A STUDY OF ALTERNATIVE POLICIES TO REDUCE TRAFFIC CONGESTION IN SEOUL

by

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We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

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ABSTRACT

Like most big cities in the world, traffic congestion is one of the most serious urban problems in Seoul. The magnitude of congestion costs in Seoul is much greater than most people realize; they are estimated to be more than twenty-eight billion won (U.S.$ 35 million) per day.

Therefore, in this thesis, a number of transportation demand management (TDM) measures are reviewed and assessed. Broadly, two categories of TDM measures are considered: "Carrot" TDM measures and "Stick" TDM measures. "Carrot" TDM measures include preferential treatment of high occupancy vehicles (HOVs), improvement of transit systems, introduction of para-transit, encouragement of ridesharing, and variable work hours. "Stick" TDM measures include parking supply controls, traffic zone systems, odd and even days rule, road use permit systems, taxation of cars, fuel taxes, parking charges, and charging for road usage. The performance of each measure is assessed against a set of criteria: efficiency, equity, feasibility, environmental effect and flexibility. As a result of the assessment, a list of policy alternatives for Seoul is proposed: preferential treatment for HOVs, fuel tax increases, improvement of transit system, and charging for road usage as major policy alternatives, and introduction of para-transit, parking charges, and control of parking supply as supplementary policy alternatives.
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2.2.1.2 Traffic Zone Systems

2.2.2 Regulatory Restraints

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2.2.2.2 Road Use Permit System

2.2.3 Use of Pricing System

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Like most residents of urban areas, citizens of Seoul have been experiencing growing traffic congestion every day. Since the 1960s, the per capita income of Korea has steadily increased along with high population growth. As income increased, the number of motor vehicles in Seoul increased to more than 1.37 million by the end of 1991. The number of motor vehicles has grown annually at a rate of more than twenty-three percent since the mid-1980s. Motor vehicles are in great demand and have exceeded the capacity of existing transportation infrastructure, thereby causing serious traffic congestion.

From the viewpoint of people who experience it, traffic congestion is exasperating because of the time lost sitting in traffic jams and the frustration of crawling along instead of moving at normal driving speeds. From the viewpoint of society as a whole, traffic congestion is undesirable because it misallocates scarce resources and causes economic inefficiency (Downs, 1992).

Congestion can be tackled by either supply-side or demand-side strategies. The supply-side strategies attempt to improve traffic conditions by increasing the carrying capacity of the
transportation system. These encompass tactics such as the construction or expansion of urban roads, and of mass transit systems. The demand-side strategies attempt to reduce the number or duration of vehicle movements during peak hours. These involve tactics such as high occupancy vehicle (HOV) lanes, ridesharing and improved transit services.

It is unlikely, however, that road capacity will be able to keep pace with the rapid growth in travel demand resulting from increases in population and vehicle ownership. Thus it may be that some forms of traffic demand management will be necessary to curtail congestion.

2. PURPOSE

The traditional approach to urban transportation problems focused on supply-side strategies. This approach has been largely unsuccessful. Today's urban transportation problems have arisen despite large annual expenditures on urban transportation systems. Cities in developing countries often devote fifteen to twenty-five percent of their annual expenditures to their transport systems, and sometimes much more (World Bank, 1986). The overwhelming nature of the urban transportation problem has sometimes tempted governments to try to solve it by spending vast amounts of money on subways and highway infrastructure. These capital-intensive projects have not always been cost-effective. Thus, transportation demand management (TDM) measures have been highlighted to alleviate
the effects of travel demand growth on traffic congestion and road infrastructure requirements.

The purpose of this study is to identify suitable policy alternatives to reduce traffic congestion in Seoul, Korea. This study will draw up a short list of suitable alternatives to constrain the rapidly growing automobile traffic effectively. The short list should be subjected to a full evaluation prior to actual implementation.

3. METHOD

In order to identify suitable policy alternatives for reducing traffic congestion in Seoul, the evidence will be sifted through a review of existing literature on actual experience or academic research.

Chapter 2 provides an overview of the traffic situation in Seoul. Seoul is one of the most congested cities in the world and requires immediate measures to solve its transportation problems.

Chapter 3 estimates the level of congestion costs in Seoul. From this we can find some justification for traffic restraint measures and evaluate investment projects designed to relieve congestion. Moreover, staggering congestion costs can be a warning to vehicle users and policy developers.
Chapter 4 reviews the transportation demand management (TDM) measures which are categorized broadly into two types: "carrot" measures and "stick" measures. Details are as follows:

1. Carrot TDM Measures
   - Preferential Treatment for HOVs
   - Improvement of Transit System
   - Introduction of Para-transit
   - Encouragement of Ridesharing
   - Variable Work Hours

2. Stick TDM Measures
   1) Physical Restraints
      - Parking Supply Controls
      - Traffic Zone Systems
   2) Regulatory Restraints
      - Odd and Even Days Rule
      - Road Use Permit System
   3) Use of Pricing System
      - Taxation of Cars
      - Fuel Tax
      - Parking Charges
      - Charging for Road Usage

Chapter 5 reviews the application of TDM measures to Seoul and their expected performance, which will be assessed against a number of criteria. The criteria are:

- Efficiency
- Equity
- Feasibility
- Environmental Effect
- Flexibility

Chapter 6 concludes the thesis with a summary of evaluation and policy recommendations in the short and long term.
CHAPTER 2
TRAFFIC CONDITIONS AND PROBLEMS IN SEOUL

1. CITY CHARACTERISTICS

1.1 Socio-economic Concentration

The urban transportation situation in Seoul is of critical importance for all of Korea. Although the area of Seoul (636 square kilometres) comprises only 0.63 percent of the land mass of the whole nation, it contains major transport facilities such as the international airport and the underground, and twenty-five percent of the employees. Traditionally, Korea cultivated a strictly hierarchical political system in which the central government in the capital exercised enormous influence on the whole nation; most decisions have been made in the capital city. Such an inherited political culture has accelerated the rapid urban growth and economic concentration in Seoul.

As a result, the serious traffic congestion in Seoul may have significant effects on the entire national economy and may stifle efforts to raise the level of national economic development.

1.2 Population

The population of Seoul reached 10.6 million at the end of 1990. Even though the growth rate of the Seoul population has been higher than that of the whole nation, it has been decreasing in recent
years from a 2.46 percent annual growth rate between 1981 and 1986
to 2.05 percent between 1986 and 1990.

Table 2-1: Population Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (1,000)</th>
<th>Annual Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1981</td>
<td>1986</td>
</tr>
<tr>
<td>Seoul</td>
<td>8,676</td>
<td>9,799</td>
</tr>
<tr>
<td>Nation</td>
<td>38,723</td>
<td>41,184</td>
</tr>
</tbody>
</table>

* Source: Seoul Development Institute (1993a)

2. TRAFFIC SITUATION

2.1 Car Ownership

Car ownership has increased by 21.4 percent per annum for the last
five years. This is due to an increase of income level, changes in
living patterns and growth in population. At the end of 1991, the
total vehicle registration of Seoul was 1,374 thousand, seventy-one percent being private passenger cars, as shown in Table 2-2.
Table 2-2: Car Ownership Trends in Seoul

<table>
<thead>
<tr>
<th>Description</th>
<th>'81</th>
<th>'86</th>
<th>'91</th>
<th>'81-'86</th>
<th>'86-'91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>111.1</td>
<td>708.6</td>
<td>977.1</td>
<td>22.7</td>
<td>25.9</td>
</tr>
<tr>
<td>Taxi</td>
<td>29.3</td>
<td>42.3</td>
<td>58.8</td>
<td>7.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Bus</td>
<td>14.8</td>
<td>52.2</td>
<td>108.4</td>
<td>28.2</td>
<td>15.7</td>
</tr>
<tr>
<td>Truck</td>
<td>66.5</td>
<td>117.8</td>
<td>230.4</td>
<td>12.1</td>
<td>14.4</td>
</tr>
<tr>
<td>Total</td>
<td>221.6</td>
<td>520.8</td>
<td>1,374.7</td>
<td>18.6</td>
<td>21.4</td>
</tr>
</tbody>
</table>

* Source: Seoul Development Institute (1993a)

It is notable that the number of vehicles in Seoul is equal to 29.3 percent of the total employees and accounts for 32.4 percent of all vehicles in the country.

2.2 Trips

Daily total trips by purpose in Seoul have increased annually by 3.8 percent between 1989 and 1991, which is double the growth rate of population. As shown in Table 2-3, the largest portion of trips involve returning home. One interesting fact is that the annual growth rate of certain purposes for trips has increased more rapidly than those for other trips. It seems to be the result of more diversified living patterns.
Table 2-3: Trips by Purpose, Daily

<table>
<thead>
<tr>
<th>Purpose</th>
<th>'89 Trip (1,000)</th>
<th>'89 Share (%)</th>
<th>'91 Trip (1,000)</th>
<th>'91 Share (%)</th>
<th>Annual Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home to School</td>
<td>2,785</td>
<td>13.6</td>
<td>3,006</td>
<td>13.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Home to Work</td>
<td>3,424</td>
<td>16.7</td>
<td>3,690</td>
<td>16.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Returning Home</td>
<td>8,584</td>
<td>41.9</td>
<td>9,170</td>
<td>41.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Business</td>
<td>2,468</td>
<td>12.0</td>
<td>2,641</td>
<td>11.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Other</td>
<td>3,250</td>
<td>15.8</td>
<td>3,590</td>
<td>16.2</td>
<td>5.1</td>
</tr>
<tr>
<td>Total</td>
<td>20,519</td>
<td>100.0</td>
<td>22,097</td>
<td>100.0</td>
<td>3.8</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1992)

Daily total trips by mode have grown but shifted substantially between 1986 and 1991. An increase in trips by subway/railway was dominant between 1889 and 1991, whereas between 1986 and 1989 the number of car trips increased rapidly (see Table 2-4). It means that as the subway/railway system expanded, a lot of people changed their travel mode from bus to subway/railway. The ratio of bus trips to total trips decreased annually by 6.4 percent between 1989 and 1991.

Table 2-4: Trips by Mode, Daily

<table>
<thead>
<tr>
<th>Mode</th>
<th>1986 Trip (1,000)</th>
<th>1986 Share (%)</th>
<th>1989 Trip (1,000)</th>
<th>1989 Share (%)</th>
<th>1991 Trip (1,000)</th>
<th>1991 Share (%)</th>
<th>Annual Growth Rate (%) 86-'89 89-'91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>3,494</td>
<td>18.5</td>
<td>5,672</td>
<td>24.3</td>
<td>6,003</td>
<td>24.7</td>
<td>17.5</td>
</tr>
<tr>
<td>Bus</td>
<td>8,978</td>
<td>50.1</td>
<td>11,551</td>
<td>48.5</td>
<td>10,118</td>
<td>41.7</td>
<td>8.8</td>
</tr>
<tr>
<td>S/R</td>
<td>2,330</td>
<td>13.0</td>
<td>3,069</td>
<td>13.1</td>
<td>5,082</td>
<td>29.9</td>
<td>9.6</td>
</tr>
<tr>
<td>Taxi</td>
<td>5,118</td>
<td>17.4</td>
<td>3,063</td>
<td>13.1</td>
<td>3,078</td>
<td>12.7</td>
<td>-0.6</td>
</tr>
<tr>
<td>Tot.</td>
<td>17,920</td>
<td>100.0</td>
<td>23,354</td>
<td>100.0</td>
<td>24,281</td>
<td>100.0</td>
<td>9.1</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1990a & 1992)
2.3 Travel Speed

The average travel speed in Seoul decreased by twenty-eight percent from 32.55 km/h in 1989 to 23.58 km/h in 1991 (see Table 2-5). An exception is in the case of the Central Business District road where there was no significant change in travel speed between 1989 and 1991. This means that the road congestion in the CBD is so severe that enough delay was generated to constitute a deterrent to the growth of traffic. On outskirt roads the travel speed decreased by 32.1 percent. It shows that traffic congestion was getting worse in all urban areas.

Table 2-5: Travel Speed in Seoul

<table>
<thead>
<tr>
<th>Description</th>
<th>1989</th>
<th>1991</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>32.55</td>
<td>23.58</td>
<td>-28.0</td>
</tr>
<tr>
<td>CBD</td>
<td>18.69</td>
<td>18.56</td>
<td>-0.7</td>
</tr>
<tr>
<td>Outskirt</td>
<td>37.17</td>
<td>25.25</td>
<td>-32.1</td>
</tr>
<tr>
<td>Urban Expressway</td>
<td>49.30</td>
<td>32.02</td>
<td>-17.0</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1992)

2.4 Road Network

The road network in Seoul is essentially radial, converging to the central area of Seoul. There are few orbital routes or ring roads. Most trips force drivers to pass through or close to the CBD. Such a situation, combined with the rapid growth in traffic demand, has led to the transport system being unable to meet demand adequately.
As for the supply of roads, it increased by 3.3 percent annually from 4,651 km to 5,471 km between 1966 and 1971; by 2.0 percent from 5,471 km to 6,689 km between 1971 and 1981; and by 1.1 percent from 6,689 km to 7,425 km between 1981 and 1991 (Seoul Development Institute, 1993b). The rate of the supply of road capacity has been decreasing year by year due to the high cost of acquiring lands and the lack of available lands.

In addition to traffic congestion, the overburdened road network has made traffic accidents one of the major causes of death and injury in Seoul.

2.5 Mass Transit Systems

More than sixty percent of the daily trips in Seoul are carried out by mass transit systems, mainly the bus and subway systems.

The current structure of the bus industry is characterized by a large number of small- to medium-sized independent companies. In contrast to bus operations in most cities of the world, bus services in Seoul are provided by eighty-nine private companies with fleet sizes averaging ninety-eight buses. Specific routes are licensed to individual operators. There are 423 separate routes in Seoul (see Table 2-6). The implication of this is that there is a substantial overlap
between companies on sections of routes, and therefore there are incentives for companies to operate efficiently to retain market share.

Table 2-6: Bus Company Statistics

<table>
<thead>
<tr>
<th>Number of Companies</th>
<th>Number of Employees</th>
<th>Number of Buses</th>
<th>Average Company Size</th>
<th>Number of Routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>25,413</td>
<td>8,734</td>
<td>98</td>
<td>423</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1993b)

Increased congestion in Seoul has reduced the operating frequencies per bus per day from 7.5 in 1988 to 6.3 in 1992 (Seoul Development Institute, 1993a), and hence the financial performance of bus companies has deteriorated. No direct subsidies, however, are given to bus operators, and some companies have gone bankrupt as a result of poor revenues.

Since subway construction started in 1971, the Seoul subway system has grown to a total of 188 kilometres. In addition, about 100 kilometres of subways are currently under construction.

There is no doubt that the subways have had a substantial impact. The shift from road-based modes of transport to subways has helped stabilize the level of road congestion in the CBD despite still rapidly increasing car ownership. However, the city government has had to pay massive construction costs amounting to about two trillion won in total, and this accounts for forty percent of the annual city expenditures on average. Although the central
government subsidized more than thirty-five percent of the construction costs, nearly thirty-three percent had to be financed by foreign or commercial loans. As a result, the massive loans for the construction, in combination with high operating costs, caused an excessive burden on the city budget. Some city planners advocate the subway as the best solution for overcoming the severe traffic congestion. However, there remain a number of serious problems concerning the planning and financing of subways. It is necessary to compare the costs and benefits of subways with alternative investments, including light rail transit and bus systems.

3. TRAFFIC SITUATION IN THE FUTURE

Although the rate of growth is decreasing, it is still forecasted that the population in Seoul will continue to increase in the future. According to the urban plan of Seoul, the population of Seoul is projected to be 11.2 million in 1996 and 12.0 million in 2001.

The number of vehicles to be registered in 1996 is estimated to be 2,371 thousand, and in 2001, 3,161 thousand. These estimations are made under the assumption that the current trends regarding the cost of car ownership and operation continue.

Daily total trips by purpose are estimated to reach 23,834 thousand trips in 1996 and 24,890 thousand trips in 2001. Trips from home
to work and return trips home are estimated to reach 4,270 thousand and 10,564 thousand in 2001, respectively, and will cause further exacerbation of peak hour congestion.

Daily total trips by mode will increase to 27,754 thousand trips in 1996 and 30,020 thousand trips in 2001, respectively. The number of bus trips, which accounted for the largest number of trips in 1991, is estimated to decrease by 19.9 percent from 41.7 percent in 1991 to 21.8 percent in 2001, while the number of subway/rail trips is expected to increase by 28.5 percent from 20.9 percent in 1991 to 49.4 percent in 2001 (see Table 2-7).

Table 2-7: Traffic Situation in the Future

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>10,580</td>
<td>11,267</td>
<td>12,000</td>
</tr>
<tr>
<td>No. of Vehicles</td>
<td>1,375</td>
<td>2,371</td>
<td>3,161</td>
</tr>
<tr>
<td>Trips by Purpose</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Daily)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home to School</td>
<td>3,006</td>
<td>2,884</td>
<td>2,817</td>
</tr>
<tr>
<td>Home to Work</td>
<td>3,690</td>
<td>4,044</td>
<td>4,270</td>
</tr>
<tr>
<td>Returning Home</td>
<td>9,170</td>
<td>9,922</td>
<td>10,564</td>
</tr>
<tr>
<td>Business</td>
<td>2,641</td>
<td>3,101</td>
<td>3,175</td>
</tr>
<tr>
<td>Other</td>
<td>3,590</td>
<td>3,883</td>
<td>4,064</td>
</tr>
<tr>
<td>Trips by Mode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Daily)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car</td>
<td>6,002</td>
<td>6,029</td>
<td>6,273</td>
</tr>
<tr>
<td>Bus</td>
<td>10,118</td>
<td>8,014</td>
<td>6,534</td>
</tr>
<tr>
<td>Subway/Rail</td>
<td>5,082</td>
<td>10,976</td>
<td>14,824</td>
</tr>
<tr>
<td>Taxi</td>
<td>3,078</td>
<td>2,734</td>
<td>2,389</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1993a), Seoul Development Institute (1993a)
As a result of such an increase in total trip demand, traffic congestion is expected to be a problem affecting the whole city for most hours of the day.
CHAPTER 3
CONGESTION COSTS IN SEOUL

1. INTRODUCTION

Formal estimates confirm that the cost of congestion is high. The Texas Transportation Institute estimated that, in just thirty-nine large urban areas of the United States, the cost of congestion in 1988 alone exceeded $34 billion, or $290 per resident. Time lost from delays (at $8.80 an hour) accounted for sixty-five percent of that amount (Downs, 1992).

Throughout the European Community as a whole, it has recently been estimated that the total economic loss through urban and interurban congestion and detours amounts to 500 billion European Currency Units (ECU) per year (Jones and Hervik, 1992).

By computing the cost of congestion, we can find some justification for traffic restraint measures and evaluate investment projects designed to afford relief from congestion.

2. TRAFFIC CONGESTION CRITERIA

In order to compute congestion costs, we should define the concept of traffic congestion. What is traffic congestion? Traffic congestion may be characterized in three ways: By the volume-capacity ratio, the level of service, and traffic speed.
These three categories explain the same phenomena in different ways and are interrelated. If volume-capacity ratios increase, then levels of service get worse and traffic speeds decrease. These concepts will be explained in more detail in the following sections.

2.1 Volume-Capacity Ratio

The volume or flow is defined as the number of vehicles passing a given point per unit time, whereas capacity is defined in terms of the maximum rate of flow per unit time at which vehicles can reasonably be expected to traverse a point according to prevailing roadway, traffic and control conditions (Transportation Research Board, 1985).

If we define capacity in this way, the volume-capacity ratio cannot exceed one (In contrast, some engineers identify capacity as "design capacity", which allows a design level of service, i.e. "c". With this definition, the volume-capacity ratio may exceed one).

Even if we can define the volume-capacity ratio as a maximum of unity, there are still some difficulties in defining traffic congestion. At which precise level of volume-capacity ratio should we regard a road as congested? It is quite subjective. A Japanese transportation engineering study group concluded that the v/c ratio of 0.80 on urban roads is the criterion for congestion (Korea
2.2 Levels of Service

The concept of levels of service is defined as a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers. A level-of-service definition generally describes these conditions in terms of such factors as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience, and safety (Transportation Research Board, 1985).

The concept of levels of service was first used in the Highway Capacity Manual in 1965. Six levels of service are defined for each type of facility. They are given letter designations, from A to F, with level-of-service A representing the best operating conditions, and level-of-service F the worst. The various levels of service are defined as follows for uninterrupted flow facilities (Transportation Research Board, 1985).

- Level-of-service A represents free flow: unaffected by the presence of others, freedom to select desired speeds and to manoeuvre in excellent comfort and convenience.

- Level-of-service B is in the range of stable flow: a slight decline in the freedom to manoeuvre from LOS A, less comfort and convenience than at LOS A, and so forth.

- Level-of-service C is in the range of stable flow:
significantly affected interactions with others, selection of speed affected by the presence of others, manoeuvring requires substantial vigilance, and noticeably declined comfort and convenience.

- Level-of-service D represents high-density, but stable, flow: severely restricted speed and freedom to manoeuvre, poor comfort and convenience, and small increases in traffic flow cause operational problems.

- Level-of-service E represents operating conditions at or near the capacity level: low speed, extremely difficult to manoeuvre, extremely poor comfort and convenience, high frustration of driver or pedestrian, small increases in flow cause breakdowns.

- Level-of-service F is used to define forced or breakdown flow: stop-and-go waves, traffic amount exceeds the amount which can traverse a point.

These definitions are general and conceptual in nature. For each type of facility, levels of service are defined based on one or more operational parameters which best describes the operating quality for the subject facility type. The parameters are called "measures of effectiveness." For the urban arterial level of service, the Transportation Research Board (1985) adopted the average travel speed as the measure of effectiveness. Table 3-1 shows the arterial levels of service.
Table 3-1: Arterial Levels of Service

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Average Travel Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt;= 56</td>
</tr>
<tr>
<td>B</td>
<td>&gt;= 45</td>
</tr>
<tr>
<td>C</td>
<td>&gt;= 35</td>
</tr>
<tr>
<td>D</td>
<td>&gt;= 27</td>
</tr>
<tr>
<td>E</td>
<td>&gt;= 21</td>
</tr>
<tr>
<td>F</td>
<td>&lt; 21</td>
</tr>
</tbody>
</table>

* Source: Transportation Research Board (1985)

Therefore, in the case of urban arterials, level of service criteria coincide with traffic speed criteria in determining the traffic congestion criteria.

The problem is determining what level of service is proper for congestion criteria. Considering the definition of each level of service and the bad road conditions in Seoul, we chose the level of service C as the congestion criteria. For example, if a road has a level of service below C, it is congested.

2.3 Traffic Speed

As shown in section 2.2, traffic speed criteria coincides with level of service criteria. Thus, congestion criterion speed is 35 km/h, which is about fifty percent of the free flow speed.

2.4 Conclusion

Congestion criterion speed plays a critical role in estimating
congestion costs. The variations of the estimated congestion costs depend largely on the congestion criterion speed. By reviewing three categories of congestion criteria -- volume-capacity ratio, levels of service and travel speed -- we concluded that the travel speed of 35 km/h is the best criterion for congestion.

3. COMPONENTS OF CONGESTION COSTS

3.1 Introduction

Vehicle use in a congested traffic network creates costs for other users of the network which are not taken into account in individual transport decisions (Bertrand, 1978). External costs imposed on the rest of society by vehicles consist of road damage costs, congestion costs, accident externalities, and environmental pollution costs (Newbery, 1988). The congestion factors which are taken into consideration in this chapter are limited to higher vehicle operating costs and travel time delays caused by reduced travel speeds due to congestion. The reasons we do not concentrate on environmental pollution costs and so on are that they are very difficult to quantify and that they are relatively small (Bertrand, 1978).

3.2 Vehicle Operating Costs

Vehicle operating costs consist of fuel costs, oil and tire costs, repair and maintenance costs, and depreciation related to vehicle use (Bertrand, 1978). In analyzing the vehicle operating costs, we
treat particular vehicles as representative of all vehicles within the four classifications: (1) passenger cars: 1,500 cc; (2) bus: occupying more than 25 persons; (3) taxi: same as passenger cars; (4) truck: loading capacity 4.5 - 10.0 ton.

3.2.1 Fuel Costs

Among total vehicle operating costs, the portion of fuel costs differs according to vehicle types and travel speeds. Generally, a decrease in travel speed due to congestion increases fuel consumption. Therefore, it is necessary to establish the relationship between fuel consumption and travel speed and vehicle type. As shown in Table 3-6, for a passenger car, it is most economical when driving at the speed of 75 km/h where it consumes 0.051 l/km. A bus consumes 0.168 l/km at the speed of 67 km/h.

Table 3-2: Fuel Consumption at Various Speeds

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Travel Speed (km/h)</th>
<th>unit: l/km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>P. Car</td>
<td>0.079</td>
<td>0.066</td>
</tr>
<tr>
<td>Bus</td>
<td>0.709</td>
<td>0.230</td>
</tr>
<tr>
<td>Truck</td>
<td>0.309</td>
<td>0.233</td>
</tr>
</tbody>
</table>

Note: the above figures are calculated from the equations below:

- Passenger Car: \((4.0031 + 0.41167 \times S - 0.002741 \times S^2)^\prime\)
- Bus: \(-0.000062 + 7.539 / S + 0.0000123 \times S^2\)
- Truck: \(-0.000912 + 7.4865 / S + 0.00001602 \times S^2\)

* Source: Korea Transport Institute (1987)
Korea Energy Institute (1992)
3.2.2 Oil and Tire Costs

Consumption of oil is affected mainly by engine speed rather than travel speed. Thus, it is quite difficult to measure oil consumption at various speeds. Bertrand (1978) assumes that oil costs are a constant portion of fuel costs by vehicle; that is, speed affects oil consumption in the same way as fuel consumption. He indicates that, for passenger cars, oil use in litres is 1.6 percent of gasoline use; for buses, oil use in litres is 3.53 percent of gasoline use; the percentage for heavy trucks is 2.73 percent.

With regard to the costs associated with tire wear, Bertrand (1978) made the assumption that tire wear costs increase in proportion to fuel costs. Research by the Korea Transport Institute showed that tire wear is inversely proportional to travel speed (see Table 3-7). That is, as congestion increases, tire wear decreases.

Table 3-3: Tire Wear

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Speed</th>
<th>Unit: % / 1,000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23</td>
<td>32</td>
</tr>
<tr>
<td>Passenger Car</td>
<td>4.23</td>
<td>5.56</td>
</tr>
<tr>
<td>Bus</td>
<td>1.14</td>
<td>1.56</td>
</tr>
<tr>
<td>Truck</td>
<td>1.14</td>
<td>1.56</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1987)

Oil cost increases due to congestion might be offset by tire cost decreases. Therefore, in this study, we do not consider oil and...
tire costs in estimating congestion costs.

3.2.3 Repair and Maintenance Costs

The factors affecting repair and maintenance costs are travel speed, road and traffic conditions, weather, driving skill, and related issues. We think that the influence of travel speed on repair and maintenance is relatively small. Moreover, Korea Transport Institute (1987) showed that repair and maintenance costs are also inversely proportional to travel speed. Thus we do not take into account repair and maintenance costs in calculating congestion costs in Seoul.

3.3 Travel Time Costs

3.3.1 Introduction

Besides vehicle operating costs, congestion increases travel time costs. In order to estimate the travel time costs due to congestion, the value of time should be estimated in advance. Approaches to estimating the value of time can be categorized broadly into two types: revealed preference and stated preference. Revealed preference approaches look for situations where people make choices which involve time-money trade-offs. The situations which have been used in this approach are choice of mode, route, speed, and location.

Stated preference methods rely on people's stated valuations of travel time; for example, what people say they will do as being
distinct from what they actually do. There is the obvious risk in using stated preference methods that people will not take the questions seriously, or will have ulterior motives for the answers they give.

Most of the studies conducted are based on the revealed preference approach and the situations most commonly used involve revealed choice of transport modes or routes. But nowadays more and more studies are using the stated preference approach.

The main attributes that affect the value of time are trip purposes and income levels (these are related to trip modes). We divided trip purposes into two categories: business trips and non-business trips. Income levels are also categorized into two groups: high income level (those using passenger cars or taxis) and average income level (those using buses or subway/railway). In this study, we estimated the value of travel time by travel purposes and income levels.

3.3.2 Time Value of Business Travel

In most of the studies conducted to estimate the value of time, the trip purpose was commuting (non-business trip). It is quite rare to estimate the time value of business travel. Dawson and Everall (1972) showed that the time value of business trips is about seventy-five percent of wage rate. Waters (1992) recommended that both drivers and passengers of passenger cars be assigned a value
of 120 percent of wage rate. We assumed that the time value of business trips is one-hundred percent of wage rates.

The wage rate is calculated from average income and average work hours of the passengers and driver of the different vehicle types. The wage rate for passengers and driver of passenger cars was calculated as 6,174 won/hour. It may be argued that the wage rate of the driver is different from those of the passengers but we cannot find any data or research that distinguish between them. Moreover, as Waters (1992) recommended the same time value for both of them, we assumed that they are identical. The wage rates of bus, taxi, and truck drivers are 4,147 won/hour, 2,877 won/hour and 4,332 won/hour, respectively. For the wage rates of bus passengers, we used the average income of overall employees (see Table 3-8).

Table 3-4: Time Value of Business Trips

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Average Income per Month (won)</th>
<th>Average Work Hours per Month (hour)</th>
<th>Time Value (won/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- driver &amp; passenger</td>
<td>1,287,380</td>
<td>208.5</td>
<td>6,174</td>
</tr>
<tr>
<td>Bus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- driver</td>
<td>970,294</td>
<td>234.0</td>
<td>4,147</td>
</tr>
<tr>
<td>- passenger</td>
<td>845,300</td>
<td>208.5</td>
<td>4,054</td>
</tr>
<tr>
<td>Taxi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- driver</td>
<td>676,156</td>
<td>235.0</td>
<td>2,877</td>
</tr>
<tr>
<td>- passenger</td>
<td>1,287,380</td>
<td>208.5</td>
<td>6,174</td>
</tr>
<tr>
<td>Truck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- driver</td>
<td>847,727</td>
<td>195.7</td>
<td>4,332</td>
</tr>
</tbody>
</table>

3.3.3 Time Value of Non-Business Trips

Non-business trips can be distinguished as commuting, shopping and leisure trips (Waters, 1992). The time values of these trips also differ by the purpose of the trip. However, as the main category of non-business trips are commuters' trips, we assumed that the time value of commuting trips is representative of the time value of non-business trips. Most empirical studies estimate the value of time for commuting trips. The range of the time value is from twelve percent to eighty-two percent of wage rate, as shown in Table 3-9.

<table>
<thead>
<tr>
<th>Author</th>
<th>Country</th>
<th>Percentage of Wage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopher, P. (1968)</td>
<td>U.K.</td>
<td>21 - 32</td>
</tr>
<tr>
<td>Lee &amp; Dalvi (1971)</td>
<td>U.K.</td>
<td>40</td>
</tr>
<tr>
<td>Talvittie, A. (1972)</td>
<td>U.S.A.</td>
<td>12 - 14</td>
</tr>
<tr>
<td>McDonald, J. (1975)</td>
<td>U.S.A.</td>
<td>45 - 78</td>
</tr>
<tr>
<td>Guttman, J. (1975)</td>
<td>U.S.A.</td>
<td>63</td>
</tr>
<tr>
<td>Ghosh, et. al. (1975)</td>
<td>U.K.</td>
<td>73</td>
</tr>
<tr>
<td>McFarland &amp; Chui (1985)</td>
<td>U.S.A.</td>
<td>82</td>
</tr>
</tbody>
</table>

* Source: produced from Waters (1992)

For this study we concluded that the time value of non-business trips was fifty percent of the wage rate. And we adopted the average income of overall employees as the wage rate. Thus the time value of non-business trips is 2,027 won/hour.
4. ESTIMATION OF CONGESTION COSTS IN SEOUL

4.1 Introduction

We estimated the congestion costs by comparing the actual travel speed with the congestion criteria speed. The equation we used is as follows:

\[
\text{Congestion Costs per Day} = \text{Vehicle Operating Costs} + \text{Travel Time Costs}
\]

\[
= \text{Sum of} (FCA_i - FCC_i) \times F_P \times D \times N \times V_i + \text{Sum of} \left( \frac{D}{FCA_i} - \frac{D}{FCC_i} \right) \times \left( (VTB_D_i + VTB_P \times P_i) \times B_i + (VTN_D_i + VTN_P \times P_i) \times N_i \right) \times N \times V_i
\]

where:

\[
FCA_i = \text{fuel consumption per km by vehicle type } i \text{ at the actual travel speed}
\]

\[
FCC_i = \text{fuel consumption per km by vehicle type } i \text{ at the congestion criteria speed}
\]

\[
F_P = \text{price of fuel used by vehicle type } i
\]

\[
D_I = \text{average daily travel distance of vehicle type } i
\]

\[
N \times V_i = \text{number of vehicle type } i
\]

\[
VTB_D_i = \text{time value of business trip for driver in vehicle type } i
\]

\[
VTB_P = \text{time value of business trip for passenger in vehicle type } i
\]

\[
P_i = \text{average number of passengers in vehicle type } i
\]

\[
B_i = \text{ratio of business trip by vehicle type } i
\]

\[
VTN_D_i = \text{time value of non-business trip for driver in vehicle type } i
\]
VTNP\textsubscript{i} = time value of non-business trip for passenger in vehicle type "i"

\( N_i \) = ratio of non-business trip by vehicle type "i"

In order to calculate congestion costs using the above equation, we need data on average daily travel distance by vehicle type, average occupancy, ratio of business trips and non-business trips, fuel price, and traffic concentration rate during congestion period.

Average daily travel distance is 63.9 km for passenger cars, 312.0 km for taxis, 267.2 km for buses, and 212.7 km for trucks as shown in Table 3-10.

Table 3-6: Average Daily Travel Distance

<table>
<thead>
<tr>
<th></th>
<th>Passenger Car</th>
<th>Taxi</th>
<th>Bus</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>63.9</td>
<td>312.0</td>
<td>267.2</td>
<td>212.7</td>
</tr>
</tbody>
</table>


Average occupancy by vehicle type and ratio of business trips and non-business trips are shown in Table 3-11 and Table 3-12, respectively.

Table 3-7: Average Occupancy

<table>
<thead>
<tr>
<th>Persons/Vehicle</th>
<th>Passenger Car</th>
<th>Taxi</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9</td>
<td>2.32</td>
<td>28.1</td>
<td></td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1987)
Table 3-8: Shares of Business Trips and Non-Business Trips

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Business Trip</th>
<th>Non-Business Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>30.8</td>
<td>69.2</td>
</tr>
<tr>
<td>Taxi</td>
<td>21.8</td>
<td>78.2</td>
</tr>
<tr>
<td>Bus</td>
<td>6.5</td>
<td>93.5</td>
</tr>
<tr>
<td>Truck</td>
<td>72.5</td>
<td>27.5</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1992)

Fuel prices (before tax) in 1991 were as follows: for gasoline, 213.74 won/l, for diesel, 128.87 won/l (Ministry of Energy and Resources).

For calculating traffic concentration rate, we used the average hourly traffic volume measured by the Seoul Department of Police. There is not a great difference in traffic concentration rate among morning peak, evening peak, and the mid-day period (see Table 3-13).

Table 3-9: Traffic Concentration Rate

<table>
<thead>
<tr>
<th>Description</th>
<th>Morning Peak</th>
<th>Evening Peak</th>
<th>Mid-Day</th>
<th>All-Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Volume</td>
<td>262,552</td>
<td>251,236</td>
<td>227,626</td>
<td>3,852,840</td>
</tr>
<tr>
<td>(vehicle/hr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentration</td>
<td>6.8</td>
<td>6.5</td>
<td>5.9</td>
<td>100</td>
</tr>
<tr>
<td>Rate (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Source: Seoul Department of Police (1990)

In this study we assumed the morning peak period to be from 07:30 to 09:00, the mid-day period to be from 09:00 to 18:00, and the
evening peak period to be from 18:00 to 20:00. Thus the total congestion period is assumed to be from 07:30 to 20:00 (12.5 hours), and the traffic concentration rate during the congestion period is 76.3 percent (see Table 3-14).

Table 3-10: Traffic Concentration Rate During Congestion Period

<table>
<thead>
<tr>
<th>Description</th>
<th>Morning Peak (07:30-09:00)</th>
<th>Mid-Day (09:00-18:00)</th>
<th>Evening Peak (18:00-20:00)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration Rate %</td>
<td>10.2</td>
<td>53.1</td>
<td>13</td>
<td>76.3</td>
</tr>
</tbody>
</table>

* Source: Produced from Table 3-13

4.2 Vehicle Operating Costs

Extra fuel consumption and fuel costs due to congestion are given in Table 3-15. The total daily fuel losses amount to 6,547 thousand litres. They consist of 986 thousand litres of gasoline and 5,561 thousand litres of diesel. Converting these amounts into 1991 current values, the total fuel costs amount to 9.7 million won. Fuel costs by vehicle type are shown as amounting to 163 million won for passenger cars (17.5%), 273 million won for buses (29.5%), 48 million won for taxis (5.2%), and 443 million won for trucks (47.8%)
Table 3-11: Extra Fuel Costs due to Congestion

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Fuel Loss (thousand litre)</th>
<th>Fuel Cost (thousand won)</th>
<th>Ratio(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>762</td>
<td>162,918</td>
<td>17.5</td>
</tr>
<tr>
<td>Bus</td>
<td>2,122</td>
<td>273,409</td>
<td>29.5</td>
</tr>
<tr>
<td>Taxi</td>
<td>224</td>
<td>47,870</td>
<td>5.2</td>
</tr>
<tr>
<td>Truck</td>
<td>3,440</td>
<td>443,317</td>
<td>47.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6,548</td>
<td>927,514</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* Source: Calculated by the author

4.3 Travel Time Costs

Table 3-16 shows the total daily time loss costs by vehicle type due to congestion. The total time costs amount to 27,716 million won. For passenger cars the time costs come to 5,108 million won; for buses, 19,157 won; for taxis, 1,518 million won; for trucks, 1,933 million won. The ratio of time costs for buses to total time costs is 69.1 percent, which is the largest portion of total time loss costs.

Table 3-12: Estimated Travel Time Costs in Seoul Due to Congestion

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Time Costs (thousand won)</th>
<th>Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>5,107,554</td>
<td>18.4</td>
</tr>
<tr>
<td>Bus</td>
<td>19,156,635</td>
<td>69.1</td>
</tr>
<tr>
<td>Taxi</td>
<td>1,518,478</td>
<td>5.5</td>
</tr>
<tr>
<td>Truck</td>
<td>1,933,058</td>
<td>7.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>27,715,725</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* Source: Calculated by the author
In this study we assumed that total congestion costs consisted of vehicle operating costs (fuel costs) and travel time costs. The sum of fuel costs in Table 3-15 and time costs in Table 3-16 gives total congestion costs. As shown in Table 3-17, most congestion costs accrue to travel time costs (96.7%). It is notable that the congestion costs of bus passengers are huge and account for about 68 percent of total congestion costs. This explains why many measures to reduce urban congestion place emphasis on increasing the service quality of mass transit.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Fuel Costs</th>
<th>Time Costs</th>
<th>Total Congestion Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount</td>
<td>Ratio</td>
<td>Amount</td>
</tr>
<tr>
<td>Pax Car</td>
<td>162,918</td>
<td>0.6</td>
<td>5,107,554</td>
</tr>
<tr>
<td>Bus</td>
<td>273,409</td>
<td>1.0</td>
<td>19,156,635</td>
</tr>
<tr>
<td>Taxi</td>
<td>47,870</td>
<td>0.2</td>
<td>1,518,478</td>
</tr>
<tr>
<td>Truck</td>
<td>443,317</td>
<td>1.5</td>
<td>1,933,058</td>
</tr>
<tr>
<td>TOTAL</td>
<td>927,514</td>
<td>3.3</td>
<td>27,715,725</td>
</tr>
</tbody>
</table>

* Source: Calculated by the author

5. CONCLUSIONS

We estimated the congestion costs in Seoul by using some assumptions and relatively simple data on average travel speed, average travel distance, average occupancy by vehicle type, and other factors. Despite the crudeness of our estimation due to lack
of data, we can learn some important lessons from the magnitude of congestion cost estimates.

First, the magnitude of congestion costs in Seoul is much greater than most people realize. The reason is that since the great majority of the congestion costs occur in the form of travel time, people do not tend to value their lost time in monetary terms.

Second, as most congestion costs may be attributed to bus use, policy priorities to decrease traffic congestion should be put on mass transit. Once the service quality of mass transit is improved, this mode can attract current passenger car users. That will reduce urban congestion even more.

Third, the portion of fuel costs is relatively small. Thus in reducing congestion, the policy alternatives for decreasing travel time should be considered more important than those for increasing fuel costs.

Fourth, these overwhelming congestion costs can be a warning to vehicle users and policy developers. They should keep in mind that vehicle use in a congested traffic network creates costs for other users of the network which are not taken into account in their individual transport decisions (Bertrand, 1978).

Finally, total congestion costs estimated in this study are current
congestion costs (at the end of 1991). These figures will be greater and greater in the future as the number of vehicles increases. Thus some proper measures to reduce congestion in Seoul are imminent.
CHAPTER 4
DEVELOPMENT OF ALTERNATIVES TO REDUCE TRAFFIC CONGESTION

1. DEFINITION OF TRANSPORTATION DEMAND MANAGEMENT

Transportation Demand Management (TDM) measures are actions and policies that try to change people's travel behaviour to reduce the amount of vehicle traffic and congestion (Transport 2021, 1993). TDM measures also come in "carrot" and "stick" varieties. "Carrot" measures are relatively easy to implement, are voluntary and emphasize incentives to encourage people to change their travel behaviour. "Stick" measures are mandatory and rely on time and cost penalties to actively discourage solo driving (Transport 2021, 1993). "Stick" measures are also referred to as "Traffic restraint measures" by May, A.D. (1986). He defined them as "those that impose a restriction on vehicle use in order to achieve a significant modification in the mode, time, route, or destination of journeys." Thomson (1968) defined traffic management as all physical measures designed to influence the movement of traffic on an existing network.

In this study TDM measures are defined as all the measures which are adopted with the intention of reducing traffic volume and congestion.

2. CATEGORIES OF TDM MEASURES

The various TDM measures can be categorized by the following two
criteria (Transport 2021, 1993).

First: ease of implementation. Most "carrot" TDM measures are relatively easy to implement because they use incentives rather than penalties to encourage changes in travel behaviour. "Stick" TDM measures involve financial penalties such as tolls, taxes and increased travel time costs to affect travel decisions.

Second: effect. TDM measures may have three main effects. (1) Modal shift: some measures shift transport modes from automobiles to high occupancy vehicles. (2) Trip elimination: some measures reduce the person-trips made. (3) Shift peak demands: some measures shift trips from peak periods to off-peak periods.

Thomson (1972) divided measures for limiting traffic into three groups according to the level of impact on travel desires: traffic restriction, traffic restraint, and traffic avoidance. Traffic restriction was categorized again as physical and legal measures, and traffic restraint as fiscal and physical measures. May (1986) categorized traffic restraint measures in terms of the stage in the process of car acquisition and use at which restraints are imposed: restraints on ownership, restraints on the destination for a journey, restraints while the car is in use, and in terms of the type of penalty: physical restrictions, time penalties, regulatory controls and price.
In this study we categorized the TDM measures by use of incentive and by type of control. Table 4-1 presents a list of TDM measures categorized by the above criteria.

Table 4-1: Categories of TDM Measures

1. Carrot TDM Measures
   - Preferential Treatment for HOVs
   - Improvement of Transit System
   - Introduction of Para-transit
   - Encouragement of Ridesharing
   - Variable Work Hours

2. Stick TDM Measures
   1) Physical Restraints
      - Parking Supply Controls
      - Traffic Zone Systems
   2) Regulatory Restraints
      - Odd and Even Days Rule
      - Road Use Permit System
   3) Use of Pricing System
      - Taxation of Cars
      - Fuel Tax
      - Parking Charges
      - Charging for Road Usage

The rest of this chapter describes each measure in Table 4-1 in terms of its main characteristics, its advantages and disadvantages from actual experiences and/or from academic researches.
CARROT TDM MEASURES

3. Preferential Treatment for HOVs

3.1 Characteristics

Preferential treatment for high occupancy vehicles (HOV) gives travellers an incentive or reward for travelling by mass transit or in autos with multiple occupants (car pools or van pools). The incentives can broadly be categorized into four types (Transport 2021, 1993).

1) Economic incentives: some measures, such as reduced parking fees for HOVs, reduce the costs for the HOV user.

2) Convenience incentives: some measures, such as park-and-ride spaces for car pool users, make a particular trip more convenient for the HOV user.

3) Space incentives: some measures, such as transit malls and auto restricted zones, reserve transport facilities for HOV use only.

4) Time incentives: some measures, such as HOV lanes and traffic signal preemption, decrease the travel time for HOV users.

3.1.2 Advantages

One of the major characteristics of the HOV is its efficiency in moving large numbers of people for the same amount of road space compared to low occupancy cars. Thus, these measures reduce overall travel delays due to traffic congestion, and lower air pollutant emissions and energy consumption (Transport 2021, 1993). Moreover, as the HOVs generally offer services for the majority of
people without cars and play a key role in meeting the increasing demand for transport not only from lower income groups but also for society as a whole, it is fair to give preferential treatment to HOVs.

Furthermore, because many of the HOV preferential treatment measures result in travel time savings for HOV users, they can sometimes reduce total travel time for all vehicle users. Most of the measures for preferential treatment of HOVs have low capital costs and thus can be implemented relatively quickly (Transport 2021, 1993).

3.1.3 Disadvantages

In the case of concurrent flow HOV lanes, problems have resulted from non-priority vehicles using the lanes. The effectiveness of HOV priority lanes is closely related to the enforcement of them. It might require substantial enforcement resources to ensure that non-priority vehicles do not use HOV priority lanes.

Designating an existing traffic lane as a contra flow HOV lane is most practical on road sections having a strong directional imbalance of traffic volumes during peak periods (Transport 2021, 1993). Moreover, the violations which are common in the concurrent flow HOV lanes are very rare in the contra flow lanes due to their nature. There might be some problems in contra flow lanes with regard to traffic safety.
3.2 Improvement of Transit Systems

3.2.1 Characteristics

The fundamental strategy for improving the transit system is to encourage auto users to shift to the more efficient high occupancy modes of transport.

According to Thomson (1977), attempts to improve traffic conditions by providing more road capacity would shift travellers from public transport to private transport, which would eventually restore existing congestion levels and lower the quality of road travel to a new equilibrium, but transit ridership is less than before, thus aggravating the problems facing transit operators.

Mogridge (1985) conjectured that the only way to increase the road speed within and around the central conurbation is to increase the speed of rail or other high-capacity systems where car travel has a large suppressed demand. Also, numerous studies have correctly pointed out that the attractiveness of transit system is most sensitive to frequency and accessibility.

3.2.2 Advantages

Transit systems provide the most efficient means of moving large numbers of people, especially in dense urban areas. The maximum capacity of rapid rail transit was estimated at 60,000 passengers per hour per track; that of LRT was about 36,000; and that of buses
was 30,000 passengers per hour per lane. In contrast, the maximum number of persons which cars are able to carry was estimated at about 3,500 persons per hour per lane at the average occupancy of 1.5 persons (World Bank, 1986).

Bus services provide considerable flexibility in meeting demands for transport at various levels of quality and quantity. In many developing countries, buses are the only means of mobility that can be afforded by the urban poor (World Bank, 1986). Improved services of transit systems are helpful to those without cars and the poor in the community.

It is generally considered that well-designed modern railway systems cause minimal environmental impact (except during construction periods). Underground railways do not cause any complaints about their impact on the environment except for ground vibrations. However, the main benefit of rail transit systems could be reduction in road traffic resulting from passengers travelling by train rather than cars or buses.

3.2.3 Disadvantages

The capital and operating costs for rail transit systems differ from system to system. Massive construction and operating costs are indicated as the greatest drawback of rapid transit systems. The capital costs of underground rail systems are estimated as about 25 billion won per km in Korea (Ministry of Transportation).
The construction cost of the Sao Paulo Metro was $2,338 million, or $96 million per km at 1983 prices; the Caracas Metro' cost was estimated to be $1,440 million, or more than $117 million per km (World Bank, 1986). In the case of the Hong Kong Mass Transit Railway system, a heated controversy arose on account of the massive capital investment involved (Edwards, 1982).

The environmental impact of the construction of rapid rail systems includes many aspects. During the construction period, road traffic congestion can be a serious problem in a built-up area, together with noise, dust, visual obstruction, and so on.

Finally, there is the possibility that insufficient auto users would divert to the rail system, thus leaving the roads congested and under-utilization of costly transit investments.

3.3 Introduction of Para-Transit

3.3.1 Characteristics

Urban transportation alternatives have been traditionally perceived in terms of the private automobile versus conventional fixed route transit systems (Roos & Alschuler, 1975). As transit systems operate on fixed schedules and routes, they do not compete effectively with the automobile which operates on variable schedules and routes. Para-transit falls between the polar extremes represented by fixed route, fixed schedule transit
services and the completely flexible nature of automobile transport (Roos & Alschuler, 1975). Para-transit is defined by Silcock (1981) as "motorized public transport modes which have some flexibility in at least one of the characteristics of route, frequency or fare in contrast to bus or rail services, which are assumed to be constrained in all three." The concept of para-transit includes the use of dial-a-bus services, minibuses, jitneys, jeepneys, subscription buses, and so on.

3.3.2 Advantages

Para-transit is recognized as providing more flexible services with relatively higher speeds than conventional buses or rail systems. On the other hand, para-transit has a much larger capacity than cars. One of the major changes brought about by the deregulation of buses in the United Kingdom has been the increase in the number of minibuses. This reveals the advantages of minibuses (Banister & Mackett, 1990). Passengers perceive minibuses as more accessible, fast, comfortable and convenient. Over 87 percent of respondents in Sunderland, U.K. found the convenience of hail-and-ride helpful (Banister & Mackett, 1990). The quality of service offered by minibuses reinforces the perceptions of convenience. Passengers tend to feel more secure in a smaller vehicle where everyone is close to the driver (Gomez-Ibanez & Meyer, 1987).

The travel speed of para-transit is generally faster than those of the conventional buses. In Manila, an average travel speed of a
Jeepney on the 11-km route along the central corridor was 20 km/h in the off-peak period, whereas that of buses was 15 km/h (Gravas, 1972).

Minibuses are more suited for serving lower density areas and can offer greater route coverage. The replacement of large buses by small ones may be associated with a finer network of services or demand-responsive services, rather than higher frequencies (Banister & Mackett, 1990). It may reduce access time to minibuses and generate additional patronage.

As well as offering flexibility over space, minibuses offer flexibility over time in the sense that they may be more suitable for low levels of off-peak patronage and that the greater frequency used in the peak to match the capacity of large buses can be reduced in the off-peak, while still providing acceptable service (Banister & Mackett, 1990).

3.3.3 Disadvantages

A minibus requires the same number of staff to operate it as a large bus, so the operating costs of small buses are likely to be higher than large buses. Thus, higher fares would be charged by minibuses than conventional buses.

More minibuses are required to provide the same capacity as large buses. Therefore, minibuses may produce a net increase in traffic.
flow and could worsen traffic congestion (Unless much of their traffic is diverted from cars rather than from other public transit). Banister and Mackett (1990) concluded from discussions with operators that the increase in the size of the minibus fleet is an important contributing factor to off-road congestion.

Accessibility to minibuses does cause difficulties for elderly people due to the high step heights and the relatively narrow entrances. Storage space for luggage and shopping on the vehicle is also restricted (Banister and Mackett, 1990).

The accident rate of para-transit is often claimed to be high, mainly due to frequent stopping and starting to pick up and discharge passengers.

3.4 Encouragement of Ridesharing

3.4.1 Characteristics

Ridesharing can take the form of car sharing and van pooling. Bonsall (1981) defined car sharing as a global term which encompasses lift-giving and car pooling. Car pooling is a practice in which drivers take turns driving one another to a common destination. Van pooling is a more specialized form of lift-giving in which the driver uses a minibus rather than an ordinary car.

One of the key steps in implementing a ridesharing program is ride matching. There are various ways to make prospective matches. One
simple scheme is to put up a large map of the local area and have employees interested in ridesharing put pins in the map indicating where they live. Each person living in a given zone can then be provided with the names and telephone numbers of co-workers living in the same area, so they can arrange ridesharing. Ride matching can also be conducted by using ride matching software programs (Transport 2021, 1993).

In the U.S. from 1974, when the Emergency Highway Energy Conservation Act authorized the use of the Federal Aid Highway Funds to finance ninety percent of the cost of car pool demonstration projects, the impetus for expanded governmental involvement in the encouragement of car sharing has been remarkable. A total of 106 car sharing projects in thirty-four states and ninety-six urban areas, and twelve thousand van pools had been approved by 1981 since the introduction of the program (Greening & Jackson, '1984).

3.4.2 Advantages

Well-designed ridesharing programs can increase average vehicle occupancy and reduce vehicle-trips, vehicle-kilometres of travel, air pollution and energy consumption. In Los Angeles, Commuter Transportation Services Inc. coordinated approximately 250,000 commuters and has been successful in attracting two to four percent of the total commuters in the area to ridesharing (Transport 2021, 1993).
In the case of lift-giving, public transport users can have the chance of using more comfortable and convenient transport modes.

Ridesharing participants can also enjoy substantial cost savings over solo driving, as shown in Table 4-2 (Transport 2021, 1993).

Table 4-2: Monthly Commute Costs

<table>
<thead>
<tr>
<th>Daily Commute (miles)</th>
<th>Driving Alone</th>
<th>3-Person Carpool</th>
<th>Vanpool (13 Riders)</th>
<th>Vanpool Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>165</td>
<td>55</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>50</td>
<td>231</td>
<td>77</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>70</td>
<td>300</td>
<td>100</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>90</td>
<td>366</td>
<td>122</td>
<td>67</td>
<td>0</td>
</tr>
</tbody>
</table>


Employers have also benefitted from employee ridesharing programs because employees arrive at work less stressed and absenteeism and tardiness are reduced (Transport 2021, 1993).

3.4.3 Disadvantages

Most empirical studies show that the effectiveness of ridesharing programs is quite questionable. The percentage of target population who became car sharers did not exceed two percent in the U.K. program (Bonsall, 1981). In the U.S. car sharing program, the reduction in average vehicle miles travelled averaged 0.7 percent of work trip vehicle miles travelled. These achievements are far less than the initially stated aim in 1974 to reduce commuting vehicle miles by about twenty percent (ITE, 1981).
Moreover, ridesharing normally increases the travel time of participants compared to solo driving because of passenger pick-ups and drop-offs. It is also somewhat less convenient. One concern is not having a personal automobile at one's disposal at work in case of emergencies or unscheduled overtime (Transport 2021, 1993).

Another problem is that public transport users form a large portion of the applicants and participants of ridesharing programs. As a result, the overall net reduction in car traffic is small.

3.5 Variable Work Hours

3.5.1 Characteristics

Variable work hour schemes spread work trips over the day, thereby reducing peak period trip demand. The three basic types of variable work hours programs are as follows (Transport 2021, 1993).

1) Flexible hours: This also called flex-time. Employees can choose their own start and finish times within guidelines set by the employer. For example, an employee could work from 7 a.m. to 3 p.m. instead of the conventional 9 a.m. to 5 p.m.

2) Staggered hours: A staggers hours work schedule has different start and finish times for different departments of the organization. For example, workers in department A could work from 8 a.m. to 4 p.m. while those
in department B work from 10 a.m. to 6 p.m.

3) Compressed work weeks: In this option employees complete their required number of work hours in a fewer number of days than the standard 5 (or 6) day work week. The two most common forms of compressed work weeks (at 40-hours-per-week) are: "Nine/Eighty", in which two weeks' work is completed in nine days; and "Four/Forty", where one weeks' work is done in four days. As opposed to flexible hours and staggered hours, compressed work weeks actually reduce the total number of work trips.

3.5.2 Advantages

By displacing some peak-period work trips to other times of the day and by eliminating some work trips together, variable work hour programs can reduce peak-period traffic congestion. A flex-time demonstration project implemented in San Francisco in 1979 provided voluntary guidelines to employees on how to design and operate flexible work scheduling procedures at their offices. Some six thousand employees, or 2.3 percent of the downtown San Francisco workforce, took part in the project. Most participants chose to arrive at work earlier than the previous time. On average, transit riders saved six minutes per trip and auto commuters saved nine minutes per trip by avoiding the peak hour congestion (Transport 2021, 1993).
A compressed work week experiment was implemented for U.S. federal government employees in Denver between 1978 and 1981. Employees were given the opportunity of working a Four/Forty or Nine/Eighty schedule instead of the standard five-day work week. Among those who chose a compressed work week, almost sixty percent took Friday off and thirty-six percent took Monday. Total vehicle-miles-travelled fell by fifteen percent for the participating employees (Transport 2021, 1993).

3.5.3 Disadvantages

Variable work hours could affect the productivity of employees negatively, especially work that requires cooperation or coordination of other employees and/or other organizations.

Variable work hours could work against ridesharing because fewer people would have the same start and finish times. Also, individuals with compressed work weeks may make additional vehicle trips for errands on their days off. These trips could offset the reduction in vehicle trips to work.

4. "STICK" TDM MEASURES

4.1 Physical Restraints

Physical restraints are defined as those measures which deny or restrict access to specific parts of the road system by means of
physical barriers. In subsequent sections we will review two types of physical restraints: parking supply controls and traffic zones.

4.1.1 Parking Supply Controls

4.1.1.1 Characteristics

A freeze or a ceiling could be placed on the total number of non-residential parking spaces available within a well-developed area, such as a central business district (Transport 2021, 1993). Most studies in the U.K. in the 1960s proposed parking controls as the most readily available means of traffic restraint (May, 1986). This is because they provide a direct form of restraint on the trip ends.

Controls on parking supply can be imposed on three different types of parking facilities: on-street parking, public off-street parking and private parking.

Controls on on-street parking can be imposed by removal of spaces. For example, in central London from 1962 to 1974 nearly sixty percent of on-street parking spaces were removed (May, 1975b).

Publicly operated public car parks include those owned and operated by the local authority, those operated for them under a management agreement, and those over which they have direct control through planning conditions. The full range of control is available for
such car parks (May, 1986).

For private car parks, the only available control is that of planning permission on the provision of new spaces.

4.1.1.2 Advantages

When implemented in appropriate localities, parking supply controls can switch many low occupant auto trips destined to the locality to transit or car pool trips, thereby reducing traffic congestion.

Parking supply controls can be implemented with minimal costs to the city authority, while it does ignore costs on users.

4.1.1.3 Disadvantages

The fact that most parking space is outside local authority control substantially reduces the effectiveness of parking supply controls. The situation is made worse by the inability of parking controls to affect through traffic. In the case of London, whereas cars entering the city centre in the peak destined for public parking fell by thirty percent between 1962 and 1974, private parking and through traffic both doubled and, as a result, total traffic increased by thirty percent (May, 1975b).

The effectiveness of parking supply controls depends substantially on enforcement. Low levels of enforcement might result in an increase of illegal parking.
In addition, controls on parking supply might increase the vehicle operating costs and time costs of the car users who drive around looking for the few remaining parking spaces.

4.1.2 Traffic Zone Systems

4.1.2.1 Characteristics

Traffic zone systems usually involve physical or regulatory barriers to movement between zones within a designated orbital route (May, 1986). The principal features of traffic zone systems are as follows (Elmberg, 1972).

1) The central business district should be divided into zones.

2) Direct contact between zones by cars should be eliminated.

3) Contact between zones should only be permitted by utilizing routes outside the central business area.

4) The number of entrances and exits to each zone should be reduced to a minimum.

5) Vehicular movement should be permitted within each zone.

4.1.2.2 Advantages

Traffic zone systems redistribute vehicle flow according to the intention of transport planners. In Gothenburg, where a traffic zone system was implemented in 1970, a reduction of traffic volume by fifty percent was found on some of the streets, whereas there
was an increase of traffic volume by fifteen percent on the ring routes. Despite the increase of vehicle volume on the ring routes, surveys indicated an increase of the average travelled speed from 16.2 km/hour to 23.2 km/hour along the route clockwise, and from 14.6 km/hour to 22.3 km/hour along the route counter-clockwise. This was partially due to the redesign and signalization of an important intersection, but it was also due in part to the redistribution of vehicles on links of the radial and ring routes (Elmberg, 1972).

The cost of traffic zone systems is estimated to be moderate. The total cost in Gothenburg was estimated as SN. Crs. 1,130,000 (U.S. $220,000). Of the total cost, the reconstruction of intersections (including relocation of train stops and complete signalization) accounted for 82.3 percent, and the cost of other modifications such as route signing information accounted for the remainder (Elmberg, 1972).

4.1.2.3 Disadvantages

In order to implement the traffic zone systems, the existence of a ring route outside the central business district is the prerequisite condition. Thus this measure cannot be applied unconditionally to any city.

Traffic zone systems are also said to increase access distances from the orbital route to properties in the area, and such access
problems have often been a source of annoyance to residents (May, 1986).

Traffic zone systems are generally inflexible and unselective. As servicing and emergency vehicles can be adversely affected, some devices such as lockable posts or traversable curbs are to be incorporated with physical barriers to accommodate such vehicles (May, 1986).

One particular problem in traffic zone systems is the imbalance between demand for and supply of parking facilities within individual zones. This should be taken into account when dividing a certain area into several zones.

4.2 Regulatory Restraints

Regulatory restraints mandate certain behaviours or prohibit others. They prohibit or limit by government command the behaviours it wants to discourage and permit or require those it wants to encourage (Downs, 1992).

4.2.1 Odd and Even Days Rule

4.2.1.1 Characteristics

In odds and evens systems, vehicles whose plate numbers end with an even digit are excluded from using roads on odd-numbered dates; the remaining plate holders may not use roads on even-numbered dates.
The system operates in Athens and Lagos, where odd-numbered vehicles are permitted to enter the controlled area during the working day on certain days of the week, and even-numbered vehicles on the others (May, 1986).

In Lagos, vehicles with registration numbers beginning with an even digit shall not be driven along the designated highways between the hours of 6:00 a.m. and 6:00 p.m. on Monday, Wednesday and Friday of every week. Vehicles whose registration numbers begin with an odd digit shall not be driven on Tuesday, Thursday and Saturday of every week. However, the restraints do not apply to ambulances, military vehicles, police vehicles, diplomatic vehicles, Festival of Arts and Culture's Conference vehicles, or commercial and public transport, including taxi cabs (Ogunsanya, 1984).

4.2.1.2 Advantages

Odds and evens systems could certainly be effective in reducing congestion and environmental pollution. In the case of Lagos, according to interview data (Ogunsanya, 1984), fifty percent of the car owners used their cars to go to work "always", and the rest used them sometimes. When they did not use their cars, they shared a ride. About sixty percent of the respondents maintained that urban traffic flow greatly improved, and that there was a considerable reduction in the time spent between home and work.

The cost of implementing an odds and evens system is quite
negligible. It does not require massive capital investment. The main costs results from enforcement and administrative needs.

In addition, exemptions for car sharers will encourage car sharing.

4.2.1.3 Disadvantages

One of the major factors which reduces the effectiveness of odds and evens systems is ineffective enforcement. In Lagos, even though five thousand new traffic wardens were recruited for the scheme, the majority of car users were able to circumvent the restraint measures. According to the survey (Ogunsanya, 1984), seventy percent of the respondents agreed that they could use their cars throughout the month by bribing the traffic-wardens. In addition, very affluent people bought a second car -- and so had one with an even, the other with an odd final digit on the license plate. Some families with two cars bearing odd plates, for example, either sold one and bought another with an even plate or swapped one with another family having a car with an even plate.

With odds and evens systems, traffic is not necessarily reduced by one half; those whose vehicles are permitted on a given day may make additional trips or replace trips by those who are restricted. And there are the cost of interfering with people's preferred driving/commuting plans.
4.2.2 Road Use Permit System

4.2.2.1 Characteristics

In a road use permit system, road use is allocated on the basis of "trip need" and excludes vehicles without permits. The form of permit system varies depending on the basis for permit issue. Permits can be issued only to those easily identifiable users such as residents or to the disabled. It can be issued based on a demonstration of need to make the particular trip.

In London, a permit control system was proposed by Lane and Hodgkinson (1976) as an alternative to other types of traffic restraint such as restraint by congestion, parking controls, and supplementary licensing.

4.2.2.2 Advantages

A permit system would be fairer and more equitable than other traffic restraint measures such as cordon control type road pricing, providing that permits are issued for those who have essential need such as disabled or emergency vehicles (Lane and Hodgkinson, 1976).

4.2.2.3 Disadvantages

In a permit system, effective enforcement of violations and
checking for fraudulent permit applications would be particularly important. If this system is introduced in a large city, manpower required for enforcement and permit issuing would be significant. The major cost of a permit system results from enforcement and administrative needs.

4.3 Use of Pricing System

Measures based on use of pricing systems assign monetary value to different types of travel modes and then rely on travellers to choose among them. Their goal is to achieve more efficient use of scarce resources by making the prices of different travel options more nearly equal to their social costs so that marginal benefits will equal or exceed marginal costs (Downs, 1992). The underlying principle of the measures based on use of a pricing system is that socially optional traffic flow can be achieved when the amount which a marginal user is willing to pay for his use of the road is equal to the marginal social costs arising from his use (Button, 1982). This is shown in Figure 5-1.
The MSC curve represents the marginal social cost of the additional vehicle on existing road users. The MPC curve represents the marginal private cost curve. When the level of traffic flow is low, the marginal social cost equals the marginal private cost. As the level of traffic flow increases, the marginal social cost increases more rapidly than the marginal private cost, since the external costs imposed on other users increases rapidly as congestion rises. The individual road user makes his travel decision according to the marginal private cost. Then the equilibrium traffic flow is determined at Q1 and the cost is C1. But this decision ignores the external cost imposed on other road users.
users. From a social point of view, this is excessive because it imposes additional external costs of \( xy \) on society. The socially optimal flow is \( Q_2 \), where the marginal social cost is equal to demand. In order to decrease the demand for trips to \( Q_2 \), a toll of \( UV \) should be charged. While the basic theory of a congestion toll is comparatively straight-forward, its detailed implementation has been subject to debate (Button, 1982).

4.3.1 Taxation of Cars

4.3.1.1 Characteristics

A general method of inhibiting vehicle ownership is to establish high import duties, sales taxes, and annual licensing fees on vehicles (World Bank, 1986). In most countries taxes on cars have been introduced for various purposes, such as to raise general revenue, or to finance road building, or to limit the expenditure of foreign exchange. Taxes on cars would be perceived as a component of the price of owning cars. Therefore, the level and structure of the taxes influence the number of cars owned, the types of cars owned, and similar matters.

In Singapore, for example, a variety of taxes on cars were introduced to discourage car ownership (Smith, 1992). For instance, in mid-1990, a car with an open market value of S$10,000 was subject to customs duty at forty-five percent and an additional registration fee (ARF) of 175 percent, taking the new car price to S$32,000. To encourage early scrapping, a preferential additional
restriction fee (PARF) scheme was introduced in 1975 (revised in 1981). This provides that if a car is scrapped within ten years the owner pays a lower ARF for a replacement car.

In Hong Kong, the government tripled the annual license fee and doubled the first registration tax to typically eighty percent of a car's landed value (Dawson & Brown, 1985).

In practice, financial restraints on car ownership are likely to do little more than slow down the growth in the number of vehicles. As income levels rise, financial restraints must periodically be adjusted upward to remain effective (World Bank, 1986).

4.3.1.2 Advantages

When introduced properly, taxes on cars can influence vehicle ownership significantly in the short run. In Singapore, car registration dropped from 33,506 to 23,283 when additional registration fees and road taxes were increased by twenty-five percent and thirty percent respectively in 1983 (Spencer & Chia, 1985). In Hong Kong, significant tax increases in 1983 came at a time of economic downturn and led to a substantial reduction in car numbers. The licensed car fleet dropped by twenty-five percent as some fifty thousand cars came off the road (Dawson & Brown, 1985).

Taxes on cars result in a huge increase in government revenue while the costs are negligible. The revenue can be used to improve
traffic facilities and subsidize the transit system.

Taxation of car ownership may have a positive effect on the environment and on safety, depending on the degree of its impact on traffic. According to Dawson and Brown (1985), if car ownership restraint achieved twenty percent reduction in car registrations, then there would be up to a twelve percent reduction in vehicle emissions, and a six percent reduction in accident costs.

4.3.1.3 Disadvantages

A disadvantage of using the sales tax to discourage car purchases is that older cars may be less safe and break down more frequently, thereby adding to congestion (World Bank, 1986). It also deprives the low-income wage earners of the chance to purchase "my own car." Low-income households are less able to pay the prices imposed than are higher-income households. Thus it is argued that taxation on cars is regressive and inequitable. For example, in the case of Hong Kong, the people most affected by the additional tax on cars were believed to be lower-income car owning residents of the uncongested New Territories, where it is difficult to live without access to a car (Dawson & Brown, 1985).

4.3.2 Fuel Tax

4.3.2.1 Characteristics

Fuel tax increases the cost of automobile travel as a function of
use or distance and may restrain total use, but it does not affect
where and when an automobile is used. Since buses normally consume
less fuel than automobiles per passenger-kilometre carried, an
increase in the motor fuel tax would increase costs for auto travel
by a higher amount than for transit, improving the relative
economic attractiveness of transit to trip makers. Transit
vehicles could even be exempted from the fuel tax (Transport 2021,
1993).

The government of Egypt has kept the cost of fuel artificially low
for many years. As a consequence, the number of private cars in
Cairo has increased by seventeen percent per year, creating massive
congestion throughout the central city (World Bank, 1986). In this
case, an overall increase in fuel prices could have a significant
impact on the level of private car ownership and use.

4.3.2.2 Advantages

By making automobile travel more expensive, higher fuel taxes can
reduce the use of automobiles, thereby decreasing traffic
congestion, air pollution and fuel consumption. In particular, in
the aftermath of the oil crisis in the 1970s, many countries
increased fuel tax to reduce energy consumption.

Moreover, the fuel tax revenues could be placed in a dedicated
trust fund and used for transit improvements and TDM programs. The
provincial government of British Columbia currently collects a
gasoline tax of $.03 per litre in Greater Vancouver. The Vancouver Regional Transit Commission uses the tax revenues to pay part of the local share of B.C. Transit's operating and capital costs.

Another advantage of fuel tax is that it is simple to administer. Compared to taxes on car ownership, fuel tax as an indirect tax could save administrative costs and could reduce tax evasion.

4.3.2.3 Disadvantages

Since peak period work trips are less price-sensitive than trips such as shopping and recreation trips made mainly during off-peak hours, a higher fuel tax may have little effect in reducing peak period vehicle trips, and therefore on reducing road infrastructure requirements (Transport 2021, 1993). Many studies show that the sensitivity of peak period trips to petrol price changes is fairly small. According to Lewis (1978), petrol price elasticities for London were estimated as -0.024 on weekday peak and as -0.360 and -0.369 on Saturday and Sunday respectively. Blase (1980) concluded that only if petrol prices were to increase by more than thirty percent, would there be a substantial impact on traffic levels in London.

Fuel tax is non-selective and it does not discriminate where and when the vehicle is driven. A vehicle trip during rush hour on a congested freeway section may pay the same gas tax as an off-peak trip of the same distance on lightly used arterial streets, even
though the rush hour trip incurs more social costs (Transport 2021, 1993).

4.3.3 Parking Charges

4.3.3.1 Characteristics

A variety of parking pricing tools could be used to influence travel mode choice in favour of transit, or to reduce travel frequency. Major types of parking pricing measures could be classified as follows (Transport 2021, 1993).

1) Changing the rate structure of public sector parking: Set higher prices for long term parking, for rest period parking, and for single-occupant automobiles.

2) Parking tax: Levy a direct tax on parking spaces, such as an annual dollar amount per parking space. Such a tax could be applied universally, or only to specific types of parking spaces in designated zones.

Among a number of methods of parking control, pricing control has been the most commonly used form in many areas. This is because pricing control is more flexible and simple to operate and easier to understand than other measures of parking control (May, 1975).

In Singapore, parking charges within the restricted area were raised substantially to further discourage the use of private cars, as a complementary measure of the Area Licensing Scheme (World Bank, 1986).
4.3.3.2 Advantages

Appropriately imposed parking charges raise parking costs sufficiently to steer auto drivers in the direction of transit, thereby reducing traffic congestion. The effects of parking pricing on use of automobiles depends on the availability of alternative spaces and on the amount of through traffic. Elliot et al. (1977) estimated that in order to restrain fifty percent of present users of long term parking in central London, charges should be doubled; to restrain sixty percent, charges should be tripled.

Parking charges could produce substantial revenue, and this can be used to help fund the required transit improvements on other TDM programs. The provincial government of British Columbia recently amended the B.C. Transit Act to authorize the Vancouver Regional Transit Commission to levy a tax on non-residential parking spaces as a component source of revenue for the local share of transit costs (Transport 2021, 1993).

In addition, parking charge measures can be implemented with minimal capital costs and low operating costs. There may be only some administrative and enforcement costs to the government.

4.3.3.3 Disadvantages

High parking charges would unfairly favour those who are better able to pay the charge and would penalize those who have to park.
They tend to cause substantial increases in illegal parking, and therefore must be accompanied by strict enforcement of parking regulations.

High charges for parking may also create many unproductive trips, for example, when drivers circulate in traffic waiting for passengers or looking for cheaper parking places (World Bank, 1986). Furthermore, parking charges cannot control through traffic, which is often a primary cause of congestion in city centres. As a result, parking charges may be more effective as a restraint when it forms part of a more comprehensive demand management scheme (World Bank, 1986).

4.3.4 Charging for Road Usage

4.3.4.1 Characteristics

Relying on congestion alone to ration road use places a high and inequitable cost on all users of the congested road. Therefore, various direct and indirect methods of charging for congestion have been considered and implemented in many countries. Of all the forms of fiscal restraints, road pricing has received the most attention. The initial concept of road pricing was for a system in which drivers were charged the difference between the average cost and the marginal cost (May, 1986). Charging could be broadly categorized as off-vehicle recording versus on-vehicle metering (Hau, 1992). With off-vehicle recording, the actual charging is performed off the vehicle -- as with the telephone, gas and
electricity charges -- even though a transponder may be placed on
the vehicle itself in the case of automatic scanning. With on-
vehicle metering, actual charges are registered on the vehicle
itself using automatic meters (such as using smart cards).

There are important interrelationships between the primary
objective behind the introduction of road pricing, the type of
charging system used, the spatial pattern of charging and the time
distribution of the charges (Jones & Hervik, 1992). As shown in
Table 4-3, if the objective is to reduce congestion (this is also
the primary objective of this study) in the city, then:

1) A cordon, area license, or travel-related charge may be
appropriate.

2) It will usually be desirable to locate the restricted
area boundary at a point where longer-distance through
traffic can detour to avoid payment, but one that
incorporates the main congested area.

3) Charges are normally varied by time of day to reflect
congestion, being greatest at peak periods and zero when
traffic is light.
Table 4-3: Relationships between Road Pricing Objectives and Type of Scheme

<table>
<thead>
<tr>
<th>Objective</th>
<th>Type of Scheme</th>
<th>Spatial Pattern</th>
<th>Time Distribution of Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>reduce congestion</td>
<td>a cordon, an area license, travel related charge</td>
<td>boundary of main congested area</td>
<td>varies by time of day</td>
</tr>
<tr>
<td>raise revenue</td>
<td>a cordon</td>
<td>cordon intercepting maximum traffic</td>
<td>uniform charge</td>
</tr>
<tr>
<td>environmental protection</td>
<td>multiple cordon area-wide on an area license</td>
<td>greater period</td>
<td></td>
</tr>
</tbody>
</table>

* Source: Jones and Hervik (1992)

Regardless of the objectives or the precise form of implementation of a road pricing scheme, there are three general issues that arise: 1) technological aspects of implementation; 2) socio-political aspects of implementation; and 3) behavioral aspects of implementation (Jones & Hervik, 1992). These issues will be reviewed in detail in the following section. Singapore is the only city to have actually applied area licensing. Since 1975, Singapore has operated the Area Licensing Scheme in an attempt to restrain the use of private cars. Vehicles can enter the restricted area only at clearly marked entry points, and low-occupancy private cars are required to display a special area-license disk for which a fee of U.S. $2.50 per day (or U.S. $50 per month) during the morning and afternoon peak periods is required. Private cars with four or more occupants, goods vehicles and buses are exempt from paying the area-license fee (World Bank, 1986).
In the cases of Kuala Lumpur and Bangkok, where steps have been taken to introduce area licensing, initial setbacks have delayed implementation (Armstrong-Wright, 1986).

In 1986, Hong Kong initiated an electronic road pricing experiment in which 2,600 autos were equipped with automatic vehicle identification devices and sensors were installed on key bridges and roads. The vehicle users were billed through the mail for their trips across the toll facilities. The project was judged a success in terms of the technology, but met with adverse public reaction due mainly to personal privacy concerns. Thus the Hong Kong authorities decided to discontinue the system (Transport 2021, 1993).

In the Netherlands, the Ministry of Transport is planning to implement a large-scale road pricing scheme. The preferred system is an electronic pricing system, using smart card technology to allow anonymous prepayment charging (Stoelhorst & Zandbergen, 1990).

4.3.4.2 Advantages

By charging for movement at congested times and in congested areas, road pricing can be designed to affect those vehicles that contribute most to the problems of car use. Moreover, there is no limit in theory to the level of charge that can be imposed (May, 1986). Their effectiveness depends on the response of drivers to
the price.

In 1975, the Area Licensing Scheme in Singapore reduced peak period car traffic entering the restricted zone between 07:30 and 10:15 a.m. by seventy-three percent, from 42,790 in March to an average of 11,363 in September and October (Holland & Watson, 1978). Although the Singapore scheme achieved a substantial reduction in traffic, and hence there were perceived improvements in congestion, too much restraint had been achieved, at least in the short term. Desk studies have attempted to determine the optimal charging level, at least in social cost-benefit terms (May, 1986). In London, for example, it was estimated that an optimal all-day charge of around 60 p to 100 p per day would achieve a net benefit of around £24 m.p.a. (at 1973 prices) (May, 1975). With regard to the equity issue, the Singapore scheme showed that most of the benefits accrue to the majority of commuters because nearly ninety percent of households travelled by bus both before and after the scheme was put into effect. The productivity of buses would increase significantly because of higher average operating speeds.

As for technological aspects, although simple road pricing systems (e.g. the Singapore Area Licensing Scheme) have been successfully introduced using manual payment systems, more comprehensive schemes in denser urban areas will need to rely on some form of electronic payment system, for two reasons (Jones & Hervik, 1992): (1) Because of the difficulty of collecting charges related to use and those
charges varying according to congestion levels; and (2) Because of the space required for toll booths. The solutions to these problems fall into two categories: (1) An Automatic Vehicle Identification (AVI) system, where each vehicle carries a passive electronic tag, which is read by roadside equipment without the vehicle stopping; and (2) A smart card or a decrementing card, which contains a certain stored value from which units are deducted as the vehicle passes charging points. The smart card can also settle the issue of privacy which has long been debated. There is no need to identify the vehicle or driver unless the card is out of money.

4.3.4.3 Disadvantages

Low-income motorists would pay the same toll as higher-income motorists, which could be viewed as a form of regressive taxation. A greater portion of lower-income individuals than higher-income individuals would decide to switch to transit for their peak period trips or decide to switch their trips to off-peak periods (Transport 2021, 1993). Moreover, for a road pricing system to be reasonably effective, the charges to individual users must be related to how much they use congested streets and the degree of congestion on those streets. But in most urban areas it is impractical to try to collect charges for road use at the time they are incurred. The use of toll booths might well aggravate congestion (World Bank, 1986), hence the need for sophisticated and expensive electronic collection methods.
Enforcement is another major concern. Any system would have to be designed to make it possible to identify vehicles that try to evade charges; equipment would have to be proofed against tampering (Armstrong-Wright, 1986). But these arguments could be mitigated by introduction of Smart Cards or Automatic Vehicle Identification systems.

In addition, if there still are feasible alternative "free" routes, traffic could divert to the free routes and simply transfer congestion there (Transport 2021, 1993). But this can be avoided by a careful design of the road pricing scheme. Still, some governments, that of Australia for example, require that there be a free option to a toll road.

The privacy issue is perceived to be an important one and the manner in which it can be handled is dependent on the technology used for collection of the charge.

Above all else, city authorities have been reluctant to try road pricing, partly because of doubts as to whether the system will work, and partly out of fear of public reaction (World Bank, 1986). But this may be overcome by the governments' will to cope with congestion in a way that is unlikely to be popular with motorists. A substantial effort to achieve public acceptance and the flexibility to respond to changing conditions are prerequisites of the system.
CHAPTER 5
ASSESSMENT OF ALTERNATIVES FOR SEOUL

1. INTRODUCTION

The advantages and disadvantages of each policy alternative and foreign experience with them have been analyzed in former chapters. However, the same achievements could not necessarily be guaranteed for Seoul. Therefore, the expected performance of each policy alternative, if it were applied to Seoul situations, will first be identified in the following section. A rating system has been designed to evaluate each alternative in relation to five criteria: efficiency, equity, feasibility, environmental effect, and flexibility.

2. APPLICATION OF ALTERNATIVE CONGESTION POLICIES TO SEOUL

2.1 "Carrot" TDM Measures

2.1.1 Preferential Treatment for HOVs

There are ten concurrent-flow HOV priority lanes in Seoul which operate from 07:00 to 10:00 during the morning peak and from 17:00 to 21:00 during the evening peak (see Table 5-1). HOV priority lanes are differentiated from other lanes by blue lines and traffic signs showing the starting point and the ending point of the priority lanes.
Table 5-1: HOV Priority Lanes in Seoul

<table>
<thead>
<tr>
<th>Route</th>
<th>Length (km)</th>
<th>Operating Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hankang-ro</td>
<td>4.0</td>
<td>07:00 - 10:00</td>
</tr>
<tr>
<td>Wangsan-ro</td>
<td>4.1</td>
<td>07:00 - 10:00</td>
</tr>
<tr>
<td>Kangnam-daero</td>
<td>4.1</td>
<td>07:00 - 10:00, 17:00 - 21:00</td>
</tr>
<tr>
<td>Dongjak-ro</td>
<td>7.3</td>
<td>07:00 - 10:00, 17:00 - 21:00</td>
</tr>
<tr>
<td>Konghang-ro</td>
<td>3.8</td>
<td>07:00 - 10:00, 17:00 - 21:00</td>
</tr>
<tr>
<td>Soosaek-ro</td>
<td>7.2</td>
<td>07:00 - 10:00, 17:00 - 21:00</td>
</tr>
<tr>
<td>Hyan choong-ro</td>
<td>9.0</td>
<td>07:00 - 10:00, 17:00 - 21:00</td>
</tr>
<tr>
<td>Tongil-ro</td>
<td>4.0</td>
<td>07:00 - 10:00, 17:00 - 21:00</td>
</tr>
<tr>
<td>Banpo-ro</td>
<td>6.4</td>
<td>07:00 - 10:00</td>
</tr>
<tr>
<td>Wangsipni-gil</td>
<td>8.0</td>
<td>07:30 - 09:30</td>
</tr>
</tbody>
</table>

* Source: Seoul Development Institute (1993a)

After introducing the priority lanes, the average travel speed of buses increased by 15.4 percent from 15.33 km/h to 17.69 km/h, but that of passenger cars decreased by 5.8 percent from 21.76 km/h to 20.50 km/h (Seoul Development Institute, 1993a). However, HOV priority lanes provoked protests by some interest groups, such as shop owners along the priority lanes and taxi operators, in addition to the common unfavourable reactions by motorists. In Seoul, reaction from motorists was more substantial than that of any other interest group due to their higher social status. Enforcement was another major concern. More police officers were needed in order to identify vehicles which invade the priority lanes. In overall evaluation, HOV priority lanes are considered as successful and effective in reducing traffic congestion. City government is supposed to expand the HOV priority lanes by converting some existing lanes into priority lanes.
2.1.2 Improvement of Transit Systems

The rapid rail transit lines operating in Seoul consist of four lines with a total length of 118 kilometres. Passengers per day number about 3,400 thousand (see Table 5-2).

Table 5-2: Rapid Rail Transit in Seoul

<table>
<thead>
<tr>
<th>Line</th>
<th>Route</th>
<th>Length (km)</th>
<th>Passengers per day (thousand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line 1</td>
<td>Seoul Station to Chongryangrhee</td>
<td>7.8</td>
<td>871</td>
</tr>
<tr>
<td>Line 2</td>
<td>Sungsoo to Sungsoo</td>
<td>54.2</td>
<td>1,417</td>
</tr>
<tr>
<td>Line 3</td>
<td>Chichook to Yangjae</td>
<td>27.7</td>
<td>477</td>
</tr>
<tr>
<td>Line 4</td>
<td>Sangkye to Sadang</td>
<td>28.3</td>
<td>635</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>118.0</td>
<td>3,400</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1993)

The major underground rail system in Seoul will probably encourage the dominance of the existing city centre due to its greater accessibility. The routes for the extension of existing rail transit systems or new construction are generally recognized to be those stretching to the newly developed residential areas.

The major problem in improving the underground rail system is how to finance the massive construction and operating costs. Serious restraints on city finances are getting worse and worse.
Nonetheless, the pressure of citizens demanding construction of new rail transit lines is so great that the city government plans to invest more than 600 billion won per year on constructing new rail transit lines.

Buses in Seoul will be the major transport mode even in the future. Among the alternatives reviewed, the improvement of buses would be one of the most progressive for lower income groups. This is because over forty percent of bus users are in the lower income group (KAIST, 1983). As a result, the necessity for the improvement of bus services (and rapid rail transit) itself is generally recognized in the society. In the past, while recognition of the necessity for bus improvements had been one thing, implementation had been another matter. For example, although many years had passed since the introduction of bus lanes, the effectiveness of bus lanes was still in doubt owing to the problem of enforcement. But nowadays, city government intends to expand the bus lanes and strengthen enforcement measures.

In terms of financial considerations, bus systems will be one of the most favourable alternatives from the government's point of view. This is because buses in Korea are operated completely by private operators. But nowadays, as the revenues of bus companies are falling rapidly, a subsidy from the city government will be required in the near future. But the finances available to the city cannot accommodate all the demands for spending.
2.1.3 Introduction of Para-transit

At present, there exists a type of para-transit -- called a "village bus" -- in Seoul. But it ironically suffered from both over-regulation and under-regulation as analyzed by Alschuler (1975). Over-regulation took the form of lack of precise legal definition resulting from statutes which were not flexible enough to deal appropriately with innovative concepts.

With complement in statutes, a highly organized para-transit service would appear to attract considerable demand from potential car and taxi users, considering the successful operation of seating buses which offer higher quality, no standing service, and cover a comprehensive network.

At first, the operators of village buses had limited licenses which restricted the routes and fares of the village buses. They could offer local services from residential areas to subway stations, using small buses at a fare below that of the normal service.

Now city authority plans to use village buses as a complementary system to support regular bus services.

Considering the inadequate operation of taxi type para-transit systems in many developing countries, bus-type systems will ensure more efficient road use in Seoul. Although there is little information, such types of para-transit service would perhaps capture a considerable amount of potential car ownership demand.
Most of the users of para-transit will be those of the middle income group.

2.1.4 Encouragement of Ridesharing

In general, car sharing potential in Seoul may be much lower than that in developed countries. This is partly because car owners regard car ownership as a symbol of social status and may be reluctant to share their cars with others, partly because car sharing may suggest invasion of privacy. Moreover, so far the Seoul city government has not made rigorous efforts to encourage ridesharing by giving incentives such as free parking permits or tax exemption.

However, if car sharing is introduced as part of a comprehensive traffic demand management scheme, it might be able to offer a lower cost method of reducing peak congestion to a certain extent.

2.1.5 Variable Work Hours

It is difficult for city government to implement variable work hours except at its own offices because work start and finish times are not legislated, and are a matter of individual company policy (Transport 2021, 1993). But with voluntary cooperation of companies, schools and other organizations, there exist certain types of staggered work hours in Seoul. Even if work start times vary between 07:30 and 10:00 according to the types of organizations, it is generally accepted that the variations are so
small that they do not affect the level of congestion. But recently some major companies announced that they are going to adopt flexible work hours and compressed work hours. These may well be regarded as the green light to the expansion of variable work hours throughout the country.

2.2 "Stick" TDM Measures

2.2.1 Physical Restraint

2.2.1.1 Parking Supply Controls

In 1990, the total number of parking lots in Seoul contained approximately 410 thousand stalls, including those in residential-structure parking lots. Compared to the nearly 1,200 thousand vehicles registered, the supply of parking facilities in Seoul is regarded as highly insufficient (see Table 5-3).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>On-Street</th>
<th>Off-Street</th>
<th>Affiliated</th>
<th>Vehicles</th>
<th>Stalls per 1,000 Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>73.9</td>
<td>4.2</td>
<td>14.5</td>
<td>55.3</td>
<td>221.6</td>
<td>333</td>
</tr>
<tr>
<td>1984</td>
<td>127.2</td>
<td>6.2</td>
<td>21.9</td>
<td>99.1</td>
<td>377.2</td>
<td>337</td>
</tr>
<tr>
<td>1987</td>
<td>311.1</td>
<td>8.8</td>
<td>30.1</td>
<td>272.1</td>
<td>631.8</td>
<td>492</td>
</tr>
<tr>
<td>1990</td>
<td>406.9</td>
<td>14.4</td>
<td>42.9</td>
<td>349.7</td>
<td>1,193.6</td>
<td>341</td>
</tr>
</tbody>
</table>

* Source: Roh (1991)
Therefore, most transport specialists, including a majority of transport planners, believe that the number of parking lots in Seoul should be increased substantially in order to cope with rapidly increasing demand (Roh, 1991). Of course, parking lots should be created with balance in regard to area, type, and scale. Thus the likelihood of government acceptance of a parking supply reduction scheme is far away for the time being.

In the long run, the present parking policy, which concentrates on expansion of parking supply, would attract more car traffic into the city centre. Therefore, there are some movements within the parking division of the city government to fix the number of parking lots in the central business district (except residential parking).

2.2.1.2 Traffic Zone Systems

The traffic zone systems in Gothenburg are generally accepted as having achieved successful results. However, introduction of traffic zone systems to Seoul is not very promising because of its geographical conditions.

The layout of the city centre in Seoul is not easy to divide into appropriate traffic zones which will have only a limited number of exits; this is because the streets are arranged in a grid-style layout. Also, any effort to provide a proper orbital route outside the CBD would be restricted by the limited space, because most of
the surrounding area of the CBD is densely concentrated, and quite mountainous in some areas. If the controlled area were expanded to the outer CBD boundary, an orbital route could be provided more easily than in the case of the CBD area. However, the major problem is the difficulty of dividing the area into appropriate traffic zones.

Nonetheless, it is worthwhile to consider introducing traffic zone systems around large apartment complexes or to specific congested areas according to the characteristics of the areas.

2.2.2 Regulatory Restraints

2.2.2.1 Odd and Even Days Rule

Odds and Evens is relatively inflexible and hence runs the risk of substantial over-restraint. Moreover, as this measure is designed to deprive people unconditionally of the use of their cars on certain days, at least there should be a provision of an efficient and well-coordinated system of mass transit.

If a Lagos-type scheme were implemented in Seoul, there would need to be much stricter enforcement than that in Lagos.

During the Seoul Olympic period in 1988, Seoul implemented the odds and evens using citizens' voluntary participation to reduce traffic congestion. The results of voluntary odds and evens were quite notable. Traffic volume decreased by 33.8 percent and travel speed
in the CBD increased from 20.5 km/h to 34.4 km/h (Seoul Development Institute, 1993).

Even if the effects of odds and evens are remarkable as shown above, the durability of the effects are quite dubious. If this kind of scheme were implemented on a permanent basis, the high-income motorists would try to find ways of circumventing the scheme by purchasing a second car with a complementary number. Above all, car owners will use their cars more intensively on unrestricted days. The number of passengers using taxis and seating buses would increase substantially. As a result, the traffic situation would not meet the theoretical reduction by half of the traffic volume in the controlled area.

2.2.2.2 Road Use Permit System

The impact of a road use permit system could vary widely depending on the range of authorized vehicles and the width of the controlled area.

If permits are issued restrictively for essential purpose vehicles, it would be easy to enforce, and the impact on traffic would be noticeable. However, if permits were issued widely, the impact on traffic would be insignificant. In addition, if the residents of controlled areas are exempted from the control, it could increase the number of residents' cars legally or illegally.
With regard to business cars, an allocation should be devised based on highly sophisticated criteria such as number of employees or area of business space. It would be hard to make an accurate assessment of the required need case by case. It requires not only a substantial amount of manpower for license issuing and enforcement, but it would also be criticized for its possible discrimination among different businesses.

In practice, a restrictive permit system in which permits are issued only for essential purpose vehicles or residents would be nearly impossible to implement considering the vital role of the CBD. If the controlled area were expanded, such a problem would become more serious. Therefore, it is not likely that this policy will be pursued for some very specific areas and circumstances.

2.2.3 Use of Pricing System

2.2.3.1 Taxation of Cars

In Korea, current national taxes on cars consist of special excise taxes and value-added taxes. There are also four local taxes: the automobile ownership tax, the acquisition tax, the registration tax and the license tax. In addition, car buyers also have an obligation to purchase public subway bonds when buying automobiles (see Table 5-4).
Compared with most other countries, Korea has a more complicated tax structure and higher tax rates. Six kinds of taxes are levied during automobile purchase, compared to one or two taxes in other countries. Korea levies more taxes than any other foreign country for owning automobiles. Tax rates for purchasing automobiles are three times as high and eight and a half times as high as those of Japan and the United States, respectively. The tax rates charged on possessing automobiles are 140 percent, 640 percent and 1,500 percent of those of Japan, France and the United States, respectively (see Table 5-5).
Table 5-5: An International Comparison of Auto-Related Taxes
(Based on Taxes for a 1,500 cc Car)

<table>
<thead>
<tr>
<th>Acquisition Kinds</th>
<th>Ratio to Car Price (%)</th>
<th>Possession Kinds</th>
<th>Ratio to Car Price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>6</td>
<td>34.2</td>
<td>3</td>
</tr>
<tr>
<td>Japan</td>
<td>2</td>
<td>11.5</td>
<td>2</td>
</tr>
<tr>
<td>U.S.</td>
<td>1</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>W/Germany</td>
<td>1</td>
<td>14.0</td>
<td>1</td>
</tr>
<tr>
<td>U.K.</td>
<td>2</td>
<td>23.3</td>
<td>1</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
<td>29.1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Source: Lee (1991)

These high automobile taxes effectively restrained car ownership for the last two decades. Thus Korea had one of the lowest automobile ownership rates in the world, as shown in Table 5-6.

Table 5-6: Automobile Ownership Rates

<table>
<thead>
<tr>
<th>Country</th>
<th>Taiwan</th>
<th>Japan</th>
<th>U.S.A.</th>
<th>U.K.</th>
<th>Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP per Capita($)</td>
<td>3,198</td>
<td>1,948</td>
<td>10,987</td>
<td>17,551</td>
<td>9,923</td>
</tr>
<tr>
<td>Cars per 1,000 pop.</td>
<td>49</td>
<td>85</td>
<td>282</td>
<td>539</td>
<td>300</td>
</tr>
</tbody>
</table>

* Source: Korea Transport Institute (1990)

However, this situation may not last very much longer, as the GNP is increasing rapidly, and there is pressure to reduce taxes on passenger cars to encourage the automobile industry. Attempts to increase the existing level of taxes on cars would encounter severe opposition not only from motorists but also from the auto industry.
2.2.3.2 Fuel Tax

Fuel tax is comparatively simple to administer and has a direct relationship to the amount of vehicle use. Thus it is desirable to increase fuel tax to reduce traffic congestion. As the fuel tax in Korea is relatively low compared to that of developed countries, as shown in Table 5-7, an increase in the fuel tax may not provoke serious opposition from motorists.

Table 5-7: International Comparison of Fuel (Gasoline) Taxes

<table>
<thead>
<tr>
<th>Country</th>
<th>Fuel Tax Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>100</td>
</tr>
<tr>
<td>France</td>
<td>296</td>
</tr>
<tr>
<td>West Germany</td>
<td>183</td>
</tr>
<tr>
<td>Japan</td>
<td>178</td>
</tr>
<tr>
<td>U.K.</td>
<td>68</td>
</tr>
<tr>
<td>U.S.</td>
<td>32</td>
</tr>
</tbody>
</table>

* Source: Lee (1991)

However, the effectiveness of the increase in fuel tax depends on the response of drivers to the fuel price. Studies of response to petrol prices suggest short run elasticities of 0.1 to 0.3 (May, 1986). According to the Korean Ministry of Energy and Resources, the elasticity of auto usage to petrol prices was estimated at 0.09. Thus substantial increases of petrol tax are needed to have any significant effect on the extent of road usage. However, with the higher petrol tax, more people would tend to use diesel-powered cars. This is because total taxes for diesel are only forty percent of the price while those for gasoline are 140 percent. Under present circumstances, it is quite difficult to raise the tax
level of diesel to that of gasoline because diesel is mostly used by buses. Therefore, some special provision to avoid such effects would be required.

2.2.3.3 Parking Charges

Parking charge policy in Seoul has been used as one of the primary policies to control parking demand. However, the policy did not play the role it was intended to because it was a control subject to central government. Because the parking charges had been controlled as a public utility fare, it was set below the market price. The low parking fee worsened the earnings and the financial balances of the parking businesses and stagnated the construction of parking lots.

Now, the pricing system of parking lots has been liberalized and is on the way to adopting market pricing systems. The market pricing system will raise parking fees downtown, given the high level of demand, and thus the high parking fee will reduce the number of drivers trying to park downtown.

Although there is little information on the elasticity of parking charges in downtown Seoul, the Korea Transport Institute (1990b) explains that it is very low. According to the city planners, the higher charges in the city centre in contrast to elsewhere have increased the turnover of on-street parking in the city centre.
2.2.3.4 Charging for Road Usage

A toll system is already operating in Seoul at the three tunnels at the boundary of the CBD area. The charge is 100 won for a car, which is principally levied in order to cover construction costs. It seems unlikely that motorists would be dissuaded from making a car trip as a result of such a low toll. On the other hand, the system is often criticized since the manual toll collection methods used often lead to congestion on approach roads.

If the same type of Area Licensing Scheme Singapore uses were to be implemented in Seoul, a similar sort of impact would be felt on overall traffic levels in the restricted area.

The effects of an Area Licensing Scheme would vary depending on the area of control and the amount of the license fee. If restrictions were imposed in the CBD area, it would impose the restrictions on the most cars effectively. However, given the inadequate number of parking lots and the insufficient orbital routes at the boundary of the CBD, it could transfer parking and congestion problems to outside the city centre. In the case of the outer CBD boundary, it not only covers less congested areas excessively, but also will require more efforts for enforcement.

With regard to electronic road pricing, cordon control-type systems seem to be more feasible for Seoul than point pricing-type schemes. This is because they would not result in the undesirable changes in
driving route selections which would be expected under a point pricing scheme. If a cordon control-type electronic road pricing system were introduced with the same conditions of charge level, controlled period, etc. as in the cordon control type area licensing scheme, the overall impact on the road traffic would be very similar to that of area licensing schemes.

For Hong Kong, its island-like situation would be favourable for the successful implementation of an electronic road pricing scheme. In Seoul, which has more complex travel patterns, the application of an electronic road pricing system would need more detailed planning.

3. ASSESSMENT OF POLICY ALTERNATIVES FOR SEOUL

3.1 Introduction

We have analyzed twelve policy alternatives to reduce traffic congestion in Seoul and reviewed the expected performance of each alternative when applied to Seoul situations. From this it is possible to suggest the relative performance of each alternative to meet certain criteria.

In the assessment of the performance of the various TDM measures categorized in Chapter 4, we use five criteria below which will be reviewed in the following section:
3.2 Assessment Criteria

3.2.1 Efficiency

In congested conditions each additional vehicle in the traffic stream can add significantly to the total time spent and costs incurred by those that it joins (May, 1986). According to Smeed (1968), each additional driver was likely to impose time losses for other vehicles equal to his own travel time at 21 km/h, and double his own time at 16 km/h.

In practise, individual motorists will only consider their own costs and take no account of the congestion impact of their trip on other vehicles. If they were to be restrained, the saving in travel costs to others would exceed the lost personal benefits to the driver.

Although the reduction of these drawbacks is one of the main objectives of TDM measures, efficiency considerations also impose constraints on the designs of TDM measures. In particular, it is important to ensure that the resources involved in administering
and enforcing the measures, and for drivers in using it, do not exceed the resource savings achieved through TDM measures. Additional resource costs outside the immediate target area as a result of transfer to other routes, modes or times of travel need to be carefully assessed (May, 1986).

In this study, we rated the degree of efficiency by how effective the alternatives were in reducing traffic congestion. Most alternatives are regarded as effective. Preferential treatment for HOVs, improvement of transit system, and odd and even days rule have significant effects on traffic congestion, while encouragement of ridesharing and variable work hours have minor effects in Seoul.

3.2.2 Equity

Equity is related to the theme of the distribution of costs and benefits in society. There are clear equity arguments in favour of restraining those who impose a net burden on the traffic strain; of protecting from congestion those with particular needs; of reducing the environmental impact of traffic on residents and pedestrians; and of restricting through traffic in the interests of city centre vitality. These arguments often represent a major element in the justification of "stick" measures, but equity issues are equally often used to dismiss restraint proposals. The most frequent criticism is of the effects of fiscal controls on lower income car
users (May, 1986). But inequalities can also arise through relocation of traffic problems, regulatory controls on those who have no alternative, and time penalties on those who place a high value on time. If the full range of equity issues arising from restraint is to be considered, it is important to identify separately the effects by user type, location, income level, journey purpose (or need), and the effects on both users and non-users (May, 1986).

In this study, the degree of equity among alternatives is rated according as how much the poor are benefited by the implementation of alternatives. By this rating, preferential treatment for HOVs and improvement of transit system rank the most fair and just alternatives; in contrast, fuel tax and charging for road usage are considered least equitable.

3.2.3 Feasibility

TDM measures should be enforced and workable in the specific situation of a city. Very few proposed restraint schemes have been implemented recently. One of the major reasons for objections to the proposed schemes is that they might be unworkable or ineffective.

Perhaps the most important lesson to be learnt from recent failures to implement TDM measures is that we cannot simply assume that the
TDM measure is acceptable as an end in itself (May, 1986).

TDM measures should be administratively and operationally as simple as possible without wasting time or other resources from both the viewpoint of operators and users.

Another important aspect in terms of feasibility is the cost of implementing TDM measures. Measures which need least costs are most favourable.

In addition, the number of years required to plan, design, construct and implement the TDM measure should be as short as possible. Measures that can be put in place quickly receive more favourable assessments (Transport 2021, 1993).

Most stick measures would rank relatively low in terms of feasibility because of their innate characteristics and opposition from citizens. Preferential treatment for HOVs would be implemented with ease and minimal costs if converting existing lanes into HOV priority lanes.

3.2.4 Environmental Effect

Traffic imposes a series of environmental disadvantages and TDM measures can be designed to reduce these problems. Noise and pedestrian problems are best tackled by substantial reductions in
all traffic in the areas particularly at risk; concern over danger, vibration and visual intrusion may well justify an emphasis on restricting commercial vehicles; certain pollutants require an area-wide reduction in petrol-engined vehicle movements (May, 1986). However, considerable care is required to avoid simply transferring environmental problems to other areas.

As they are intended to reduce traffic volume, most TDM measures get a high rating with regard to environmental effect. Especially, preferential treatment for HOVs and charging for road usage would have the most favorable effects on environment.

3.2.5 Flexibility

Because the need for restraint and the precise effects of restraint methods are uncertain, it is important that the restraint policy be flexible. In this way the effect can be intensified or reduced as necessary, and adverse effects can be modified.

In addition, restraint must bear more heavily on those trips that are least justified in terms of the problems that they cause, and this process must not be substantially undermined by avoidance or evasion. At the same time, it must not impose restrictions on those who do not contribute significantly to congestion or environmental intrusion; neither must it impose hardship on those who do, but have little alternative in terms of route, mode, time

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or destination (May, 1986).

In terms of flexibility, most stick TDM measures would get a low rating because of their innate characteristics, whilst most carrot TDM measures would get a relatively high rating. Some exceptions in the stick measures are 'parking charges' and 'charging for road usage', which is fairly flexible in that charges can be relatively easily adjusted.

3.3 Summary of the Assessment

Because the performance of each policy alternative has multiple dimensions, it is not easy to summarize the results. But some method of comparing alternatives is necessary to help policy-makers choose which to pursue most vigorously (Downs, 1992). Therefore, in this chapter, each alternative is evaluated with respect to five criteria. These evaluations are admittedly subjective rather than scientific; they represent the author's best judgements. However, these assessments are not entirely arbitrary, since they have been based on the analysis presented in earlier chapters. The results of the evaluation have been summarized in Table 5-8.
<table>
<thead>
<tr>
<th></th>
<th>Efficiency</th>
<th>Equity</th>
<th>Feasibility</th>
<th>Environmental</th>
<th>Flexibility</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Carrot&quot; Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferential Treatment</td>
<td>00</td>
<td>00</td>
<td>0</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>for HOVs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement of Transit</td>
<td>00</td>
<td>00</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction of</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Para-transit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encouragement of Ridesha</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sharing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Work Hours</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&quot;Stick&quot; Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control of Parking</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Zone System</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Odd and Even Days Rule</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Road Use Permit System</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Taxation of Cars</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Fuel Tax</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Parking Charges</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Charging for Road Usage</td>
<td>00</td>
<td>-</td>
<td>-</td>
<td>00</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Note: 00: excellent, 0: good, +: moderate, -: poor
3.4 Selection of Appropriate Alternatives

Choosing optimal policies from various alternatives usually requires computations based on the weights assigned to the various relevant factors (Tversky, 1972). Some transportation planners argue that a weighting scheme must be developed in order to assign relative weights to the evaluation criteria. Yet, others (mostly economists) argue that since any attempt to assign weights to the criteria is bound to become arbitrary and subjective, it is best to leave the job to the politicians and other decision makers. Considering the limit of the analysis done in section 3.3, the author adopted the latter approach.

In this study, the alternatives which do not appear favourable against the criteria will be eliminated based on the results of assessment shown in Table 5-8 in order to narrow the potential alternatives without estimating relative weights of alternatives.

In terms of feasibility, traffic zone systems, odd and even days rule, road use permit system, and taxation of cars would appear to face obstacles for implementation in Seoul. The traffic zone system has limited prospects due to the geographical conditions of Seoul. The odd and even days rule has been eliminated because there are various ways of circumventing the system and inflexible characteristics. The road use permit system has been eliminated on account of expected enforcement and administrative requirements. Taxation of cars would encounter serious opposition from the
middle-income class who are planning to purchase cars of their own in the near future, and taxes on cars are already very high compared to those of foreign countries.

In terms of efficiency, variable work hours and ridesharing have been eliminated because of their negligible effects on traffic congestion. But their potential importance in the future may well be noted. The remaining alternatives also have some drawbacks against the criteria as shown in Table 5-8. In consequence, no alternative on its own completely meets all the requirements.

In order to overcome their individual weaknesses, a combination of alternatives would be required. On the basis of the results of the above assessments, a selected list of alternatives as shown in Table 5-9 is suggested. These selected alternatives are broadly categorized into major and supplementary alternatives rated by expected performance, and are shown in Table 5-9. The alternatives are divided into short term alternatives (five years or less) and long term alternatives (ten years or less).

<table>
<thead>
<tr>
<th>Table 5-9: Selected List of Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
</tr>
<tr>
<td>Short Term</td>
</tr>
<tr>
<td>Preferential Treatment for HOVs/ Fuel Tax</td>
</tr>
<tr>
<td>Long Term</td>
</tr>
<tr>
<td>Improvement of Transit System/ Charging for Road Usage</td>
</tr>
<tr>
<td>Supplementary</td>
</tr>
<tr>
<td>Introduction of Para-Transit/ Parking Charges</td>
</tr>
<tr>
<td>Control of Parking Supply</td>
</tr>
</tbody>
</table>

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Over the last two decades, car ownership in Seoul has increased dramatically in response to rapid economic growth and policies which did not discourage car ownership and use. The transportation policies in Seoul are mainly concerned with the provision of new roads and the building of subway systems. Despite major investments, these are not sufficient to cope effectively with the problems caused by traffic congestion.

The magnitude of congestion costs in Seoul is much greater than one might think. Calculations here indicate the cost of congestion in Seoul to be 28,643 million won per day. Most of the congestion costs accrue as travel time costs. These enormous congestion costs can be a warning to vehicle users and policy developers. One might wonder: Do these indicate that appropriate policy alternatives to reduce congestion are imminent?

The alternatives reviewed in this study are categorized by use of incentive and by type of control. A list of measures are shown below.

1. Carrot TDM Measures
   - Preferential Treatment for HOVs
   - Improvement of Transit System
   - Introduction of Para-transit
   - Encouragement of Ridesharing
   - Variable Work Hours
2. Stick TDM Measures

1) Physical Restraints
   • Parking Supply Controls
   • Traffic Zone Systems

2) Regulatory Restraints
   • Odd and Even Days Rule
   • Road Use Permit System

3) Use of Pricing System
   • Taxation of Cars
   • Fuel Tax
   • Parking Charges
   • Charging for Road Usage

These policy measures are reviewed in terms of their advantages and disadvantages, and expected performance when applied to the Seoul traffic conditions. Finally, they are assessed against the following criteria: efficiency, equity, feasibility, environmental effect, and flexibility.

As all the alternatives have some drawbacks in relation to one or more of the criteria, combinations of alternatives are suggested. On the basis of assessment here, a selected list of alternatives for Seoul is recommended, and is shown below:

<table>
<thead>
<tr>
<th>Major</th>
<th>Supplementary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Term</td>
<td>Preferential Treatment for HOVs/ Fuel Tax</td>
</tr>
<tr>
<td>Long Term</td>
<td>Improvement of Transit System/ Charging for Road Usage</td>
</tr>
</tbody>
</table>
Reducing congestion is worth the effort because traffic congestion costs billions of dollars in wasted time and fuel each year (Downs, 1992). However, it seems likely that policy makers will be reluctant to adopt some TDM measures, especially "stick" measures, until they have a clearer understanding of their effects and gain public support. Very few proposed restraint schemes have, in practice, been implemented, and a recent review suggested that the reasons for this were concerns that restraint might be ineffective, might be unfair to certain groups in society, or might involve an unacceptable restriction on freedom of movement (May, 1986). Thus, to implement TDM measures effectively, stronger initiatives from policy makers will be needed to generate public support. When the public accepts that "something needs to be done" to deal with traffic congestion, and measures are shown to be acceptable as means of achieving goals, the restraint measures can be implemented effectively. The rapidly increasing congestion costs in Seoul suggest that Koreans may be approaching the point where they will acknowledge the need for and accept TDM policies. This study has identified the most appropriate policies to pursue.
REFERENCES


Bertrand, Trent J. (1972), "Congestion Costs in a Transport System: with an Application to Bangkok", JTEP, September, 244-279.


City of Seoul (1990, 1992), City Administration, Seoul.


Korea Advanced Institute of Science & Technology (1983), Seoul Transportation Improvement Project, Seoul.


Korea Productivity Centre (1991a), A Study on Improvement of Management of Bus Companies, Seoul.

Korea Productivity Centre (1991b), A Study on Rationalization of Taxi Fare, Seoul.
Korea Transport Institute (1987), A Study of methods for charging
tolls in major highways, Seoul.

(1990a), A Study of Alternatives to
Reduce the Use of Passenger Cars, Seoul.

(1990b), A Study of Parking Demand
Management for Seoul, Seoul.

(1992), A Study of Congestion Costs,
Seoul.

(1993a), Transportation Improvement Plan
for Seoul, Seoul.

(1993b), A Study on the improvement of
the Bus Fare System, Seoul.

Kraus, Marvin (1989), "The Welfare Gains from Pricing Road
Congestion Using Automatic Vehicle Identification and On-
Vehicle Meters", Journal of Urban Economics 25, 261-81

Lane, R. and D.H. Hodgkinson (1976), "A Permit System for Traffic
Restraint", Traffic Engineering & Control, March, 94-97,100.

Year of Operation", Traffic Engineering & Controls, April,
216-222.

Lee, K.Y. (1988), "Appraisal and Possible Improvement of the
Present Tax System for Automobiles", The International
Conference on Transportation Policy in the Seoul
Metropolitan Area, Hyundai Research Institute, Seoul.

Time", The Manchester School of Economic and Social Studies,
Vol.37, pp.213-236.

(1971), "Variations in the Value of Travel Time :
Further Analysis", The Manchester School of Economic and

Road Traffic Levels", JTEP, Vol.12 (1)

Measures", Transportation Quarterly 39 (1), 125-133.

May, A.D. (1975a), "Supplementary Licensing: An Evaluation",
Traffic Engineering & Control, April, 162-167.


Oum, Tae H. and Yimin Zhang (1990), "Transportation Infrastructure Pricing in the Presence of Lumpy Investment," David Gillen (ed), Canadian Transportation Policy, John Deutsch Institute, Queen's University, April, 112-128.


Seoul Department of Police (1990), White Paper on Transportation, Seoul.


Thomson, J.M. (1977), Great Cities and Their Traffic, Gollancz,
London.

Transport 2021 (1993), Transportation Demand Management Measures and Their Potential for Application in Greater Vancouver, Burnaby.


Transport Safety Promotion Authority (1989), A Study of Estimating Average Daily Travel Distance by Type of Vehicle, Seoul.


