licensing Fees		-37.72		
LTA Motor Vehicle Registration Fees				-20.31
LTA RTS Lease and Licensing Fee		-5.73		
Total	578.34	1,080.80	27.34	34,548.41

Table 5.2: Main Actors and Their Contributions to Public and Private Transport. Here, the lower bound estimates for private automobile transport costs are used.

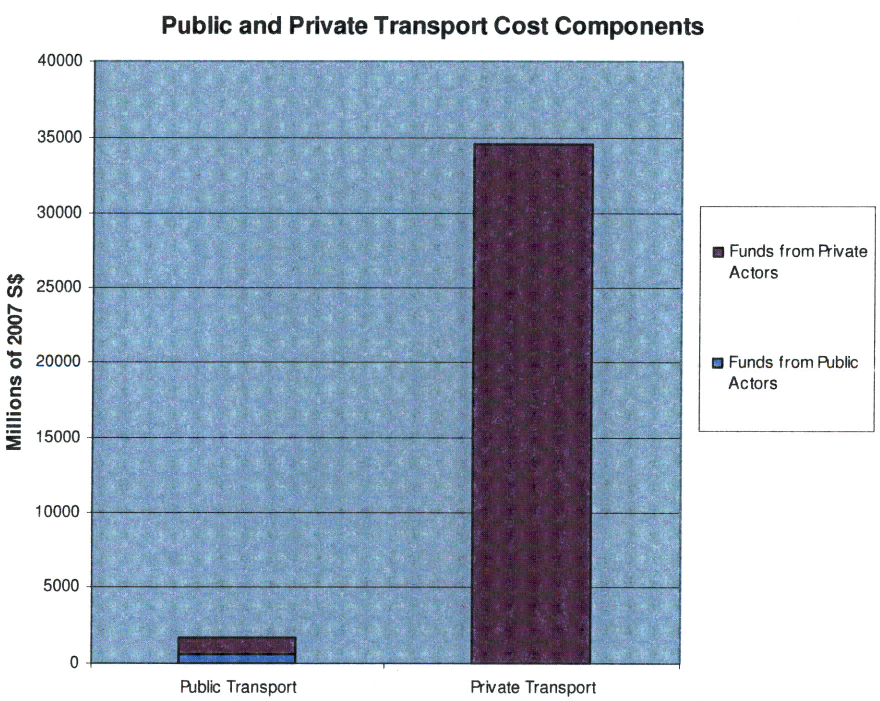

Figure 5.2: The Contrast between Expenditures on Public and Private Transport in Singapore.

	Public Transport	Private Transport
Total Expenditure	S$1.66 Billion	S$34.58 Billion
Total Passenger Miles Travelled	11.583 billion passenger-km	11.42 billion car-km Or 16.90 billion passenger-km
Normalized Cost per Distance	S$0.143 per passenger-km	S$3.03 per car-km Or S$2.05 per passenger-km

Table 5.3: Summary of Cost Comparisons.

Using the aggregate cost results, we derived per passenger-km and per trip cost functions and applied them to all trips recorded in the 2004 home travel survey data. We also assumed that the monetary Value of Time (VOT) of each traveler ranged from 45% to 70% of his or her average wage rate. It was found that in 2004, on average, trips made with the private automobile as the main mode lasted 0.36 hours door-to-door while trips made with public transport as the main mode lasted twice as long at 0.72 hours. On the other hand, the average economic cost of an auto trip was S$28.64, while that of a public transport trip was S$1.20. On average, time costs constituted between 66 to 75 % of the total cost of a public transport trip, while it amounted to between 9 to 14% of a private automobile trip, even when applying the higher wage rates of private automobile users. This is as summarized in **Figure 5.3** below.

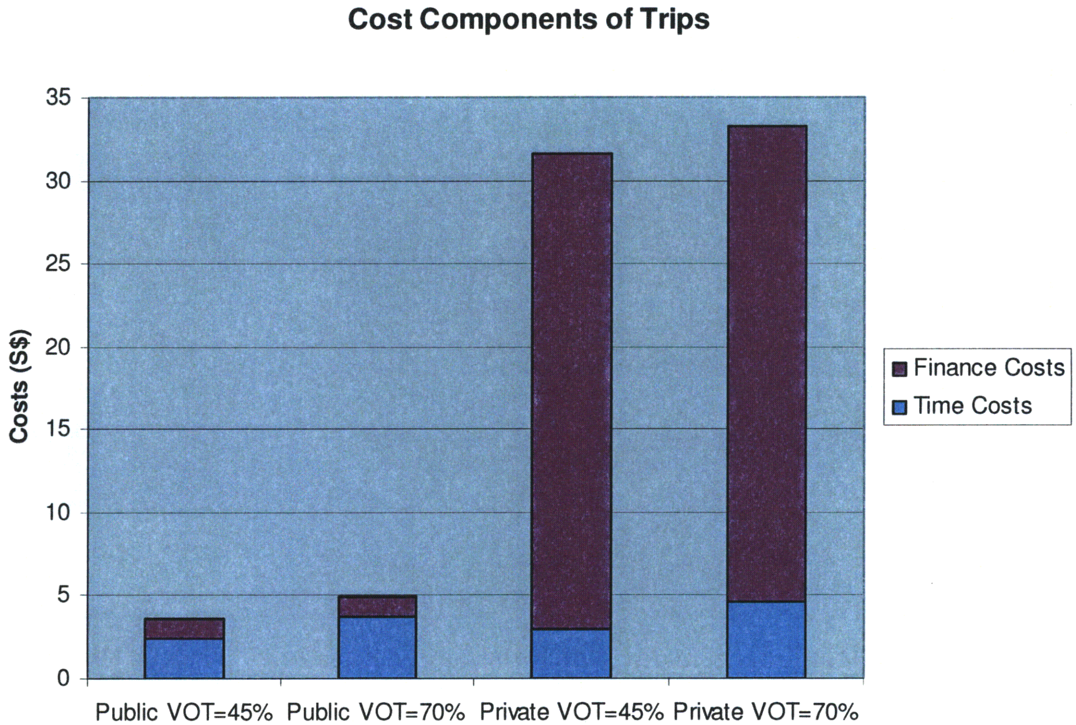

Figure 5.3: Cost Components of Trips with Either Public or Private Modes as the Main Mode

We further compared trips made with private car driver as the main mode with trips made with public transport as the main mode, between all origin-destination combinations of the 82 postal sectors in Singapore, and found the zonal combinations for which the differences in average and total economic costs, time costs, and total costs were the greatest. These zonal combinations represent targeted areas for which society and public transport users stand to gain the most if appropriate action is taken. Figure 5.4 shows corridors for which the total cost savings to society is greater than S$40,000 should all private car drivers switch to using public transport as the main mode for each specific trip.

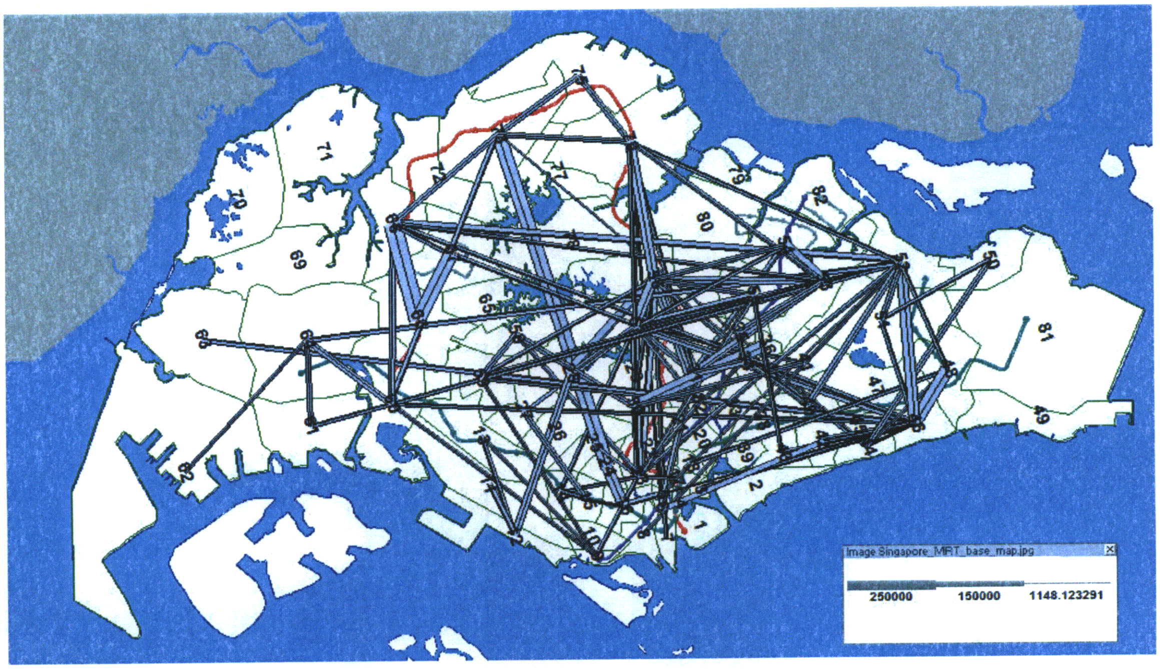

Figure 5.4: Zonal combinations for which the total cost savings to society is greater than S$40,000 should all private car drivers switch to using public transport as the main mode for each specific trip.

5.2 <u>Recommendations</u>

We can make several key recommendations resulting from the findings of this thesis.

1. Parking Costs as the Single Greatest Hidden Cost.

The average cost to society for each private car driver trip was estimated to be S$35.94. On the other hand, the average season parking charges in the CBD ranges from S$160 to S$200 per month[60]. Even if we assume that season parking charges at home costs the same, and that each private car driver only commutes once to and from work per day for twenty working days a week (thus making 40 trips per month), this translates to a direct cost to private car drivers of a maximum S$10 per trip, or less than 30% of the total economic costs to society. Thus, a large percentage of the actual economic costs which parking represents are absorbed by employers or retailers.

[60] Land transport Authority. "Land Transport Master Plan."

According to Singapore's Land Transport Master Plan,

> "Unlike many cities in the world such as London, Hong Kong, Tokyo and New York, which rely on parking surcharges or restrictions to limit parking supply, Singapore adopts the approach where the Government determines the minimum parking provision while parking charges are market-driven, left to individual building owners and car park operators to determine. The current approach ensures adequate car park provision and allows the market to optimize the use of parking spaces through pricing."

Though the LTA has argued that the scaling up of Electronic Road Pricing (ERP) should be the main avenue through which the marginal costs of driving are better reflected to drivers, a consequence of placing a lower, and not upper, limit on the parking supply in the CBD is that the availability of parking spaces becomes a form of comparative advantage in the competition for retail business or top employees. The more property owners are willing to provide additional parking spaces at a subsidized cost, the greater the proportion of parking costs that will eventually be "hidden" from private automobile drivers.

Table 5.4 below reproduced from Singapore's Land Transport Master Plan[1] compares Singapore's CBD parking rates and supply with that of other similar cities.

	Singapore	Hong Kong	London	Tokyo
Season Parking in CBD (S$) (average per month)	160-200	720-850	>400	420
Parking Spaces per 1,000 jobs in CBD	165	23	85	40

Table 5.4: Comparison of Singapore's CBD Parking with Similar Cities.

Compared to similar cities, Singapore's CBD has significantly lower parking charges and a larger supply of parking lots. Today, there are 49,000 parking lots in the CBD when only 29,000 should be provided according to today's car parking provision standards. According to the Land Transport Master Plan, today's apparent oversupply is due to the fact that many of the existing buildings in the CBD were built while car parking provision standards were more generous. These car park provision standards were lowered in 1990 and again tightened in 2002. In 2005, the Land Transport Authority (LTA) further introduced the Range-Based Car Parking Standard (RCPS) where building owners within the CBD area and within 400m of RTS stations were allowed to reduce their parking supply by a further 25%. However, the continued surplus of car parking lots in the CBD suggests that building owners are slow to react to these changes and have a tendency to over-provide as a means of staying competitive. The overprovision of car parking lots in the CBD region in turn leads to lower prices being passed on to drivers as building developers and owners willingly absorb these "hidden costs".

It remains to be seen whether the introduction of the RCPS will have a significant effect in reducing the number of parking lots in the CBD area and raising the prices. In lieu of that, the LTA should consider the introduction of an upper limit to car park provision.

2. Lowering Time Costs of Public Transportation

We have shown that 66% to 75% of the costs to society for an average public transport trip are time costs, compared with the 9 to 14 % for the private automobile. The best way to make public transport even more competitive compared to the private automobile would thus be to reduce the difference in time costs. Indeed, the Land Transport Master Plan states the LTA's target of reducing the door-to-door journey time of public transport users to under 60 minutes for 85% of all public transport trips, up from the current rate of 71%.

In order to achieve this goal, the LTA plans to:

- Take on the role of a central bus planner by 2009. This will improve the integration of services currently managed by the two different public transport providers.
- Accord greater priority to buses on the roads to improve the average operating speed of buses.

- Double the RTS network infrastructure from 138km today to 278km by 2020 to enhance its spatial coverage.
- Introduce greater competition among public transport providers by shortening the license period for future RTS operating licenses.

It is interesting to note that throughout the previous chapter, our comparison of time costs involve the comparison of the perceived travel times for each stage of the journey. Hence, in addition to reducing the clock time for door-to-door journeys, improving the service quality of public transport trips is also a means for bridging the gap in perceived time costs between the two different modes. To this end, the LTA seeks to enhance the overall journey experience through the provision of covered linkways and pedestrian bridges, integrated transport hubs, real time traveler information, and other improvements in amenities.

Our findings in **Section 4.7** of the previous chapter thus help pinpoint specific trips where improvement action can be better targeted. Most of our recommendations which result directly from our findings of that section have already been discussed in detail, so they are summarized here:

- Zonal combinations with the greatest average and total time cost differences between public and private transport modes have been indentified. These are the areas that should be targeted first with public transport service improvements.

- Several of the above-mentioned zonal combinations can be seen to intersect with two or more radial RTS lines a distance away from the interchanges of these lines in the CBD. This suggests that connectivity of the RTS lines at the periphery of the island would significantly reduce the time cost disadvantage of public transport. The soon-to-be-completed Circle Line would serve well to this end.

- Certain zonal combinations already well-linked by RTS infrastructure can offer large total time cost savings to potential private car drivers contemplating a switch to public transport by just a slight improvement in LOS or reduction in headways, due to the sheer volume of private car drivers making those trips.

- The geographical features of the island physically limit the coverage and connectivity of the RTS network where total time cost differences between the 2 modes are amongst the largest. This suggests that the introduction of premium bus services that closely resemble the operation of private vehicles between these regions may be the best solution.

- There are trips where there are actually reductions in average and total time costs if private car drivers switched to public transport. Yet, these trips are still being made with the private car. It would be interesting to investigate further into the reasons as to why these seemingly irrational choices are still being made, and how public transport can be improved to be competitive in these areas.

3. Short Automobile Trips as the Most Costly to Society.

From **Figure 4.14** in the previous chapter, we see that the greatest total cost savings to society occur if certain short regional automobile trips were made with public transport instead. This provides motivation to improve feeder public transport services, or even non-motorized transport amenities in those specific regions even more to discourage private car owners from driving for these trips.

Ultimately, however, the current imbalance between car ownership costs and usage costs may be the single most dominant factor in influencing drivers to make non-discretionary private automobile trips, even when attractive alternatives abound, simply to make good on their sunk costs on vehicular ownership. From our results in **Chapter 3**, discounting parking costs since much of it is hidden from private automobile owners, depreciation, financing, insurance and road tax form about 75% of all costs to private automobile owners, as recently as CY2007. Vehicle ownership costs are thus about 3 times as much as vehicle usage costs. Even though there have been recent efforts to reduce annual road taxes and ARF charges to reduce fixed vehicle ownership costs, while increasing Electronic Road Pricing (ERP) charges to shift some of those costs to usage costs, these may not be sufficient in the future given that Singapore is looking to reduce the vehicle population growth rate from the current 3% a year to 1.5% from May 2009. Lowering the vehicle quotas will have inflationary effects on COE prices and drive up fixed ownership costs significantly again.

As such, in addition to current efforts, it may be necessary to consider schemes such as pay-as-you-drive insurance, or to undertake measures to unhide the vast costs of parking to better reflect the true usage costs of driving to the automobile user.

5.3 Areas for Future Research

1. Include more travel modes.

In this thesis, we have compared private automobile car and driver trips against bus and RTS trips, as these two are the most significant modes of transport in Singapore. We have not included in our analysis taxicab trips, motorcycle and scooter trips, walking trips, and cycling trips. It would be interesting to see how all these modes economically compare with the modes we have analyzed.

2. More rigorous parking cost estimates.

Given the order of magnitude that parking costs constitute, it will be desirable to have a more robust and rigorous methodology for estimating our parking costs. Due to data limitations, we have used construction, design, and operation and maintenance costs gathered from studies based in the U.S..

The average land prices that we have used in our analysis may also not be representative of the entire region, since we only have data on the prices of bulk land released by the government for development after 1993. The prices of land can vary quite substantially even within a HDB estate, depending on location, for example. Furthermore, we have used the minimum parking provision guidelines stipulated by the LTA to estimate the total number of parking lots, when in fact, developers might provide more parking spaces than required, as witnessed by the apparent oversupply of parking lots within the CBD. As such, there is significant room for our parking cost estimates to improve in accuracy.

3. FY2008-2009 as a good year for research.

In this thesis, we have strived to use the latest data available to paint a picture as recent as possible. As such, we have used data from CY2007 for the private spending on the automobile, data from FY2006-2007 for public spending on the automobile and public transport, and finally applied our cost estimates to travel survey data from 2004. Thankfully, there have been no major changes in transport infrastructure from 2004 to 2007 that would adversely alter the travel times reported in the 2004 survey, with the exception of the addition of 14 more LRT stations on 2 new loops. Nonetheless, our comparisons would obviously be more complete if we were able to use data from the same time period.

The LTA is lining up another transport surveyto be conducted in the later half of 2008. This survey will include more households and will be more detailed than the HIS 2004. Since the cost data we have used are available annually, while travel surveys are conducted only every 4 years, this investigation could be replicated for FY2008-2009.

4. Local vs. Non-Local Spending.

In this thesis, we have considered total spending by all actors on each main transport mode. However, how much of this spending stays within the local economy and how much of it actually leads to monetary outflows from Singapore remains an open and interesting question.

Kennedy measured expenditures external to the local economy for each transport mode for the Greater Toronto Area. In 1996, he estimated that the external cost was $0.24 per person-kilometer and $0.07 per person-kilometer for the automobile and public transportation respectively[61]. Using similar assumptions from Kennedy's work, Kothari estimated that 70.2 percent of automobile spending remained local while 87.5 percent of public transit spending remained local for the Greater London Area in 2004[62].

Since Singapore, like Toronto and London, does not have automobile producing industries, we could apply the same general assumptions and estimate how much of the spending on private and public transport remain local respectively. This would make for a more meaningful comparison of the costs of society between the two modes.

5. Include externalities.

Our comparisons in this thesis have included only the direct economic and time costs spent on private and public modes of transport, and does not take into account externalities such as air and noise pollution, congestion, and traffic accidents. Intuitively, the inclusion of these costs is likely to make the private automobile even costlier compared to public transport. This thesis can thus be viewed as a conservative estimate of the relative costliness of the automobile to society.

6. Model decision making on a disaggregate level.

In this thesis, we have argued that the automobile costs more to society than public transport, even when time costs are taken into consideration. Part of the reason why some people still choose to drive may be due to the fact that some of these costs, such as parking, are willingly absorbed by other actors. However, to fully understand the

[61] Kennedy. "A comparison of the sustainability of public and private transportation systems."
[62] Kothari. "A Comparative Financial Analysis of the Automobile and Public Transportation in London."

decision making process undertaken by commuters, and to hopefully persuade more to utilize public transport, it is essential to compare all costs to the individual rather than society on the whole. For example, staying closer to areas with good public transport accessibility may actually cost an individual more in terms of housing costs, as it may actually be cheaper to stay further away from public transport amenities and use a car instead. Modeling decision making on a more disaggregate level could thus uncover more ways in which public transport could be even more attractive, because ultimately, the choice between public and private lies with the individual.

5.4 Conclusion

Based on the analysis of this thesis, we have found that the private automobile transport system costs much more to society than does the public transport system, even when time costs are taken into account. We have also identified corridors where trips made with the automobile are the most costly to society compared to public transport. These are the areas where Singapore should focus the most if the objective is to improve the economic cost effectiveness of transport spending. Possible strategies include a parallel of local public transport improvements together with a shift of vehicle ownership costs to usage costs, and the repercussion of a greater portion of the hidden parking costs to motorists, to better reflect the 'true' cost of driving to society.

We have also identified corridors where public transport trips fare the worst in terms of time costs when compared to private automobile trips. These represent the areas where public transport improvements are most needed if the objective is to increase the modal share of public transport over private transport. Possible strategies include the increase of LOS and service quality improvements in areas where RTS infrastructure is already in place, as well as the introduction of premium quality bus services where RTS coverage and connectivity seem limited in the long run, but where the travel demand is high enough to become a target for public transport.

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APPENDIX B: LIST OF ACRONYMS

ARF: Additional Registration Fee
CBD: Central Business District
COE: Certificate of Entitlement
CPI: Cosumer Price Index
CY: Calendar Year
ERP: Electronic Road Pricing
FY: Fiscal Year
GIA: General Insurance Association of Singapore
GST: Goods and Services Tax
HDB: Housing Development Board
JTC: Jurong Town Council
LOS: Level of Service
LRT: Light Rapid Transit
LTA: Land Transport Authority
MAS: Monetary Authority of Singapore
MRT: Mass Rapid Transit
MSCP: Multi-Storey Car Park
OMV: Open Market Value
PARF: Preferential Additional Registration Fee
RF: Registration Fee
RTS: Rapid Transit System
TCRP: Transit Cooperative Research Program
URA: Urban Redevelopment Authority
VOT: Value of Time
VQS: Vehicle Quota System
VTPI: Victoria Transport Policy Institute