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***INCREASING JOB OPPORTUNITIES IN A
SUB-REGION AS A POTENTIAL FOR
REDUCING AIR POLLUTION
AND FUEL CONSUMPTION***

By

***Mohammad-Reza Tayyaran, B.Sc. (Civil)
Isfahan University of Technology, 1987***

***A Thesis Submitted to the
Faculty of Graduate Studies and Research
in Partial Fulfilment of the Requirements
for the Degree of***

Master of Engineering

***Department of Civil and Environmental Engineering
Carleton University
Ottawa, Canada
January 1994
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INCREASING JOB OPPORTUNITIES IN A SUB-REGION AS A POTENTIAL FOR REDUCING AIR POLLUTION AND FUEL CONSUMPTION

submitted by:
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in partial fulfilment of the requirements for
the degree of Master of Engineering

Chair, Department of Civil and
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January 1994

ABSTRACT

A methodological framework is developed in this research to examine the effects of land use patterns on resulting air quality of an urban area. The traditional four-step modelling system is employed to investigate the travel patterns. The resulting emissions and fuel consumption are estimated using vehicle kilometres of travel (VKT) figures.

The city of Kanata within the Regional Municipality of Ottawa-Carleton (RMOC) is selected as the location for this analysis. Data on the 1986 National Capital Region Origin-Destination survey, and socioeconomic variables are gathered.

Five major scenarios illustrating possible future employment schemes are developed. Within each scenario, a number of sub-scenarios is developed, each indicating a specific transit level of service. Using a demand model, (i.e., Quick Response System II [QRS II] transportation simulation software) estimates of 2011 travel demand under each of the scenarios are made. Calculations of fuel consumption and emissions are then made for each scenario.

The results are presented as totals both for the RMOC and for Kanata. It is concluded that providing more job opportunities in the study area (and within a reasonable range, of course) could improve the resulting air quality and reduce the fuel consumption from a regional perspective.

ACKNOWLEDGEMENTS

The research reported in this thesis was carried out under the supervision of Professor A.M. Khan, whose advice, guidance and encouragement during the course of the study was greatly appreciated.

The author wishes to extend his thanks to the members of Transportation Planning Division of the Regional Municipality of Ottawa-Carleton, especially Mr. G. Kent, for their sincere cooperation and the provision of data throughout this research.

I am also grateful to my wife, Faryaneh, for her encouragement, support and patience throughout this research.

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CHAPTER I

INTRODUCTION

1.1. BACKGROUND

The transportation sector consumes approximately 55% of petroleum products in Ontario, of which, the automobile accounts for about half of the total. Consequently, automobile transportation is a major contributor to air pollution in urban areas as well as to global emission problems (Willis & Soots, 1992). Also, within the transportation sector, more than 90% of passenger and 75% of freight movements are made by automobile and truck modes respectively. This clearly shows the dominance of the highway mode of transportation. Accordingly, these modes are the foci for measures to reduce fuel consumption and emissions (Willis & Soots, 1992). Considering the above statistics, air pollution is now considered as a serious problem in larger Canadian cities, particularly in the Greater Toronto Area. The impacts of these pollutants on the human body vary in effect from eye irritations and nausea to aggravation of respiratory system and cardiovascular system (Willis & Soots, 1992; Godish, 1991).

As for economic impacts of air pollution, in the United States alone, the annual cost to human health and the environment is estimated at between \$4 billion and \$93 billion due to mobile source pollution (Gordon, 1991). In addition to air pollution-related diseases, about 120,000 deaths each year are attributed to air pollution (Cannon, 1990).

The above concerns have caused the transportation planners and engineers to search for means to reduce traffic congestion and air pollution. As a result of research and experience, Transportation Demand Management (TDM), Transportation System Management (TSM), land use planning, infrastructure capacity expansion, and new fuel and vehicle technologies have been recognized as techniques for reducing traffic congestion and improving air quality. Among the above techniques, land use planning is of much current interest and subject to considerable debate. The reason for this is the knowledge that there is a strong interaction between land use and transportation.

1.2. AN OVERVIEW OF THE LAND USE-TRANSPORTATION RELATIONSHIP

The relationship between land use and transportation is of great importance. Transportation is a derived demand, meaning that people do not travel for the sake of travel, but to partake in their desired activities. Transportation can therefore influence the urban structure. Likewise, changes in land use patterns have a considerable impact on the performance of the transportation system. This two-way relationship is usually referred to as land use-transportation interaction (Young, 1990). The land development and facility relationship is a circular one, and it can take several years to complete a single cycle. In the short run, land use has the predominant effect on the transportation system. For instance, the impact of a new shopping centre on the street system that surrounds it, may require major roadway and/or transit improvements (Meyer & Miller, 1984). In the long run, the predominant influence is that of the provision of transportation infrastructure and the technological achievements on urban form because of the resultant improvement in

accessibility. This impact is quite evident in the historical development of Canadian and U.S. cities. In the 1800s, when urban travel was made mainly by unmotorized means (i.e., foot and on horseback), city structures were highly centralized around the urban core (Meyer & Miller, 1984). However, by introducing more advanced transportation technology in the twentieth century, urban areas have been expanded and characterized by increasing dispersal or sprawl. In most cities in the United States as well as in other developed and developing countries, urban growth has occurred in the form of low density bedroom suburbs located at the urban fringe, and in some cases even lower density developments emanating from these suburbs (Hanson, 1992; Meyer & Miller, 1984).

The dispersed development pattern is criticized by many planners. Based on studies by Real Estate Research Corporation and Wachs (cited in Hanson, 1992), it is argued that this pattern, as compared to the compact development, involves higher infrastructure costs, higher levels of energy use and air pollution as a result of the increased number of journeys and trip lengths, and greater noise and safety problems. Other undesirable environmental and social indications, as stated by Weaver and Wachs (cited in Hanson, 1992), include the devastation of prime agricultural and other environmentally significant lands, and the isolation of the non-driving groups such as the poor, young, old, and handicapped.

An essential element contributing to the evolution of sprawled land use patterns has been the emergence of the automobile as the major mode of personal transportation (Hanson, 1992). Using the automobile as a means of personal travel is no longer a luxury. Rather, it is viewed as a necessity for travelling between highly dispersed trip origins and

destinations. Other factors, namely the evolution of technology in transportation, personal preferences for residential location in suburban and rural areas (Hanson & Jacobs, cited in Hanson, 1992), the low price of rural land, and telecommunications (Nilles et al., cited in Hanson, 1992) have also played large roles in providing for the land use dispersal.

Ever increasing levels of congestion and air pollution in metropolitan areas, along with very tight budget for facility expansion, have urged the authorities to control the growth in a manageable way, through zoning ordinances, subdivision regulations, building codes, etc. or in general, through "Growth Management" plans. In its recent report, The World Resource Institute (cited in Chinitz, 1990) listed several worldwide problems including acid rain, global warming, deforestation, and the reduction of biodiversity as a result of unmanaged growth. In fact, unmanaged growth has two features. The first is " ... USING THE WRONG LAND. An example is appropriating wetland for development. The second is USING LAND THE WRONG WAY. Urban sprawl that encourages automobile use and results in an inappropriate pattern of development is illustrative." (Chinitz, 1990).

Urban form as it relates to the transportation system can affect it in different ways. A hypothetical city with only one Central Business District (CBD), and several bedroom communities located in its suburbs is much more likely to generate higher vehicle miles of travel (VMT) for journeys to work compared to the same city with multi-use town centres in suburban areas instead of bedroom communities.

Dependence on the automobile as the dominant mode of urban transportation coupled with 2 to 3% annual growth in vehicle kilometres of travel (VKT) in urban areas

directly affects the air quality (DeCorla-Souza & Schoeneberg, 1992). An extensive investigation of the relationship between automobile-related air pollution and urban land use was carried out by Ingram and Pellechio (cited in Horowitz, 1982) for the Boston area. The purpose of this study was to examine the impacts of land use changes on the air quality of this area. Four land use scenarios were developed. Of these, only the centralization of population and employment scenario provided significant reductions on total regional automobile HC¹ and NO_x emissions by 15 and 18% respectively. However, this scenario increased the traffic density in the centre of the Boston region and consequently, increased the annual average CO concentration in parts of that area by nearly 100%. Another study of land use policy for the Washington, DC, area conducted by Roberts (cited in Horowitz, 1982) showed that the dense centre scenario (i.e., growth in population and employment mainly in the centre of the region and in inner suburbs) and transit-oriented scenario (i.e., growth in population and employment mainly along the transit corridors) produced fewer daily automobile trips and VKT than the other scenarios. However, this study did not estimate the resultant emissions. If they had been estimated, the total automobile HC and NO_x emissions almost certainly would have been lower in these scenarios than those of the current plan scenario (Horowitz, 1982). In a study for Hartford, Voorhees et al. (cited in Evrensel, 1989) estimated that the average trip length of an urban form with a single activity centre would increase approximately 22 percent as compared to that of an urban form with balanced sub-centres.

Development of subregions with a balance of residential and employment

¹ A comprehensive definition of this and other air pollutants is presented in Chapter VI.

opportunities has provided planners with an effective way to reduce travel demand. " ...the **balanced subregion** concept assumes that, given the opportunity, people would live closer to their jobs in order to minimize transportation expenses and commute times" (Evrensel, 1989). From an environmental point of view, this would result in less traffic volume on the transportation system and consequently less emissions (Evrensel, 1989). Supportive to this concept is the study undertaken by the Southern California Association of Governments (SCAG, 1989) for the Southern California region. The study showed that compared to the "no-action" scenario, the redirection of 9% of the new employment to housing-rich areas and placing 5% of the new housing units to job-rich areas would cause a reduction of vehicle kilometres travelled by 8.5%, vehicle travel hours by 37% and reactive organic gases (ROGs) by 33%. This scenario also resulted in a more balanced distribution of jobs and housing among sub-regions.

Another study in Chicago by Northern Illinois Planning Commission (cited in Evrensel, 1989), revealed that concentrating developments along relatively high density corridors would give the lowest levels of particulate matters and NO_x concentrations. The important characteristic of this scenario was the existence of fairly high residential and industrial developments along corridors which were surrounded by a large green area. Therefore, the presence of the green belt adjacent to pollutant sources was regarded as an important measure for pollution reduction.

In a study by Kurtzweg and Weig (cited in Evrensel, 1989) for Seattle, Washington, two different land use patterns with their corresponding transportation networks were evaluated for their effects on the resulting air quality. Scenario A assumed

the current trends in land development. Another scenario B assumed the "cities and corridors" concept for land development (Figure 1.1). Total emissions produced in scenario A were about 12 percent higher than those produced in scenario B.

On the other hand, other studies have shown that higher density land use scenarios would have very marginal or even no positive effects on air quality. Bae (1993), in a critical examination of the SCAG study, has pointed out that measures aimed at reducing VKT (i.e., growth management plan, mode shift strategies, alternative work schedules, etc.) have only a modest impact on reducing air pollution. Using available data, he has shown that emission reductions derived from VKT-related control measures account for only 33 to 46 percent of the transportation emission reductions with the growth management plan accounting for only 4 to 19% of reductions for the critical pollutants. In other words, he believes that technological measures such as alternative fuels and low-emission vehicles are much more important for reducing automobile emissions than transportation measures aimed at reducing VKT. They account for up to two-thirds of emission reductions. Also, in a study by DeCorla-Souza and Schoeneberg (1992) after an evaluation of several perceptions and realities about the relationship between transportation and air quality, it was concluded that coordinated land use planning, infrastructure capacity expansions, and pricing strategy are only long term (i.e., several decades from now) solutions for restraining the VKT growth and that technological innovations are the basic solutions in the short term.

Giuliano (1991), in a study on the jobs-housing balance issue examined the commuting patterns of workers living in planned communities. Planned communities as

Figure 1.1 Cities and Corridor Concept (as modified by Evrensel, 1989)

defined in that study, were considered as self-contained units in which jobs and housing mixes were matched to provide people with the opportunity to work close to home. She reviewed a broad study of planned communities in the United States which was conducted during the 1970s. In part of that study, commute patterns between 15 matched pairs of planned and unplanned communities were compared. The comparison of work trip characteristics in planned and unplanned communities revealed that median worktrip time and worktrip distance were almost the same for both groups of communities. The analysis also showed that in planned communities, relatively few proportion of workers lived and worked in the same community. The key reason for this was attributed to the high cost of housing in those communities (Zehner, 1977). In addition, the Zehner study found that even in communities with more jobs than workers, most of the workers worked outside their home community (Giuliano, 1991).

In 1979 and 1990, studies were conducted for the Denver region on the relationship between land use, transportation, and air quality (Scheuernstuhl & May, 1991). In the 1979 study, five alternative land development pattern scenarios corresponding to the year 2000 were developed. The five land use scenarios were: two multi-activity centre scenarios; a dispersion scenario; a centralization scenario; and a "higher growth" scenario. The transportation system was assumed to be identical for all scenarios. Each of these scenarios was compared to a "null" case which basically represented the current trend of low density suburban growth pattern at that time. The results of the analysis showed that the alternative land use scenarios had very marginal effects on air quality. However, no further analysis was done to find out why so little

change occurred in the resulting air quality of various scenarios. The 1979 study used the same transportation system (in terms of highway and transit network) for each of the scenarios. Therefore, the only variable was the land use spatial distribution. However, this assumption might not be appropriate. Each land use scenario needs its own compatible transportation system, especially in terms of transit service. Concentrating the additional employment and population in the central core without improving the transit system in that area or without encouraging other environment-friendly modes of travel would cause increased traffic congestion which in turn would deteriorate the air quality.

The 1990 study for the same region was intended to understand whether any differences might occur in the 2010 air quality as a result of implementing the 2010 plans. One of these plans was the Regional Transportation Plan (RTP) based on the continuation of the current trend towards the low density land development pattern. The other plan was a 2010 higher density scenario based on employment growth concentrated along seven rapid transit corridors called for in the 2010 RTP. In addition, the transit system was assumed to be improved substantially along the corridors. A standard four-step model was used to estimate travel patterns for the two scenarios. The results of the analysis demonstrated that the high density scenario resulted in a higher CO level. However, other pollutant levels as well as vehicle miles of travel remained relatively unchanged between the two scenarios. The reasons for these results as implicitly mentioned in their report (May & Scheuernstuhl, 1991) could be attributed to the following:

- The high density scenario was based on a much higher percentage of future population growth concentrated in transit corridors, compared to the scenario of

expected employment growth, which led to an imbalance of employment-to-population ratios.

- A proper accessibility to the transit system was not provided. This subsequently led to the continuation of dependence on private automobiles.

These studies demonstrate that there are different points of view regarding the relationships of urban form, transportation, and air quality. In the context of land use planning, all of the studies have demonstrated the results of their empirical tests on different land use patterns to support their hypotheses. These results, then, imply that there is more research needed in this area. It is the purpose of this research to provide a better understanding of this interrelationship of transportation, land use, and air quality.

1.3. PROBLEM DEFINITION

As shown in the previous section, the interrelationship of land use patterns, resultant transportation demand, and air quality impacts is the subject of much speculation and debate. Some planners have hypothesized that the low density, dispersed structure of typical urban and suburban developments has forced dependency upon the single occupant vehicle to access both work and non-work destinations. These planners believe that the continuation of the dependency on the automobile mode results in more vehicle kilometres of travel and the corresponding degradation of air quality. Conversely, others believe that the development of higher density patterns and concentration of employment and population along the transit corridors or in the central area cores will result in no

changes or marginal benefits in terms of air quality (May & Scheuernstuhl, 1991).

Having expressed these points of views, it was considered advantageous to conduct an investigation in this area by studying this interrelationship in order to determine how and to what extent automobile-related air pollution in cities may be reduced. In this regard, the Transportation Research Board (1992) has also defined a proposed research to investigate the impact of density and development pattern on personal transportation decisions and the resulting air quality impacts.

In this research, four alternative land use scenarios were developed for the study area² and then the traditional four-step Urban Transportation Modelling System (UTMS) was deployed to forecast travel patterns for each of the scenarios. The resulting emissions of alternative scenarios were then compared against each other.

1.4. RESEARCH OBJECTIVES

The main objectives of this study are:

- 1) to develop and apply a methodology for energy and emission analysis of selected land use-transportation scenarios;
- 2) to quantify and assess the significance of air quality impacts of different urban growth scenarios; and
- 3) to suggest land use-transportation coordination for improving air quality.

the Official Plan of the Regional Municipality of Ottawa-Carleton has adopted the **"Cities and Corridors"** concept (RMOC, 1988). It is based on three major (satellite)

² This is described later in Chapter II.

urban centres¹ outside the green belt as the focal points for the Region's future development. According to this concept, cities are developed at moderate densities and each acts as the activity centre for the surrounding subregion. In addition to the development of high capacity rapid transportation links to the Central Business District (CBD), this concept would promote a job and housing balance by concentration of both residential and employment development. In theory, this concept should improve the air quality because of the close proximity of housing, shopping and employment opportunities. Moreover, walking and cycling would be encouraged. Furthermore, this concept could increase the efficiency of transit service when cities are linked by a transit system (Evrensel, 1989). A rapid transit service would connect central cities and satellite cities while the feeder transit, oriented toward the city centre, would provide mobility within the cities. By improving the efficiency of the regional transit system as a competing mode of travel with private automobile, the cities and corridor concept would improve air quality (RMOC, 1988; Evrensel, 1989; Delcan Corporation, 1991).

However, owing to the scope of this research study, it is not the intent to determine a preferable urban form. For an existing urbanized region, existing socio-economic and transportation system characteristics would serve as constraints. In most instances, a substantial change in the urban structure will be economically and politically impractical or even impossible because the housing and commercial development infrastructure already in place is massive and cannot be relocated. For these reasons, this study is concerned with methods (in the context of land use planning) to improve the

¹ for a full explanation of the Region's urban configuration and the study area see Sec. 2.2.

Region's air quality and at the same time maintain the main features of the Official Plan.

1.5. SCOPE

Due to the fact that the morning and/or afternoon peak periods represent the highest demand upon the transportation network, and the majority of the trips made during rush hours are home-based work (HBW) trips (i.e., trips that have one end at home and the other one at work), the study deals only with HBW trips made in the afternoon peak hour (i.e., between 4:00 to 5:00 pm). Therefore, all the necessary input data for analyses such as travel times, observed Origin-Destination survey, distance travelled, etc., correspond to that period of time.

Three major modes of travel are taken into account for the study area: Auto, Transit, and Bicycle. Bicycle trips, however, are not simulated as auto or transit, since the behavioral mode choice model cannot handle this mode at present. Therefore, bicycle trips are estimated based on limited information obtained from a few technical reports and some limited bicycle survey results undertaken in Ottawa.

1.6. THESIS ORGANIZATION

Chapter 2 explains the study methodology. The study area and assumptions made for further analyses are also discussed.

Chapter 3 contains a description of the 1986 Origin-Destination survey carried out in the National Capital Region, and base case 1986 scenario plus alternative future land use scenarios for the study area.

In Chapter 4, the four-step transportation modelling system is explained. Some important characteristics of the Quick Response System II (QRS II) - the computer program used for forecasting impacts of land use scenarios on travel patterns- is discussed as well. The procedure for calibrating the QRS II in terms of trip generation, trip distribution, and modal split is discussed in full.

Based on the findings of Chapter 4, the model application for future travel forecasts is explained in Chapter 5. This basically deals with travel demand analyses of various future scenarios. A more detailed description of alternative future scenarios in terms of their transit characteristics is also provided. The results of travel demand analyses are presented at the end of the chapter.

Chapter 6 first explains briefly the air pollution terminology, pollutant sources, and the principal pollutants. Based on the results obtained in Chapter 5, it then presents the energy consumption and emission estimates of alternative scenarios.

Chapter 7 includes a summary of the thesis, and conclusions. In addition, extensions or recommendations for further study are made.

Appendix A contains land use information for 1986 and 2011. Appendix B provides lists as well as outputs of the programs (Basic) which were developed for estimating district-to-district travel times in 1986 and 2011. In Appendix C, results of person trip simulations for various scenarios are presented. Appendix D includes the list of the developed program (Basic) for the estimation of district-to-district travel distances in 2011. Finally, Appendix E contains the assumed itineraries taken by buses serving between Kanata and the rest of the Region in 2011.

CHAPTER II

RESEARCH FRAMEWORK AND THE STUDY AREA

2.1. RESEARCH FRAMEWORK

The research methodology is developed to analyze changes to the *given* future land use scenarios for the study area. Figure 2.1 illustrates the study framework. Having assumed the Base future land use pattern for the study area, alternative land use scenarios are developed by increasing the number of employment opportunities in selected zones. It is hypothesized that providing more job opportunities in the City of Kanata⁴ within its existing area boundaries (i.e., higher-density land use pattern) coupled with transit improvements could induce more internal trips that would otherwise be destined to other zones outside the area. Following the definition of the various land use scenarios, the vehicle kilometres of travel (VKT) are computed using the modelling framework. Finally, the total emissions and fuel consumption for the scenarios are calculated.

2.2. STUDY AREA

As mentioned above, to test the research hypothesis, the West Urban Community located at the west part of the Ottawa-Carleton Region was selected as the case study. It includes the city of Kanata and the village of Stittsville, with the latter as part of the

⁴ This is explained later in Sec. 2.2.

Figure 2.1 Study Framework

Figure 2.2 The Eleven Area Municipalities Within The RMOC (RMOC, 1992a)

township of Goulborn. Fig. 2.2 shows the Region and the area under study. The Regional Municipality of Ottawa-Carleton covers an area of approximately 2,767 square kilometres (1,068 square miles). About 90% of this area is rural, and the rest is built-up (RMOC, 1992a). The RMOC consists of eleven area municipalities, namely: cities of Ottawa, Gloucester, Kanata, Nepean, and Vanier; the townships of Cumberland, Goulborn, Osgoode, Rideau, and West Carleton and the village of Rock-Cliffe Park. The total population in the Region for 1986 is 606,639 (RMOC, 1988). At the same time, the total number of dwelling units and employment for the study area have accounted for about 4 and 3% of the Region's totals respectively. For the year 2011 however, these figures are estimated to be about 9% and 8% respectively (RMOC, 1991). Table 2.1 summarizes the demographic data for the Region and the study area.

The presence of a large greenbelt is a unique feature in the RMOC. It separates the older, more established urban areas which it surrounds from the newer, less developed areas located outside the greenbelt. Based on the RMOC Official Plan, three large areas outside the greenbelt known as the West, East, and South Urban Centres will collectively accommodate most future growth in the RMOC (Delcan Corporation, 1991). The west and east urban centres are generally referred to as Kanata and Orleans respectively (RMOC, 1988). Figure 2.3 illustrates the geographic areas in the RMOC. The Central Area (generally called Central Business District or simply CBD) is the main focal point and has the highest concentration of employment in the Region (RMOC, 1992a). Therefore, selecting the West Urban Community (hereafter referred to as Kanata) as the case study, with its mix of housing and jobs, eventually verifies the research hypothesis.

Table 2.1 RMOC Growth Projections (RMOC, 1991)

	RMOC		STUDY AREA	
	1986	2011	1986	2011
Population	606,639	871,000	31,519	90,034
Dwelling Units	228,130	368,000	9,740	31,523
Employment	340,820	560,000	9,213	43,507

Figure 2.3 Geographic Areas In The RMOC (RMOC, 1992a)

2.3. ASSUMPTIONS

To proceed with analyses, the following assumptions are made:

- The future base case and all other alternative scenarios correspond to the year 2011.
- Based on conversation with the Planning Department of the RMOC, it is concluded that the employment levels forecasted for year 2011 within Kanata could increase by 20% (25% in specific zones) without undermining the integrity of the future land use plan. This is the basis for creating alternative scenarios.
- In order to compare the alternative scenarios with each other, the number of dwelling units in Kanata are kept constant. Consequently, as will be explained in more detail later in Chapter 4, the total number of trips produced in that area remains the same for all scenarios.
- The level-of-service (LOS) approach is used to estimate the vehicular emissions (Purvis, 1991). That is, total emissions are calculated by simply knowing the total vehicle kilometres of travel (VKT) and the emission factors (grams of pollutants/VKT). The effects of vehicle speed, cold start, hot soak, hot start, etc. are assumed to be incorporated in the emission factors.
- The 258-zone system of the Transportation Department of RMOC is used to aggregate the zones into a 29-districts system.
- The land use information (i.e., population, employment, dwelling units) and travel information (eg. O-D survey, travel times, travel distance, etc.), are based on the 258-zone system. These were obtained from the Transportation Department of the

RMOC.

CHAPTER III

THE 1986 AND 2011 LAND USE SCENARIOS

3.1. INTRODUCTION

In the Fall of 1986, a comprehensive origin-destination survey was undertaken in the region consisting of the Regional Municipality of Ottawa-Carleton and the Communauté Régionale de l'Outaouais (Fig. 3.1). The purpose of the survey was to compile information on the travel patterns of the residents of the National Capital Region, both urban and rural (RMOC, 1992b).

The study was carried out by the TRANS committee- a joint technical committee on transportation systems planning in the National Capital Region. The TRANS survey included the mailing of a questionnaire to a small sample of households in the Region. After incorporating the valid returned questionnaires into a database, the data were manipulated to be representative of the population (RMOC, 1992b). This survey provided a rich source of information on the travel patterns in the Region which is used in many transportation planning studies (RMOC, 1992a; RMOC, 1992b). This paper is indebted to that study for the required travel analysis.

3.2. TRANSPORTATION MODELLING

The Transportation Planning Division of RMOC currently uses a 258-traffic zone

Boundary Locations For The Regional Municipality of Ottawa-Carleton,
The Communauté Urbaine De L'Outaouais And The National Capital Commission

Figure 3.1 Regional Boundaries (RMO, 1992a)

system which covers the entire area, as illustrated in Fig. 3.1. This zoning system is too large and cumbersome to work with in examining the distribution of trips and land use variables. Furthermore, because this study deals only with a small part of the whole region, a 29-district system is established to summarize both trip tables and land use data. The district system is designed such that it is as compatible as possible with the RMO's 19-district system. Figures 3.2 and 3.3 provide a rough sketch of the 19- and 29-district systems respectively. The major difference between the two systems is observed in the Kanata area. District 16 in the RMO's district system is broken down to seven smaller ones in this study, so that it provides more detailed travel patterns in the study area. The conversion of 258-traffic zone system to the 29-district system ensemble is presented in Table 3.1. It lists the 258 traffic zones which comprise each of the 29 districts. With respect to this:

- 1) Districts 26 through 29 are external to the coverage area by the National Capital Region; and
- 2) Districts 19 through 25 are located within the study area of this research.

3.3. SCENARIOS

In order to examine possible opportunities for air quality improvements in the medium term to 2011, a series of scenarios of future land use patterns for the area under study are developed. The scenarios examine the impacts of various employment scenarios and transit level of service on resulting air quality.

General assumptions that apply to all scenarios are explained. It is assumed that

Figure 3.2 19 District System (RMOC, 1991)

Figure 3.3 29 District System

the transportation system infrastructure remains constant in all future scenarios. All determinants of travel are assumed to be constant, except the employment and transit supply factor changes which are explicitly noted as part of the developed scenarios examined here.

In all future scenarios, technological changes that improve the fuel economy of vehicles are taken into account in fuel consumption and emission rates. These estimates are discussed in detail in Chapter 6. Also, each of the future scenarios contains a number of sub-scenarios which examine the effects of transit level of service changes. However, because these sub-scenarios basically reflect the transit characteristics of the computer program used, they will be explained in Chapter 5.

3.4. 1986-BASE CASE SCENARIO

This scenario is basically used for the purpose of model calibration. The first step in every transportation forecasting process is to calibrate the model used against the real case, so that it will replicate the observed situation and then be applied to the future forecasts. Given all the necessary information from the 1986 O-D survey and from the transportation system characteristics, this scenario constitutes the basis for the horizon year 2011 travel forecasts.

The 1986 land use data obtained from the Transportation Department of RMOC for the 258 zone system are aggregated to form the 29-district land use data presented in Table 3.2. The original land use data are shown in Appendix A.1.

Table 3.1 The Conversion of 258 Traffic Zones to 29 Districts Ensemble

District	Comprising Zones
1	1,2,3, 11-21
2	4-10, 22-25, 201
3	90-98, 100
4	68-89
5	99, 101-109
6	26-45, 57,58
7	59-67
8	46-56
9	120-124
10	135-138, 221-226
11	110,142,143,202,204, 234-237, 246-247
12	144-145, 203, 238-244
13	139,141,230,231,245
14	111-119, 140,205, 227-229, 232-233
15	125-128
16	156,157,162, 165-181, 185, 248-253
17	132-134
18	146-155, 158-161, 163,164, 182-184, 186,187, 254-258
19	130
20	216-219
21	206,210,211
22	131
23	207-209
24	212-215
25	129,220
26	188,189
27	190,191,193,194
28	192, 195-197, 200
29	198,199

Table 3.2 The 1986 Land Use Data of 25 Districts in the 29-District System

District	Dwelling unit	Retail Employment	Other Employment	Total Employment
1	22950	4525	92073	96598
2	15516	4289	32663	36952
3	20250	4978	14903	19881
4	22525	4039	38063	42102
5	10245	916	8447	9363
6	30250	5263	42136	47399
7	13205	2837	11257	14094
8	17365	2889	8232	11121
9	6875	664	7354	8018
10	8120	646	3152	3798
11	13436	1772	4614	6386
12	7865	179	1414	1593
13	4387	371	4256	4627
14	14325	1538	14245	15783
15	4420	1055	9710	10765
16	33939	6782	15936	22718
17	6365	460	2664	3124
18	36149	7081	38652	45733
19	2740	88	696	784
20	1786	167	955	1122
21	8	115	342	457
22	1842	170	545	715
23	15	35	4846	4881
24	24	0	69	69
25	3325	546	639	1185
$\Sigma =$	298197	51405	357863	409268

3.5. YEAR 2011 BASE LAND USE SCENARIO (SCENARIO NULL)

Scenario Null provides a base-line so that the results of other scenarios can be compared against this scenario. The projected land uses for the 25 districts within the region are shown in Table 3.3. The original 258-zone land use data for year 2011 are provided in appendix A.2. For an easier comparison of the land use patterns in the Kanata area, Table 3.4 represents its land use characteristics in 1986 and 2011. Also, Fig. 3.4 illustrates a rough sketch of the districts within the study area. In that figure, the thick lines represent the district boundaries while the thin lines represent the zone boundaries as defined in the 258-zone system of RMOC.

Table 3.4 demonstrates, as compared to the 1986 land use data, that there are four districts, namely: 20, 21, 23, and 25 which will be substantially developed by the year 2011. Therefore, the total employment in those districts is increased incrementally to establish the alternative scenarios. This table also demonstrates that the Jobs-housing ratio is increased by 45% from 0.95 in 1986 to 1.38 in 2011, indicating that this area will be shifting from a "bedroom community" towards a "bedroom-workplace" .

The details of the transit network in 2011 for the study area are not available. However, in a transit study for the West Urban Community, a conceptual strategic plan is developed for transit service in the year 2011 (Delcan Corporation, 1991). As shown in Figure 3.5, the transitway is extended westward in the highway 417 corridor from Woodroffe Ave. to the WUC with a transitway station located at the west end of the Kanata Town Centre, near the Highway 417/Ferry Fox Dr. interchange. Local routes (i.e., feeders) within WUC are oriented along major collector and arterial roads, toward the

Table 3.3 The 2011 Land Use Data of 25 Districts in the 29-District System

District	Dwelling unit	Retail Employment	Other Employment	Total Employment
1	31805	5230	113240	118470
2	18675	5672	35925	41597
3	26505	5592	23507	29099
4	25175	4378	44085	48463
5	16051	1736	20462	22198
6	33810	5552	45380	50932
7	13825	3591	13252	16843
8	21239	3803	14903	18706
9	7630	845	10985	11830
10	27420	4363	24287	28650
11	19320	4555	26805	31360
12	28840	1546	24789	26335
13	13540	1473	9269	10742
14	34130	4843	35226	40069
15	4935	1105	14504	15609
16	56092	11026	35411	46437
17	13797	538	5026	5564
18	55520	10385	55480	65865
19	2990	150	725	875
20	6000	1400	5600	7000
21	7062	2523	9018	11541
22	1860	175	575	750
23	3493	452	15083	15535
24	43	2	4	6
25	10075	750	7050	7800
$\Sigma =$	479832	81685	590591	672276

Table 3.4 The Study Area Land Use Characteristics in 1986 and 2011

District	1986 LAND USE					2011 LAND USE				
	Dwelling Units	Retail Employ ¹	Other Employ ²	Total Employ ¹		Dwelling Units	Retail Employ ¹	Other Employ ²	Total Employ ²	
19	2740	88	696	784		2990	150	725	875	
20	1786	167	955	1122		6000	1400	5600	7000	
21	8	115	342	457		7062	2523	9018	11541	
22	1842	170	545	715		1860	175	575	750	
23	15	35	4846	4881		3493	452	15083	15535	
24	24	0	69	69		43	2	4	6	
25	3325	546	639	1185		10075	750	7050	7800	
$\Sigma =$	9740	1121	8092	9213		31523	5452	38055	43507	
	JOBS/HOUSING = 0.95					JOBS/HOUSING = 1.38				

proposed transitway station and the Highway 417 corridor.

Based on this conceptual plan, the following assumptions are made for developing the transit network for this land use scenario:

- The 1992 Transit System Map of OCTranspo is assumed to be the transit network in Kanata with the exception of the following modifications:
 - the local routes currently terminated at Kanata Town Centre are shifted toward the new location of the previously explained transit station.
 - Two more local routes (arbitrarily named 300 and 301) are added to the local transit network. These routes basically serve the areas within the developing districts. Route 300 has a south-north direction serving districts 25, 19, 21, and 23 and passes through the recommended transit station. Route 301 connects district 20 (village of Stittsville) to the transit station.
- The transit system for the whole region is based on the Transitway programme approved by the Region's Council (RMOC, 1988). This 10-year programme (started in 1981) has a total length of approximately 31 kms, as shown in Fig. 3.6. As of July 1991, a total of 21.7 kilometres of Transitway along with 3.3 kms of the Ottawa River Parkway is in operation (RMOC, 1992a). East- and west-ward extensions to the Transitway programme, shown as "Future Extensions" in Fig. 3.6, are the subjects of detailed environmental studies. A total of approximately 32 kms of transitway extensions are considered for further study (RMOC, 1992a). These include:

Figure 3.4 Study Area and District System Within the Area

Figure 3.5 Conceptual Strategic Plan of Transitway for Kanata (Delcan, 1991)

Figure 3.6 The RMO Transitway Programme (RMO, 1992a)

"...Baseline Station to Strandherd Drive	9 km
Blair Road to Regional Road 57 (Trim Road)	11 km
West Transitway at Queensway Station to Kanata	12 km"

For the purpose of this study, it is assumed that these extensions would be in operation by the year 2011 and that transit trips between Kanata and the rest of region (districts 1-18) would be basically made via the transitways.

3.6. SCENARIO A

This scenario assumes a 10% increase in total employment expected in 2011 in each of the four susceptible-for-development districts in the study area. Some transit improvements in terms of bus headway, fare, and access time are assumed to create two more sub-scenarios. They are explained later in Chapter 5.

3.7. SCENARIO B

Scenario B is similar to the Null scenario except that total employment is increased by 15% in those four districts. Transit improvements in this scenario are provided as well, to create two more sub-scenarios.

3.8. SCENARIO C

Total employment in this scenario is increased 20% for each of those four districts. Bus headway for the local routes are decreased even more to provide a better service to the study area. Like scenarios A and B, it is comprised of three sub-scenarios.

3.9. SCENARIO D

Scenario D assumes a 25% increase in total employment only in districts 21 and 23. These districts will have the highest concentrations of employment in the future, so it is decided to examine the impact of local high increases in employment on the resulting air quality. This scenario, however, consists of five sub-scenarios which like other scenarios, takes into account the effects of transit improvements.

Table 3.6 summarizes the employment characteristics for all future scenarios including the Null case.

Table 3.6 Total Employment in the Study Area in 2011 for Alternative Scenarios

DISTRICT	SCEN. NULL	SCEN. A	SCEN. B	SCEN. C	SCEN. D
19	875	875	875	875	875
20	7000	7700	8050	8400	7000
21	11541	12695	13272	13489	14426
22	750	750	750	750	750
23	15535	17088	17865	18642	19419
24	6	6	6	6	6
25	7800	8580	8970	9360	7800
Σ	43507	47694	49787	51881	50275
Jobs / Housing	1.38	1.51	1.58	1.65	1.59

NOTE: Numbers written in bold indicate change in employment with respect to the Null scenario.

CHAPTER IV

TRAVEL DEMAND ANALYSIS AND MODEL

CALIBRATION

4.1. INTRODUCTION

This chapter presents the methodology utilized to estimate total intra- and inter-zonal trip interchanges for the study area. The Urban Transportation Modelling System (UTMS) approach for transportation demand analysis is first described. This chapter then explains the Quick Response System II (QRS II), the computer program which is used for simulating the travel patterns in the study area. In order to forecast the future travel patterns for different land use scenarios in the study area, it is first necessary to calibrate the model against an observed situation. The 1986 O-D survey is the source of information for such a calibration. The parameters in QRS II are adjusted to replicate the district-to-district auto and transit trips observed in 1986. Data input, calibration of the model, and its application for future scenarios are discussed later.

4.2. THE URBAN TRANSPORTATION MODELLING SYSTEM (UTMS)

The urban transportation modelling system (UTMS) is a system of models which provides the transportation planners with a standard approach for modelling the urban travel demand. It is used to predict the number of trips generated within an urban area

by type and time of day, zone-to-zone trip interchanges (i.e., origin-destination flows), the mode of travel used in making these trips, and the paths taken in the highway network by these trips (Meyer & Miller, 1984). In its final output, UTMS predicts a set of modal traffic volumes on links in a network. There are two major inputs to UTMS: (1) attributes of the activity system that generates these flows and (2) the transportation system characteristics which serve these flows. The UTMS is composed of four major steps as shown by Fig. 4.1 (Meyer & Miller, 1984). Each of these steps are described below:

1. *Trip generation.* This step estimates the number of trips that are produced by and attracted to each zone from a knowledge of land use characteristics of each zone (Meyer & Miller, 1984; Hutchinson, 1974).
2. *Trip distribution.* This step predicts the distribution patterns of trips generated in each zone among various destination zones (Stopher & Meyburg, 1975).
3. *Modal split.* This stage simulates the manner in which the origin-destination flows use each of the available modes of travel (Hutchinson, 1974).
4. *Trip assignment.* This step predicts the way in which O-D flows for each mode are distributed over the links of their respective networks (Hutchinson, 1974; Meyer & Miller, 1984).

Given the time-consuming and iterative nature of this approach computer methods became necessary. The availability of microcomputers has led to the development of numerous microcomputer-based programs (e.g. T-Model, EMME-2, MicroTrips, QRS II) for long- and short-term transportation planning projects. QRS II is one of these programs which is used by most transportation agencies for travel analysis and forecasting purposes.

Figure 4.1 The Framework for Urban Transportation Modelling System

Source: Meyer & Miller (1984)

It should be noted that the QRS II consists of a set of equations which have to be calibrated for land use and transportation systems of interest. In the following sections, while the four-step modelling for the case study is described in full detail, some important characteristics of QRS II and assumptions are explained.

4.3. QUICK RESPONSE SYSTEM II

The QRS II used for this study is Version 3.5 of "QRS II for Windows" developed by AJH Associates (1992b). It is a computer program for examining the effects of land use developments on traffic patterns. The QRS II is available in three editions: the 300-zone edition of QRS II is used for travel demand analysis of small areas, while the 600- and 900-zone editions of QRS II can be used for comprehensive demand analysis in cities as large as one and a half million in population (AJH Associates, 1992b).

The QRS II is interfaced to another program for data entry and data manipulation called the General Network Editor (GNE). The program used for this study is Version 4.0 of "GNE for Windows" developed by AJH Associates (1992a). It is used for storing, analyzing, retrieving, and displaying transportation network data. In fact, all data for QRS II are entered through GNE. Before performing any analysis, the highway network and the set of zones must be integrated. In QRS II, each zone is represented by a special type of node, called a centroid. Also, in QRS II, there is a special type of link called centroids connector which connects a centroid to the highway network. In addition, this link tells QRS II about the amount of time and cost which is required for originating and terminating a trip at a specific zone. QRS II uses this integrated network to estimate the

travel times along their respective shortest paths between every pair of zones (AJH Associates, 1992b).

4.3.1. Level of Detail of the Networks

The networks developed in QRS II can vary widely in terms of their level of detail. A very detailed network could look like a street map of a city with all the roadways drawn on the network. In addition, information on link travel times, geometric features of intersections, and the capacity of each link would be provided by the network. A moderately detailed network could contain only arterials and freeways. However, all link travel times and intersection delays could be estimated by QRS II based on the scale drawing of the network. In its simplest form, the highway network in QRS II could comprise of only a few centroids and a few centroid connectors without any streets or intersections (AJH Associates, 1992b). **The networks developed for different future scenarios in this study include only centroids and centroid connectors.**

4.3.2. Reports

Many reports are produced by QRS II. For example, one of these reports is a file that contains traffic volumes assigned to each link. The QRS II also provides reports in the form of text files. For example, highway volumes or turning movements are listed for specifically requested links or intersections respectively. The QRS II reports the number of inter-zonal as well as intra-zonal vehicle trips. These reports are easily viewed and printed in most Window and non-Window word processors (AJH Associates, 1992b).

4.4. 1986-BASE CASE SYSTEM CALIBRATION

4.4.1. Trip Generation

The trip generation step in QRS II predicts the number of trips produced by and attracted to each zone for three trip purposes: home-based work, home-based nonwork and nonhome-based trips. The estimated trip productions and attractions in this step are exclusively person-trips, not vehicle-trips. Furthermore, they are calculated for a 24-hour period (AJH Associates, 1992b).

In QRS II, trip production for a zone is a function of average zonal income and automobiles per household, whereas trip attraction is a linear function of retail employment, non-retail employment, and dwelling units in that zone. In QRS II, however, it is possible to completely override the trip productions and attractions calculations. That is, for each centroid, the trip production and attraction for each of QRS II's three trip purposes can be inputted directly. In the 1986 survey, because the trip productions and attractions for each zone (based on 258-zone system) are available, they are inputted into QRS II directly to avoid calculations of the trip generation step.

Because the trip productions and attractions for HBW trips in the afternoon peak hour are based on the 258-zone system, they are aggregated into the 29-district form by simple summation of the corresponding figures of the comprising zones for each district. Table 4.1 illustrates the observed trip productions and attractions for the 29-district system in 1986.

Table 4.1 Observed Trip Productions and Attractions for 29-District System in 1986

District	Trip productions	Trip attractions
1	20349	3933
2	7296	2933
3	3124	5131
4	7553	5529
5	2235	3710
6	9845	6943
7	1444	3309
8	1239	4803
9	1421	2256
10	618	2372
11	733	4843
12	345	2953
13	419	1168
14	1917	4279
15	2762	1442
16	3881	8679
17	339	1983
18	10617	9107
19	212	1084
20	161	626
21	0	0
22	1290	426
23	547	177
24	0	7
25	136	1375
26	108	17
27	231	0
28	52	0
29	227	16
Σ	79101	79101

4.4.2. Trip Distribution

The patterns of spatial interaction among zones are represented by trip distribution. The objective of the model is to distribute the total number of trips produced in each zone among all the available attraction zones. The zonal trip ends (i.e., the productions P_i and attractions A_j predicted in the trip generation step) are usually linked based on the time, distance, or cost of travel between the zones for all origin and destination zones. In addition, the variables affecting the distribution patterns include population, employment, and other socio-economic characteristics of the zones (Harvey & Deakin, 1992).

The gravity model is the most common model currently used for accomplishing the trip distribution. Its name is based on a loose analogy to Newton's Law of Gravitation. A typical form of the gravity model is as follows (Khisty, 1990):

$$T_{ij} = \frac{K_{ij} P_i A_j f(t_{ij})}{\sum_{j=1}^n K_{ij} A_j f(t_{ij})} \quad (4.1)$$

where:

T_{ij} = Number of trips that go from origin zone i to destination zone j

P_i = Total trips produced by zone i

A_j = Total trips attracted to zone j

$f(t_{ij})$ = "Travel time factor", a function of the spatial separation of zones i and j

K_{ij} = The adjustment factor

QRS II also uses the gravity model for calculating trip interchanges between each

pair of zones. The process of iterations for performing trip distribution is described in the QRS II reference manual and is explained below (AJH Associates, 1992b):

At each iteration, the process is applied to satisfy the trip attraction constraint⁵:

$$\sum_{i=1}^n T_{ij} = A_j \quad (4.2)$$

The trip production constraint:

$$\sum_{j=1}^n T_{ij} = P_i \quad (4.3)$$

is always satisfied. Equation 4.2 is fulfilled by calculating the "attractiveness" of each zone, B_j^s , for Sth iteration. Before the first iteration, QRS II sets:

$$B_j^1 = A_j$$

Then at each iteration, T_{ij} is calculated as follows:

$$T_{ij} = \frac{P_i B_j^s f(t_{ij})}{\sum_{j=1}^n B_j^s f(t_{ij})} \quad (4.4)$$

At each iteration, new values of trip attraction (i.e., B_j^{s+1}) are also estimated:

$$B_j^{s+1} = \frac{B_j^s A_j}{\sum_{i=1}^n T_{ij}} \quad (4.5)$$

The new values of B_j s are used for the next iteration, (s+1).

⁵ Equations 4.2 through 4.7, and Eqs. 4.10 and 4.11 are borrowed from QRS II Reference Manual.

4.4.2.1. Travel Time Factors

In QRS II, the travel time factor (or friction factor) is a function of travel times (t_{ij}) between each pair of zones. Travel time factors can take one of the two functional forms: "exponential" and "power", or can take any values defined by the user (AJH Associates, 1992b). The "exponential" function has the following form:

$$f(t_{ij}) = \exp(-\beta t_{ij}) \quad (4.6)$$

The "power" travel time factors are of the form:

$$f(t_{ij}) = t_{ij}^{-\beta} \quad \text{for } t_{ij} > 0 \quad (4.7a)$$

and

$$f(t_{ij}) = 1 \quad \text{for } t_{ij} = 1 \quad (4.7b)$$

β is the trip distribution parameter and is different for each trip purpose. "... The value of the parameter is inversely related to the average trip length (in units of time) for that purpose. Large parameters imply that origins are close to destinations. Conversely, small parameters imply that origins are distant from destinations" (AJH Associates, 1992b).

A note on friction factors is provided here. A major drawback of using Eq. 4.6 or Eq. 4.7 is that they assume that travel time is the only factor affecting the patterns of trip interchanges among the zones. However, it is known that the cost of travel (most importantly out-of-pocket costs), distance, etc. have considerable impacts on the patterns of trip distribution (Meyer & Miller, 1984). Therefore, modellers employ the "impedance factor" in practice which is a function of the costs of travel in addition to travel time (RMOC, 1990).

Another equally important point is the assumption of the stability of the friction factor. Recalling the gravity model of Eq. 4.1, it implies that the perception of travel time (or generalized cost) in the future would be the same as it is at present (Stopher & Meyburg, 1975). However, in light of the rapid improvements in transportation technology as well as changes in people's lifestyles, this perception of "time" is likely to be different in the future. In other words, due to the lack of any behavioural assumptions in the model, it is a "descriptive" model rather than a "predictive" one (Meyer & Miller, 1984).

4.4.2.2. Trip Distribution calibration

To calibrate the QRS II's trip distribution model (i.e., finding the appropriate β) the following procedure is used:

1) The 1986 observed travel time matrix⁶ for afternoon HBW trips for the 258-zone system, obtained from RMOC, is aggregated to produce a 29-district travel time matrix. Given observed trip table and travel time matrix, a computer program (Basic) is developed to calculate the weighted travel times between each pair of districts. The basic formulation is as follows:

$$t_{ijw} = \frac{\sum_{i'=1}^m \sum_{j'=1}^n t_{i'j'} T_{i'j'}}{\sum_{i'=1}^m \sum_{j'=1}^n T_{i'j'}} \quad \text{For } i=1 \text{ to } 29 \quad j=1 \text{ to } 29 \quad i \neq j \quad (4.8)$$

where:

⁶ These are automobile travel times and include access and egress times as well (about 2 min. each).

t_{ijw} = Weighted travel time from district i to district j

$t_{i'j'}$ = Observed travel time from zone i' (within district i) to zone j' (within district j)

$T_{i'j'}$ = Observed trips from zone i' (within district i) to zone j' (within district j)

m = Number of zones in district i

n = Number of zones in district j

The program listing and resulting travel time table are presented in Appendix B.1.

The intra-district travel times, however, are calculated slightly different from inter-district ones in that, for all districts except districts 19 and 22 (which are composed of only one zone each), internal travel times are taken as 75% of those calculated by Equation 4.8⁷. To estimate the intra-district driving times for districts 19 and 22, another method is employed: the intra-district driving time is taken as one-half of the average travel time from each of these districts to their adjacent zones⁸ (U.S. Department of Commerce, 1965). Because there is no observed internal trip for district 24, the intra-district travel time for this district is also calculated based on the latter method. The resulting internal travel times are presented in Appendix B.1.

2) A Mini-QRS II network containing only centroids, external stations (i.e., those districts that are outside the RMOC coverage area), and centroid connectors is developed.

⁷ As explained later in this section, the rule of thumb for calculating intra-zonal travel time for a zone is to take one-half of the average travel time from that zone to its adjacent zones. However, because in this study, districts are quite large (in some cases they contain 27 zones), using this method could result in large errors. On the other hand, for small districts, it was observed that using the modified method yielded similar results as compared to those obtained from applying the rule of thumb. Therefore, it was concluded that for this study, applying the modified method for all districts would result in more reliable estimates.

⁸ Based on 258-zone system, the adjacent zones to districts 19 and 22 are: 128,206,214,217,220; and 128, 206,207,210,211, respectively.

Centroids and external stations are drawn on GNE's Sketch Pad. The zonal data for centroids and external stations (e.g. intrazonal travel times, HBW trip productions and attractions) are then entered. Each pair of centroids and external stations are connected with a centroid connector. Centroid connector attributes (i.e., district-to-district travel times) estimated from the previous step are entered into the network. Fig. 4.2 depicts the 1986 developed network. However, it can be seen that not all the centroids (or external stations) are inter-connected. This is because only those pairs of districts with observed HBW trips are connected to each other.

3) An initial parameter (β) is assumed. QRS II is run and the average trip length is calculated by QRS II. The result is compared to the actual average time. If the average trip length is small, the corresponding parameter is lowered and vice versa. **The runs are repeated until calculated and actual trip length agree in the first two decimal digits. This is the only criterion in QRS II for calibrating the trip distribution parameter.**

This procedure is used for both functional forms of friction factor (i.e., "exponential" and "power") to see which one fits better into real observation. Figure 4.3 presents the observed and simulated trip length frequency distribution for both of the functional forms. In this figure, it is observed that for short travel times (i.e., less than 15 minutes), the "power" function provides considerably more discrepancies with the observed curve as compared to the behaviour of "exponential" function. Therefore, **the "exponential" form is selected for application to future scenario forecasts.**

To provide a finer picture, Figure 4.4 illustrates the "exponential" trip length frequency distribution for the first 60 minutes of travel times. Also, based on resulting trip

Figure 4.2 The 1986 Developed Base Network

Figure 4.3 Simulated "Exponential" and "Power", and Observed Trip Length Frequency Distribution

Figure 4.4 Simulated Exponential and Observed Trip Length Frequency Distribution of the First 60 Minutes

distribution parameter, Table 4.2 represents the actual and simulated person trips for the study area while Table 4.3 shows the actual and simulated person trips between Kanata and some other selected districts⁹. Although person trips within Kanata are underestimated by about 20%, Table 4.3 and the resulting simulated trip frequency distribution show that the results are still satisfactory. The actual and simulated person trips for the whole region are presented in Appendix C.1.

4.4.3. Modal Split

Mode choice models predict the share of trips for each available mode of travel. At the very least, these models address auto and transit as the major vehicular modes. These models represent mode choice decisions of the traveller as a function of modal characteristics and socio-economic characteristics of traveller and household. Today, behavioral mode choice models have replaced the earlier methods of estimating "modal split" such as diversion curves and regression models. Mode choice models may be used on either an aggregate basis (i.e., zone-level) or a disaggregate basis (i.e., household-level) and results are aggregated to the zone level afterwards (Harvey & Deakin, 1992).

In particular, the multinomial logit model is the most common form currently used (Meyer & Miller, 1984):

$$P_u = \frac{e^{y_u}}{\sum_{j=1}^N e^{y_j}} \quad (4.9)$$

where:

⁹ These are the districts that had transit trip interchanges with the study area. Section 4.6 provides an explanation of these.

P_{it} = Probability that an individual t takes alternative i

V_{it} = Utility, or overall attractiveness of mode i for individual t

N = Number of available modes

The utility function V_i almost always contains variables such as travel time, travel cost, traveller's income, and the auto ownership level. It is normally a linear function of the variables. Indeed, some simple mode choice models have only the above variables plus the mode-specific constants which capture the effects of other factors which are not included in the model. However, more complicated models contain additional variables such as in-vehicle and out-of-vehicle travel times, waiting time, gender, age, etc. (Harvey & Deakin, 1992; Meyer & Miller, 1984).

4.4.3.1. Transit Terminologies in QRS II

QRS II calculates modal split based on the various captivity rates and the difference between automobile disutility and transit disutility. However, before proceeding further, it is helpful to explain some terminologies used in QRS II to better understand how the modal split step works. They are presented here exactly as defined in the QRS II Reference Manual (AJH Associates, 1992b):

Captivity. "... Captive riders are those people who must make a trip, but have no alternative other than transit". The extent of captive riders varies from place to place. Experience has shown that the number of captive riders in any zone reflects the number of households that do not own automobiles.

Transit zones. "... QRS II permits transit zones that are different from highway

Table 4.2 The 1986 Simulated Versus Observed Person Trips Within Kanata

TO FROM	19	20	21	22	23	24	25	P _i
19	0	7.2	0	29.4	12.6	0	0	49.2
20	0	27.7	0	0	0	0	0	27.7
21	0	0	0	0	0	0	0	0
22	181	35	0	55.4	23.7	1.2	155.4	451.7
23	77.4	15	0	23.7	4.5	0	66.6	187.2
24	0	0	0	0	0	0	0	0
25	0	7.2	0	22.4	9.6	0	10.6	49.8
A _j	258.4	92.1	0	130.9	50.4	1.2	232.6	765.6

OBSERVED PERSON TRIPS IN KANATA

TO FROM	19	20	21	22	23	24	25	P _i
19	33.6	12.9	0	5.6	2.1	0	0	54.2
20	12.6	13.5	0	5.8	2.4	0.2	32.5	67
21	0	0	0	0	0	0	0	0
22	98.7	45.5	0	42.6	15.9	0.7	110	313.4
23	40.4	18.6	0	16.4	8.8	0.3	45	129.5
24	0	0	0	0	0	0	0	0
25	0	7.0	0	2.6	1	0	22.7	33.3
A _j	185.3	97.5	0	73	30.2	1.2	210.2	597.4

SIMULATED PERSON TRIPS IN KANATA

Table 4.3 The 1986 Actual and Simulated Person Trips Between Kanata and Other Districts

FROM ---> TO	OBSERVED	SIMULATED	FROM ---> TO	OBSERVED	SIMULATED
K ¹ ---> 1	120	80.2	1 ---> K	662.8	727.4
K ---> 2	0	7.6	2 ---> K	157.8	207.4
K ---> 4	57	101.4	4 ---> K	61.6	276.8
K ---> 6	210	206.3	6 ---> K	538.2	500.2
K ---> 7	93	86.8	7 ---> K	29.2	42.7
K ---> 15	102	144	15 ---> K	591.4	395
Σ	582	626.3	Σ	2041	2149.5

NOTE:

- 1 K stands for Kanata; districts within Kanata are aggregated to represent the whole study area.

zones. Transit zones are created by subdividing highway zones. Unlike highway zones, transit zones do not have a centroid. Rather, they are indicated by a transit centroid connector. For example, if a highway zone is to be subdivided into four transit zones, it would have four centroid connectors. Each centroid connector goes between the highway centroid and a stop or transfer point. The key attribute of a centroid connector is the *area split*."

Area split. "... Area split is the percentage of highway zone that is within transit zone and served by transit. Ideally the area split should be based on total trip ends (i.e., productions plus attractions). However, it may not be possible to estimate total trip ends for pieces of land as small as some transit zones. Alternatively, the area split may be based on the amount of developed land. When transit zones fully cover a highway zone, the sum of the area splits should be 100%. The sum of the area splits could be less than 100% when some of the highway zone is not served by transit."

Production extra disutility. "... Extra disutility has units of minutes and sometimes is added to transit trips that are produced in a particular zone. This attribute is provided in QRS II principally to accommodate theories of mode split that attempt to vary disutility according to the socioeconomic characteristics of zones."

Attraction extra disutility. "... This attribute is the same as production extra disutility but is added to transit trips that are attracted to a particular zone."

In QRS II, to perform the modal split analysis, first the disutility difference for the trip purpose k , D_k^{jk} , is computed by the following formula (AJH Associates, 1992b): "...

$$D_d^{yk} = \frac{t_y + t_n - D_y - D_n}{2} - D_k^c - D_i^p - D_j^a \quad (4.10)$$

where:

t_{ij} = travel time from zone i to zone j;

t_{ji} = travel time from zone j to zone i;

D_{ij} = weighted average disutility from zone i to zone j by transit;

D_{ji} = weighted average disutility from zone j to zone i by transit;

D_k^c = transit specific constant for purpose k;

D_i^p = production extra disutility for zone i; and

D_j^a = attraction extra disutility for zone j."

As can be seen, the disutility difference, D_d^{yk} , is a function of the travel time and weighted disutility in both directions of travel.

Then, using a logit formulation, the split of trips to transit is made as follows (AJH Associates, 1992b): "...

$$P_{ijk}^t = S_i S_j \left[\frac{(1 - Y_{ik})}{(1 + \exp(-M_k D_d^{yk}))} + Y_{ik} \right] \quad (4.11)$$

where:

P_{ijk}^t = probability that a person trip from i to j takes transit;

S_i = sum of the area splits for zone i (expressed as a fraction);

S_j = sum of the area splits for zone j (expressed as a fraction);

Y_{ik} = captivity for zone i and for purpose k (expressed as a fraction); and

M_k = Mode Split Multiplier for purpose k

D_a^{jk} = difference between automobile and transit disutility.

Both legs (direct and reverse) of the trip have the same mode split."

4.4.3.2. Transit Network Development

To calibrate the QRS II 's modal split step, it is first necessary to develop the transit network and setup transit zones. The following steps were involved (AJH Associates, 1992b):

1) The 1986 OCTranspo Transit System Map, plus timetables and itineraries of local routes in the study area, and other routes outside the study area serving Kanata were obtained from the OCTranspo Planning Department's Library.

2) The district boundaries as defined in Chapter III were drawn on the 1986 System Map in a distinctive colour. Any areas within the districts where there were no developments (e.g. lakes, farms, forests, etc.) were hatched out.

3) The service area boundary of each route was sketched (400 metres to either side of a route; 400 meters at each end).

4) Each transit zone was delineated. Based on the service area of the routes, the area splits were calculated.

The routes' itineraries for the study area were drawn on GNE. Bus frequencies, link-by-link travel times, area splits, access times¹⁰, and transit fare (an average of \$1.2 based on the 1986 data) were used as inputs into the network. Figure 4.5 depicts the complete transit system network developed for the study area. It is appropriate to note

¹⁰ Based on 400 meters service area, a default value of 4 min. is adopted.

Figure 4.5 The 1986 Developed Transit Network For The Calibration Purpose

here that the transit network contains only the local routes serving Kanata and those routes outside Kanata which provide service to Kanata. Therefore, the attempt for modal split calibration, contrary to the trip generation and trip distribution steps, required calibration of the study area and not the whole region.

4.4.3.3. Modal Split Calibration

The results of the 1986 Origin-Destination survey for mode share were obtained at the district level. The 258x258 trip matrices were aggregated to the 19 districts identified in Sec. 3.2 (RMOC, 1990). The 19x19 1986 transit mode share table is listed in Table 4.4. This table, however, includes all trip purposes during peak hour. To be able to use this table for HBW trips, it is assumed that 90% of these modal shares correspond to HBW trips¹¹. As shown in Table 4.4, there are only a few number of districts outside Kanata namely: 1,2, 4,6,7,15 which indicate observed transit interaction with Kanata. The main advantage of using this table is the full compatibility of these districts which indicate observed transit trips to and from Kanata (district 16 in 19-district system), with those identified in the 29-district system.

Given the simulated person trips obtained from the trip distribution step and actual person trips, the weighted average percentage of transit shares for trips within Kanata, trips from other districts to Kanata, and trips from Kanata to other districts are calculated

¹¹ Based on the RMOC information provided in class notes by Shalal (1992), "in general, about 90% of all automobile peak hour trips are HBW ones." It is assumed here that this is the case for transit trips as well. As a word of caution, this may not apply to some cases (as seen in Table 4.6, there is a 44% transit share from Kanata to district 2, whereas there is no observed trip for this pair at all). However, since this table is based on the most comprehensive data available, the author makes the above assumption to proceed for further analyses.

as shown in Tables 4.5 and 4.6. Table 4.5 shows the calculation of transit share for trips originating in districts outside Kanata, while Table 4.6 presents the calculation of transit share for trips originating in Kanata and destined outward. Since there are discrepancies between simulated and observed trips in the trip distribution step, using the transit shares as the criteria for transit calibration instead of the number of transit trips directly, has the advantage that a proportional number of person trips will be allocated to transit. Also, it is important to mention that although there are only three districts (2,6,15) that reflect observed transit trips destined to them from Kanata, the weighting of transit share is based on the same number of districts shown in Table 4.5. This is because QRS II would have assigned some transit trips from Kanata to external districts anyway. Therefore, weighting the transit share based on all districts involved, assures that total transit trips from Kanata will not be over-estimated. For the calibration purpose, there are four parameters namely: the Mode Split Multiplier¹² (M_k) identified in Eq.4.11, extra production disutility, extra attraction disutility, and captivity rates that are subject to adjustments. Here, the objective is to reach as close as possible the observed weighted transit shares, as shown in Table 4.7. The parameters are changed one at a time, starting with the most important one (i.e., M_k). In each run, if the output shows a trend of agreement with the observed case, the value(s) of the parameter(s) is(are) increased in the same direction, otherwise it(they) is(are) increased in the opposite direction. This process is repeated several times (in this study more than 20 times) until the percentage of weighted simulated and actual transit

¹² Recalling the Eq. 4.11, this parameter controls the overall transit share and is inversely proportionate to the comprehensiveness of the transit service (AJH Associates, 1992b).

Table 4.5 Calculation of Transit Trips From Other Districts To Kanata

Districts of Interaction	Fraction of Observed Transit ¹	# of Observed Person Trips	# of Observed Transit Trips	# of Simulated Person Trips	# of Transit Trips Required Based on Obs. Transit Share	Modified # of Transit Trips Required Based on Obs. Transit Share (Col.5 × 0.918 ²)
1 ---> K ³	0.48	662.8	318	727.4	349.2	320.6
2 ---> K	0.64	157.8	101	207.4	132.7	121.8
4 ---> K	0.19	61.6	11.7	276.8	52.6	48.3
6 ---> K	0.20	538.2	107.6	500.2	100	91.8
7 ---> K	0.18	29.2	5.3	42.7	7.7	7.1
15 ---> K	0.08	591.4	47.3	395	31.6	29
Σ	-	2041	590.9	2149.5	673.8	618.6

Notes:

1- The corresponding cells in Table 4.4 are multiplied by 0.9 to account for HBW trips.

2- Based on the above values:

Actual Weighted average transit share for trips destined to Kanata = $590.9/2041 = 0.289$

$\Rightarrow 0.289/0.314=0.918$

Simulated Weighted average transit share for trips destined to Kanata = $673.8/2149.5 = 0.314$

3- Districts within the study area (19-25) are aggregated to form one large district named K (i.e., Kanata).

Table 4.6 Calculation of Transit Trips From Kanata To Other Districts

Districts of Interaction	Fraction of Observed Transit ¹	# of Observed Person Trips	# of Observed Transit Trips	# of Simulated Person Trips	Transit Trips Required Based on Obs. Transit Share	Modified # of Transit Trips Required Based on Obs. Transit Share (Col.5 $\times$ 0.846 ²)
K ----> 1	0	120	0	80.2	0	0
K ----> 2	0.44	0	0	7.6	3.3	2.8
K ----> 4	0	57	0	101.4	0	0
K ----> 6	0.09	210	18.9	206.3	18.6	15.7
K ----> 7	0	93	0	86.8	0	0
K ----> 15	0.10	102	19.4	144	27.2	23
Σ	-	582	38.3	626.3	49.1	41.5

Notes:

- 1- The corresponding cells in Table 4.4 are multiplied by 0.9 to account for HBW trips
- 2- Based on the above values
 Actual Weighted average transit share for trips originated in Kanata = $38.3/582 = 0.066$
 $\Rightarrow 0.066/0.078 = 0.846$
 Simulated Weighted average transit share for trips originated in Kanata = $49.1/626.3 = 0.078$
- 3- Districts within the study area (19-25) are aggregated to form one large district named K (i.e., Kanata).

shares are reasonably agreed. For transit trips within Kanata, the observed modal share is:

$$0.11 \times 0.9 = 0.099 \approx 0.10$$

Therefore, the required number of simulated transit trips is:

$$0.10 \times 597.4 = 59.7 \approx 60 \text{ trips}$$

Tables 4.7 and 4.8 show the final result of transit calibration after several runs. Table 4.7 illustrates the aggregated results. Comparing these figures to target numbers in Tables 4.5 and 4.6, the results are quite satisfactory. Table 4.8 represents in more detail the resulting transit trip matrix for the study area.

4.4.4. Traffic Assignment

As mentioned earlier, this step is not performed because the necessary information in terms of zone-to-zone travel times are already obtained from RMOC. The travel time data are the result of several runs done by the Transportation Department of RMOC and thus are considered to be accurate enough to be used for travel forecast analyses in this study. Subsequently, the 1986 and 2011 highway networks are composed of mainly centroids and centroid connectors with the respective travel times inputted into the corresponding networks.

Table 4.7 The 1986 Observed and Simulated Transit Share Between The Study Area and The Rest of The Region

	OBSERVED	SIMULATED
Weighted Average Percentage of Transit Share:		
OTHER ZONES ---->KANATA	0.289	0.269
KANATA ---->OTHER ZONES	0.066	0.067
WITHIN KANATA	0.10	0.108
No. of Transit Trips:		
OTHER ZONES ---->KANATA	590.9	610.2
KANATA ---->OTHER ZONES	38.3	42.1
WITHIN KANATA	76	64.3

Table 4.8 The 1986 Simulated Transit Share Within The Study Area

TO FROM	19	20	21	22	23	24	25	P _i
19	6.5	0.9	0	1.1	0.1	0	0	8.6
20	1.1	0.7	0	0.6	0.1	0	2	4.5
21	0	0	0	0	0	0	0	0
22	16.1	3.0	0	11	0.8	0	12.3	43.2
23	1.7	0.3	0	1.0	0.1	0	1.3	4.4
24	0	0	0	0	0	0	0	0
25	0	0.4	0	0.4	0	0	2.6	3.4
A _i	25.4	5.3	0	14.1	1.1	0	18.2	64.1

CHAPTER V

TRAVEL DEMAND ANALYSIS OF FUTURE ALTERNATIVE SCENARIOS

5.1. INTRODUCTION

Based on the QRS II's calibration process described in the previous chapter, this chapter provides travel demand forecast results for future scenarios plus a more detailed description of alternative future scenarios in terms of their transit characteristics. The assumptions made for each scenario are discussed as well.

5.2. HIGHWAY NETWORK DEVELOPMENT

The highway network characteristics are the same for all future scenarios except the demographic characteristics. Although this network also consists of centroids, external stations, and centroid connectors, it is somewhat different from the 1986 network. The inter-connection of centroids and/or external stations in 1986 is based on trips that were observed among districts. In 2011, however, there are no observed trips to know which pair of districts should be inter-connected. Therefore, all districts in the system are connected to each other by centroid connectors¹⁴. Fig. 5.1 illustrates the highway network of 2011.

¹⁴ External stations were not connected to each other

Figure 5.1 The 2011 Developed Highway Network

5.2.1. District-to-District Travel Times

As was done with the 1986 case, the 2011 travel time matrix for the afternoon peak hour HiBW trips of the 258-zone system, obtained from RMOC, was aggregated to produce the 29-district travel time matrix. This time, however, because there are no observed trips, the travel time between each pair of districts is simply an average of travel times between each pair of zones within the district. The basic formulation is as follows:

$$t_{ij} = \frac{\sum_{i'=1}^m \sum_{j'=1}^n t'_{i'j'}}{m \times n} \quad (5.1)$$

where:

t_{ij} = Average travel time from district i to district j ; and

$t'_{i'j'}$ = travel time from zone i' (within district i) to zone j' (within district j).

All other terms are defined in Eq. 4.8.

Again, a program (Basic) was developed and run to calculate district-to-district travel times. The program listing and resulting travel time table are presented in Appendix B.2. To develop intra-district travel times (except for districts 19 and 22) the following formulation was used:

$$t_u = 0.75 \times \frac{\sum_{i'=1}^m \sum_{j'=1}^m t'_{i'j'}}{m \times (m-1)} \quad \forall i' \neq j' \quad (5.2)$$

Intra-district travel times for districts 19 and 22 were calculated by the method described in Sec. 4.4.2.2. The resulting travel times were then entered into the network

for further analyses.

5.3. YEAR 2011 NULL SCENARIO

This section describes the trip generation, trip distribution, and modal split steps performed to calculate travel demand for the 2011 base land use scenario.

5.3.1. Trip Generation

To perform the trip generation step for the 1986 case, the observed productions and attractions were inputted into QRS II directly. For the 2011 case, however, because there were no observed trips, the land use data (e.g. retail and non-retail employment, and dwelling units) were used to perform the trip generation step. Based on the 1986 O-D survey, the HBW productions and attractions for each of the 258 traffic zones were estimated as follows (RMOC, 1990):

$$HBW\ Productions_{24\ hours} = 2.358 \times Dwelling\ Units \quad (5.3)$$

$$HBW\ Attractions_{24\ hours} = 1.865 \times Total\ Employment \quad (5.4)$$

The above equations also hold true for the estimation of 24-hour trip generations in 2011. Therefore, to be compatible with the 1986 trip generation step in terms of inputting the peak-hour trip productions and attractions, it was first necessary to find the fraction of each district's 24-hour production and attraction that would occur in the peak hour in 2011. To accomplish this, it was assumed that the same fractions observed in 1986 would be the case for the 2011 case as well. Given the observed peak hour trip

generations and 24-hour productions and attractions found by Eqs. 5.3 and 5.4, the peak hour fractions of daily productions and attractions for each district were calculated and are shown in Table 5.1. Therefore, in the 2011 base case for each district, the "leaving" fraction is multiplied by corresponding 24-hour attraction calculated by Eq. 5.4 and the "entering" fraction was then multiplied by corresponding 24-hour production calculated by Eq. 5.3 to provide a direct estimate of peak hour productions and attractions. These are illustrated in Table 5.2. Subsequently, the corresponding productions and attractions for each district were entered into the program.

5.3.1.1. Balancing Method

As can be seen from an examination of Eqs. 5.3 and 5.4, different types of equations are used to estimate trip productions and trip attractions. Therefore, the total of trip productions for the entire system is not necessarily equal to that of trip attractions. Equality constraint can be implemented by holding trip productions constant and adjusting trip attractions. Alternatively it can be done by holding trip attractions constant and adjusting trip productions (AJH Associates, 1992b). However, experience has shown that trip production estimates are usually more accurate than attraction estimates. Therefore, in this analysis, trip productions (P_j) are held constant and trip attractions (A_j) are adjusted. The adjustment for attractions is done using the following formula (AJH Associates, 1992b):

$$A'_j = \frac{P_j}{A_j} A_j \quad (5.5)$$

where:

Table 5.1 The 1986 24-Hour and PM Peak Hour Trip Productions and Attractions

District	1986 Observed PM peak hour		1986 Calculated 24-hour ¹		Fraction of trips leaving district in PMPH: (Col.2 / Col.5) ²	Fraction of trips entering district in PMPH: (Col.3 / Col.4) ²
	Leaving	Entering	P _i	A _j		
1	20349	3933	54116.1	166741	0.122	0.0727
2	7296	2933	36586.7	63783.9	0.1144	0.0802
3	3124	5131	47749.5	54317.2	0.091	0.1074
4	7553	5529	53114	72673.5	0.1039	0.1041
5	2235	3710	24157.7	16161.7	0.1383	0.1556
6	9845	6943	71966.2	81816.8	0.1203	0.0965
7	1444	3309	31137.4	24328.1	0.0593	0.1063
8	1239	4803	40946.7	19196.3	0.0645	0.1137
9	1421	2256	16211.3	13840.1	0.1027	0.1392
10	618	2372	19147	6555.8	0.0943 (median)	0.1239 (median)
11	733	4843	31682.1	11023.1	0.066	0.1529
12	345	2953	18545.7	2749.7	0.125	0.159
13	419	1168	10344.5	7986.8	0.052	0.113
14	1917	4279	33778.4	27243.5	0.070	0.215
15	2762	1442	10422.4	18581.8	0.149	0.138
16	3881	8679	80028.2	39214.2	0.099	0.108
17	339	1983	15008.7	5392.4	0.063	0.132
18	10617	9107	85239.3	78941.1	0.134	0.107
19	212	1084	4640.9	1353.3	0.157	0.168
20	161	626	4211.4	1936.7	0.083	0.149
21	0	0	18.9	788.8	0	0
22	1290	426	4343.4	1234.2	1.045	0.098
23	547	177	35.4	8425.2	0.065	5
24	0	7	56.6	119.1	0	0.124
25	136	1375	7840.3	2045.5	0.066	0.175
26	108	17	388	906	0.119	0.044
27	231	0	772	1801	0.128	0
28	52	0	773	1804	0.029	0
29	227	16	530	1253	0.181	0.03

Note:

- 1) Based on Eqs. 5.3 and 5.4.
- 2) It is assumed that conventionally a trip which leaves a zone in the afternoon is a returning trip from work to home and consequently it enters a zone to reach its home. Therefore, for each district, trips that are attracted to it due to employment opportunities are "leaving" that district, and trips that are produced by dwelling units are "entering" that district in the afternoon.

Table 5.2 The 2011 Null Scenario PM Peak Hour Productions and Attractions

District	2011 24-hour trip generation		2011 peak hour trip generation	
	P_i	A_i	Leaving (A_i)	Entering (P_i)
1	74996.2	220946.5	26955.5	5452.2
2	44035.6	77578.4	8843.9	3531.7
3	62498.8	54269.6	4938.5	6712.4
4	59362.7	90383.5	9400	6179.6
5	37848.3	41399.3	5713.1	5813.5
6	79724	94988.2	11427	7693.4
7	32599.3	31412.2	1862.7	3465.3
8	50081.6	34886.7	2250.2	5874.6
9	17991.5	22063	2265.9	2504.4
10	64656.4	53432.2	5038.7	8010.9
11	45556.6	58486.4	3860.1	6965.6
12	68004.7	49114.8	6139.3	10812.8
13	31927.3	20033.8	1041.8	3607.8
14	80478.5	74728.7	5231	17302.9
15	11636.7	29110.8	4337.5	1605.9
16	132265	86605	8573.9	14284.6
17	32533.3	10382.4	653.7	4294.4
18	130916.2	122838.2	16460.3	14008
19	7050.4	1631.9	256.2	1184.5
20	14148	13055	1083.6	2108
21	16652.2	21524	2029.7 ¹	2064.9 ²
22	4385.9	1398.8	1461.7	429.8
23	8236.5	28972.8	1883.2	1021 ³
24	101.4	11.2	0	12.6
25	23756.8	14547	960	4157.4
26	1468.6	629.5	175	28
27	2920	1251.3	374	0
28	2925	1253	85	0
29	2031.6	856	368	26
Σ	1131443.8	1253794.7	133670	139152

Notes:

- 1) Because there is no person trip recorded for this district in 1986 during peak hour, the attraction for this district is multiplied by the "median" of "leaving trips" fraction (i.e., 0.0043).
- 2) Because there is no person trip recorded for this district in 1986 during peak hour, the production for this district is multiplied by the "median" of "entering trips" fraction (i.e., 0.1239).
- 3) Because the fraction value obtained for this district is too large and actually does not make sense, again the median of "entering trips" fractions is used to calculate the trips entered to this district.

A'_j = Balanced trip attraction of district j;

A_t = Total number of trip attractions in the system;

P_t = Total number of trip productions in the system; and

A_j = Trip attraction of district j (from Col.4 of Table 5.2).

The result of the balanced trip generation is shown in Table 5.3.

5.3.2. Trip Distribution

The trip distribution parameter obtained in the calibration process (i.e., $\beta = 0.06$) is applied to the year 2011 highway network with its corresponding trip generation data to develop the HBW district-to-district person trips for the afternoon peak hour. Resulting trips for the Kanata area and some highlights of this phase for the Null scenario are shown in Table 5.4. Person trip results for alternative future scenarios and the complete trip table for the entire Region corresponding to the Null scenario are provided in Appendices C.3 and C.2 respectively.

5.3.3. Transit Modal Split

Based on the assumption made in Chapter III, the transit network for the Kanata area is developed. Arbitrarily named routes 300 and 301 are added to the local transit network and the proposed west-end transit station is the focal point for all transit routes. Figure 5.2 shows the transit network for the study area. The area split for all districts within the study area except district 20 is assumed to be 100%. Because Stittsville (district 20) is outside the Urban Transit Area, and based on a proportion of its

Table 5.3 The 2011 Balanced Peak Hour Trip Productions and Attractions

The Whole System

DISTRICT	LEAVING TRIPS (A_i)	ENTERING TRIPS (P_i)
1	28069.5	5452.2
2	9209.4	3531.7
3	5142.6	6712.4
4	9788.4	6179.6
5	5949.2	5813.5
6	11899.3	7693.4
7	1939.7	3465.3
8	2343.2	5874.6
9	2359.5	2504.4
10	5246.9	8010.9
11	4019.6	6965.6
12	6393	10812.8
13	1084.9	3607.8
14	5447.1	17302.9
15	4516.8	1605.9
16	8928.2	14284.6
17	680.7	1293.4
18	17140.6	14008
19	266.8	1184.5
20	1128.5	2108
21	2113.6	2064.9
22	1522.1	429.8
23	1961	1021
24	0	12.6
25	999.6	4157.4
26	175	28
27	374	0
28	85	0
29	368	26
Σ	139152.2	139152.3

2

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

Table 5.4 The 2011 Scenario Null Person Trip Interchange Within Kanata

TO FROM	19	20	21	22	23	24	25	P_i
19	10	16.2	16.4	2.8	6.3	0.1	33.8	85.6
20	32	171.9	52.5	8.9	20.1	0.4	129.4	415.2
21	80.8	116.1	149.7	28.7	57.2	0.9	228.1	661.5
22	47.3	72.1	104.8	24.1	54.1	0.6	159.7	462.7
23	60.3	92	125.9	32.6	87.8	0.8	191.2	591.2
24	0	0	0	0	0	0	0	0
25	35	63.9	51	9.8	20.7	0.3	150.3	331
A_j	265.4	532.2	500.3	106.9	246.1	3.1	893.2	2547.2

Average Trip length = 28.67 min.

Total Number of Trips = 139152.3

Total Person Trips From Kanata to Other Districts = 5445

Total Person Trips From Other Districts to Kanata = 8437

land area served by transit in 1992, its area split is assumed to be 85%. Other parameters are set as follows:

- Bus fare = \$2.00
- Access time = 4 min.
- Modal split parameter (M_k) = 0.009
- Bus frequency = 30 min. for all routes

Given all necessary information and required transit parameters, QRS II is run to obtain modal split in Kanata. Table 5.5 shows the results of transit trips for the study area. The 23% transit share obtained by this model is comparable to the cell (16,16) of Table 5.6. Based on that table, the split of trips to transit for Kanata (zone 16 in that figure) is $0.2 * 0.9 = 0.18$ for HBW trips. Although it over-estimates transit trips by about 27%, considering the level of aggregation used here and the fact that Table 5.6, as explained later in this section, is actually a simulated matrix and not an observed one, the result is still within a reasonable limit. Moreover, a comparison of fare and access time elasticities of the model with those obtained from another study undertaken in Ottawa-Carleton (Khan, 1981) demonstrates the proximity between models (-0.154 and -0.251 for this model against -0.204 and -0.344 in the Ottawa-Carleton study).

To account for transit trips that are destined to other districts outside Kanata, the 19x19 modal split matrix for year 2011 developed by RMOC (1990) is used (Table 5.6). This matrix is developed in the following way by RMOC: The RMOC Official Plan (1988) has established a set of peak hour transit share guidelines across a series of

Figure 5.2 The 2011 Developed Transit Network For The Null Scenario

Table 5.5 The 2011 Transit Share Within Kanata For The Null Scenario

TO FROM	19	20	21	22	23	24	25	P _i
19	2	2.5	3	0.6	1.2	0	7.6	16.9
20	6.6	45.8	11.7	2	4.4	0	30.8	101.3
21	18.3	24.2	44.3	8	17	0.1	54.1	166
22	7.9	10.1	19.6	6.4	12.6	0	26.8	83.4
23	11.7	15.5	31	9.2	24.1	0.1	37.6	129.2
24	0	0	0	0	0	0	0	0
25	9.3	13.8	11.7	2.4	4.8	0	44.8	86.8
A _j	55.8	111.9	121.3	28.6	64.1	0.2	201.7	583.6

screenlines¹⁴ to be obtained in 2011. Based on these figures, a 2011 mode split matrix is developed which achieves these Policy Guideline Modal Splits (PGMS) figures across the screenlines. The 1986 transit shares matrix is used as the starting point and after several iterations, the final 19×19 matrix is built up as shown in Table 5.6 (RMOC, 1990).

As mentioned earlier, because the districts outside the study area are compatible with the 29-district system used in this study, it is possible to use this matrix as a reference. Column 16 of this matrix is used to account for transit interactions between Kanata and the rest of the Region. These figures are, however, for all trip purposes. Therefore, they are multiplied by 0.9 to account for HBW trips.

Having obtained the transit shares and person trips results from the trip distribution step, it is a straightforward task to calculate the total number of transit trip interchanges between Kanata and the rest of the Region as presented in Table 5.7. The weighted transit share between Kanata and the rest of Region (T_w) is calculated as follows:

$$T_w = \frac{\text{Total transit trips to the rest of the region}}{\text{Total person trips to the rest of Region}} = \frac{3892}{8437} = 0.461$$

For the alternative future scenarios, because no changes are made to the transit network outside the study area, the resulting weighted transit share remains constant.

¹⁴ Transportation studies usually involve traffic counting. Such counts are used for different purposes such as validating survey data or determining traffic flow trends, and are done in specific points within the study area. Screenlines are imaginary lines that pass through these points (Meyer & Miller, 1984).

Table 5.6 The 2011 Transit Mode Share For The 19-District System (RMOC, 1990)

[illegible]

**Table 5.7 The 2011 Transit Trips Between Kanata and Rest of The Region For
The Null Scenario**

FROM ----> TO	NO. OF PERSON TRIPS	% OF TRANSIT TRIPS	NO. OF TRANSIT TRIPS (COL.2 × COL.3)
1 ----> KANATA	1638.722	0.675	1106.138
2 ----> KANATA	488.1125	0.675	329.476
3 ----> KANATA	224.216	0.54	121.0766
4 ----> KANATA	543.7207	0.36	195.7395
5 ----> KANATA	234.645	0.315	73.91318
6 ----> KANATA	981.4182	0.45	441.6382
7 ----> KANATA	176.2867	0.45	79.32901
8 ----> KANATA	317.7833	0.45	143.0025
9 ----> KANATA	275.5854	0.27	74.40806
10 ----> KANATA	754.5487	0.27	203.7281
11 ----> KANATA	142.3556	0.225	32.03002
12 ----> KANATA	186.4821	0.225	41.95846
13 ----> KANATA	58.74597	0.18	10.57428
14 ----> KANATA	370.4793	0.18	66.68627
15 ----> KANATA	883.5296	0.45	397.5883
16 ----> KANATA	228.0963	0.63	143.7007
17 ----> KANATA	184.5865	0	0
18 ----> KANATA	684.9216	0.63	431.5006
Σ	8374.2	-	3892

5.3.4. Bicycle Trips

To account for bicycle trips in 2011, first the historic data from previous surveys are integrated and then an extrapolation is made to obtain bicycle share for work trips.

5.3.4.1. Historic Information

The major reference used to obtain data on bicycle trips in the Region, is a recent cyclist profile survey completed in the summer of 1991. The objective of this survey is to establish a profile of cycling which would provide additional insight into the general characteristics of cyclists and their opinions regarding cycling in Ottawa-Carleton (Cumming-Cockburn, 1992). The most important findings of that survey as related to this research are as follows:

- About 4.8 and 3.8% of respondents cycle to work at least three times and four times a week respectively, during the summer months.
- Average cycling travel distance for work trips is about 5.5 km.

It is important to mention here that the survey also asks the respondents about the mode of transportation used most frequently for different trip purposes. However, the results of this question are not presented in the report. Despite several contacts with corresponding authorities in RMOC, it is not possible to get access to that information. Therefore, the above mentioned findings on frequency of bike usage are used as a proxy for the bicycle share of work trips. Conservatively, the value of 3.8% is used to

approximate the bicycle share of travel¹⁵.

On the other hand, the results of the 1986 O-D survey reveal that the bicycle share of travel during the PM peak period (15:30 - 17:59) and 24-hour period for all trip purposes within Kanata area are 1% (RMOC, 1992b). This number of "To Kanata" trips and "From Kanata" trips is zero. Based on this finding, it is assumed that all of the daily bicycle trips in the 1991 study (and also in 2011) will occur during the peak hour.

To compare the above results with those of other studies, some information is extracted from a technical report prepared by Marshall-Macklin-Monaghan Ltd. (1992). In reviewing some of the bicycle studies undertaken in Ontario in 1990, the following points are highlighted:

- The bicycle shares of travel in Inner Toronto and in London, Ontario are found to be 2 and 1% respectively.
- Average trip length in Toronto is 7.5 km; and
- Average speed in Toronto is 22 km/hr for 20 minutes.

It is seen that the above findings approximate those obtained in the Ottawa-Carleton study.

5.3.4.2. 2011 Bicycle Modal Split

The results of the previous section show that bicycle share has increased by 280

¹⁵ This mode split schema is based on the region-wide survey and is not broken down to the municipality level to reflect their modal split schemes. However, due to the unavailability of precise information, it is assumed that this figure is the case for Kanata as well.

percent from 1% in 1986 to a level of 3.8% in 1991. To predict the modal split in 2011, assuming the same trend, it is estimated to be 20%, a highly unlikely and unreasonable figure. Rather, it is assumed that as transit share increases by approximately 130 percent from 10% in 1986 to 23% in 2011, the bicycle trips will also increase by the same amount to the level of 8.7%.

Given the bicycle share and average travel distance for bicycle trips, and based on the trip distance matrix shown in the next chapter in Table 6.2, the district pairs within Kanata that would possibly have bicycle trip interchanges are defined as follows:

<u>From :</u>	<u>To :</u>
19	19,21,22,24,25
20	20
21	19,21,22,23,24
22	19,21,22,23
23	21,22,23
24	19,21,24
25	19,25

Therefore, by multiplying the assumed bicycle share by corresponding person trips obtained for each pair of the above districts (as shown in Table 5.4), the total number of bicycle trips for Kanata is calculated as follows:

$$\begin{aligned}
 \text{Total bicycle trips in Kanata} &= 0.087 \times \Sigma \text{ Person trips}^{16} \\
 &= 0.087 \times 1214.1 = 105.6
 \end{aligned}$$

¹⁶ Only those pairs defined above.

This bicycle trip share (i.e., 8.7%) is assumed to be constant over all of the future scenarios because no changes are made or assumed in the bicycle network (if any) or in the behaviour of cyclists.

5.4. SCENARIO A

As mentioned in Chapter III, this scenario assumes a 10% increase in the total employment in four districts within Kanata. Trip generation and trip distribution steps are performed in the same way described in Sec. 5.3, except that new employment figures are entered into QRS II¹⁷. However, for the modal split analysis within each scenario, different sub-scenarios are developed to account for sensitivity of transit shares with respect to changes in the transit system. That is, for different land use scenarios as the number of employment opportunities increase, proportional transit improvements are made to investigate their impacts on modal shares.

5.4.1. Scenario A1

This scenario is actually a "Do-Nothing" scenario, meaning that despite the increase in employment (and subsequent increase in resulting trips) there is no transit system change or improvements compared to the 2011 Null scenario. Therefore, the same network and parameters as used for the Null case are applied to run the program.

¹⁷ The new employment figures are first multiplied by 1.865 to yield 24-hour attractions and then multiplied by the corresponding "leaving trips" fractions shown in Table 5.1 to yield peak hour attractions. These numbers are then entered into QRS II. This procedure is followed for all other scenarios.

5.4.2. Scenario A2

This scenario assumes the following transit characteristics:

- Frequency of all local routes (i.e., within Kanata) = 25 min.
- Area split for district 20 = 85% (i.e., more transit accessibility)

5.4.3. Scenario A3

In this scenario, the transit system is improved further in that, in addition to changes made in scenario A2, the following changes are made as well:

- Decreasing the bus fare to \$1.5; and
- Decreasing the access time to 3 minutes.

5.5. SCENARIO B

This scenario is characterized by a 15% increase in total employment in four specific districts in the study area. By inputting new land use data, the model is run to estimate the resulting person trip interchanges. Like scenario A, this scenario is comprised of three sub-scenarios in terms of transit characteristics. In this case, the improvements are considered to be more comprehensive because of the higher employment schema.

5.5.1. Scenario B1

This scenario is the "Do-Nothing" scenario as explained earlier.

5.5.2. Scenario B2

In this case, the following transit improvements are assumed:

- Frequency of all local routes = 20 min.; and
- Area split for district 20 = 95% .

5.5.3. Scenario B3

This scenario is basically scenario B2 plus the following changes:

- Decreasing the bus fare to \$1.5; and
- Decreasing the access time to 3 minutes.

5.6. SCENARIO C

Like scenarios A and B, this scenario is composed of 3 sub-scenarios. Scenario C1 is the "Do-Nothing" scenario. In scenario C2, even more comprehensive improvements are made than those in scenario B2 in that , the frequency of all local routes is increased to a level of 15 min. and transit service accessibility of district 20 is assumed to be 100%. Scenario C3 is the most comprehensive transit scenario. It is similar to scenario C2 with the addition of the same changes as made in scenarios A3 or B3. Likewise, the corresponding parameters are changed for each of these sub-scenarios and the mode split step is performed.

5.7. SCENARIO D

Unlike previous scenarios, this scenario is composed of five sub-scenarios as

follows:

Scenario D1 assumes no change in transit system with respect to scenario Null.

Scenario D2 assumes a 20 minutes headway for all local routes.

Scenario D3 is different from all other scenarios in that one more route (arbitrarily named 302) is added to the 2011 local transit network. This route has a N-S direction and passes through districts 25, 21, and 23. This route is assigned a 30 minutes headway, similar to other routes.

Scenario D4 is an integration of scenarios D2 and D3. The final sub-scenario **D5** is scenario D4 plus a decrease of bus fare and access time to a level of \$1.5 and 3 minutes respectively.

5.8. SUMMARY OF RESULTS

For each of the above sub-scenarios the calibrated QRS II is run. The results of transit runs for all sub-scenarios are shown in Appendix C.4. Table 5.8 illustrates a summary of the results of travel demand analyses. As it can be seen from this table, the study area's total person trip productions (i.e., those trips which stay in Kanata plus those which are destined to Kanata in the afternoon rush hour from other districts) are constant for all sub-scenarios. Therefore, a comparison of the resulting air quality is meaningful. Also, the transit share between Kanata and the rest of the Region remains constant. In addition, the following points are concluded from this table:

- While the number of person trips within Kanata increases as the number of employment opportunities does, the number of trips destined to other districts (or

Table S.8 Summary of The Results of Travel Demand Analyses For Various Future Scenarios

Scn.	Description	P. trips within Kanata	Bicycle trips in Kanata	Tr. trips within Kanata	Transit Share in Kanata	P. trips Outside to Kanata	Tr. trips Outside to Kanata	Transit Share	Total person trips
Null	D.U. = 31523; Employ ¹ = 43507 Transit Fare = \$2; Access time = 4 min. Bus headway (local) = 30 min. Transit Service Accessibility = 100% (Except district 20 = 85%)	2547	105.6	584.0	0.229	8437	3892	0.461	10984
A	10% increase in Emp. (J/H) = 1.51								
A1	"Do-Nothing"	2710	112.1	624.0	0.230	8274	3816	0.461	10984
A2	Headway = 25 m. + TSA _{max} = 90%	//	//	657.4	0.243	//	//	//	//
A3	A2 + Fare = \$1.5 + Access L = 3 m.	//	//	690.3	0.254	//	//	//	//
B	15% increase in Emp. (J/H) = 1.58								
B1	"Do-Nothing"	2789	115.1	643.2	0.230	8195	3778	0.461	10984
B2	Headway = 20 m. + TSA _{max} = 95%	//	//	715.0	0.256	//	//	//	//
B3	B2 + Fare = \$1.5 + Access L = 3 m.	//	//	750.4	0.269	//	//	//	//
C	20% increase in Emp. (J/H) = 1.65								
C1	"Do-Nothing"	2868	118.4	662.4	0.231	8116	3741	0.461	10984
C2	Headway = 15 m. + TSA _{max} = 100%	//	//	778.4	0.271	//	//	//	//
C3	C2 + Fare = \$1.5 + Access L = 3 m.	//	//	815.6	0.284	//	//	//	//
D	25% increase in Emp. in zones 21 & 23								
D1	"Do-Nothing"	2799	115.1	643.5	0.230	8185	3773	0.461	10984
D2	Headway = 20 min.	//	//	685.1	0.245	//	//	//	//
D3	Addition of another route	//	//	675.4	0.241	//	//	//	//
D4	D2 + D3	//	//	715.3	0.255	//	//	//	//
D5	D4 + Fare = \$1.5 + Access L = 3 m.	//	//	750.1	0.268	//	//	//	//

in other words, returning trips from other districts to Kanata in the afternoon) decreases. Thus, by providing a better match between housing and jobs in the study area, trip destinations are re-oriented toward more internal trips that would be otherwise destined outward.

- Gains obtained from transit improvements are obvious in this table. A 25% increase in transit share from 0.23 in the Null scenario to 0.284 in the most comprehensive transit system of scenario C3 is a substantial gain.
- Since overall jobs-to-housing ratio for scenarios B and D are almost the same, they are comparable in terms of travel demands on the system. Travel demand results show that concentrating employment in a few number of focal points in the study area results in slightly more internal trips than an evenly distribution of employment throughout the study area. However, split of trips to transit is almost the same for both scenarios in their extreme case (i.e., sub-scenarios B3 and D5).

CHAPTER VI

FUEL CONSUMPTION AND AIR QUALITY

ANALYSIS OF ALTERNATIVE SCENARIOS

6.1. INTRODUCTION

This chapter first provides an introduction to pollutant sources in general, transportation-related air pollutants, and principal air pollutants. It then discusses the methodology used for calculating vehicle kilometres of travel. Finally, based on the results obtained in Chapter V, it will represent the resulting air quality and fuel consumption of various land use scenarios.

6.2. POLLUTANT SOURCES

Air pollutants may be produced directly by human activity or natural sources or may be formed in the air through chemical reactions. The first group is classified as primary pollutants and the second group as secondary pollutants (Godish, 1991).

According to another definition, pollutant sources are generally classified as point, area, or line sources, depending on their magnitudes and geographical distributions (Horowitz, 1982). A point source is a large, identifiable source of emissions such as a large, coal-fired electrical power plant. An area source is a collection of small, geographically dispersed emission sources. Taken individually, these are insignificant but

which are important collectively. Examples include furnaces used in residential and commercial buildings or vehicles on the street system of a city. Emissions from line sources are generated almost uniformly along a line, such as an urban freeway (Cambridge Systematics Inc. [CSI], 1991; Horowitz, 1982).

The emissions are related to the magnitude of pollutant sources for unit of time. For a fixed number of emission sources, emissions can be expressed per unit of time (e.g., gms/second, tonnes/year). For variable emission sources, estimates can be stated on pollution causing activity basis (e.g., gms/vehicle-km). As the emissions accumulate into the air, they produce concentrations of pollutants. Concentrations of gases are expressed in parts of pollutant per million parts (ppm) of air and micrograms of pollutant per cubic meter ($\mu\text{g}/\text{m}^3$) of air (Horowitz, 1982).

Air pollutant sources can be classified as "stationary" (i.e., from a fixed location) or "mobile", that is, transportation-related (CSI, 1991). The transportation-related emissions are discussed below.

6.3. TRANSPORTATION-RELATED SOURCES OF AIR POLLUTANTS

Transportation-related or mobile sources of air pollutants come from a variety of vehicle types. Each vehicle type has its own emission characteristics (CSI, 1991). The most important variables are the age of the vehicle, pollution control equipment used, and the type of fuel which is consumed. Highway vehicle emission characteristics are different from those of non-highway vehicles such as rail, airplane, and water vessels. In order to analyze or regulate highway vehicle emissions, the following vehicle classes are generally

used (CSI, 1991):

- "... Light-duty gasoline fuelled vehicle
- Light-duty diesel fuelled trucks
- Heavy-duty gasoline fuelled vehicles
- Heavy-duty diesel vehicles
- Motorcycles"

Each vehicle class has its own emission characteristics as well as emission standards. Due to their extensive use, light-duty gasoline fuelled vehicles (i.e., automobiles and panel trucks) are the largest source of mobile pollutants (CSI, 1991).

6.4. THE PRINCIPAL POLLUTANTS

The list of pollutants entails common combustion products, such as sulphur dioxide, carbon dioxide, carbon monoxide, hydrocarbons, and nitrogen oxide. In terms of industrial processes, many industrial by-products, such as arsenic, asbestos, beryllium, and cadmium can be emitted. A number of air pollutants due to their high concentrations in urban areas, have become cause for concern. These are: particulate matter, carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen, and ozone (Horowitz, 1982).

6.4.1. Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas which is principally produced due to incomplete combustion of organic fuels. As a stable gas, it has a lifetime of 2 to 4 months in the atmosphere. When combined with the hemoglobin

of the blood, it leads to carboxy-hemoglobin and thereby, reduces the blood's ability to carry oxygen (Wark & Warner, 1981; Horowitz, 1982). Carbon monoxide levels could be cause for concern at busy urban intersections, although CO is not fatal at the concentrations found in urban air. It can impair cardiovascular and respiratory systems and therefore it is known as a major transportation-related pollutant (Horowitz, 1982).

The relationship between CO concentrations and traffic volumes is linear (i.e., the higher the traffic volume, the higher the CO level). As vehicle speed decreases, CO emission rate increases. Therefore, CO concentrations are expected to be higher in the vicinity of congested urban roads and intersections as compared to locations where there is a free traffic flow (CSI, 1991).

6.4.2. Ozone (O_3)

"... Ozone (O_3) is a colourless gas with a pungent odour" (CSI, 1991). It is a very strong oxidizer and highly corrosive. It can oxidize materials and tissue (e.g., lung tissue). O_3 is considered highly toxic to both vegetation and animals (Cohn & McVoy, 1982). It does not have any significant direct emission sources. It is classified as a secondary pollutant, formed in the lower atmosphere as a result of chemical reactions involving HC and NO_x in the presence of sunlight.

The relationship between emissions of HC and NO_x , and ozone concentrations is not linear. Also, the patterns of spatial variations in O_3 is different from that of CO. While CO concentrations could be present at well defined areas, if O_3 levels are excessive at any given monitoring site, they will possibly be excessive over an area as large as

hundreds or thousands of square kilometres. Due to such spatial characteristics of ground level O_3 , control programs for reducing ozone concentrations have to encompass at least a metropolitan area to be effective (CSI, 1991). It is useful to mention here that large quantities of O_3 are formed naturally in the stratosphere. They are not only unarmful, but necessary to protect humans from harmful radiates of the sun. It is the concentrations of O_3 in the lower atmosphere that is considered a cause for concern.

6.4.3. Nitrogen Oxides (NO_x)

Human activity-generated NO_x emissions include both NO and NO_2 , of which NO accounts for 90-95% of the total. NO_2 is considered a primary pollutant. However, its high concentrations in the air are formed as a result of the oxidation of nitric oxide (NO) to NO_2 in the process of chemical reactions that also produce O_3 (CSI, 1991). Nitrogen oxides can contribute to chemical reactions in the air to form nitrate salts, nitrous and nitric acid, and some other organic compounds of nitrogen . Because many of these products contain acid, NO_x is considered an important cause of acid rain (Horowitz, 1982). NO_2 can corrode materials, kill plant foliage, and damage lung tissue. It is also strongly coloured and absorbs the light, resulting in reduced visibility (Cohn & McVoy, 1982).

While concentrations of NO are higher in the winter, NO_2 concentrations can peak in either the summer or winter. Of-course, geographical and climatological characteristics of urban areas can play a role in causing NO_2 concentrations. This is due to the sensitive interrelationship of meterological factors and photochemical activities (CSI, 1991).

6.4.4. Hydrocarbons (HC)

Hydrocarbons (HC) are defined chemically as organic compounds that contain only carbon and hydrogen. However, in air quality studies, the term "hydrocarbons" is often used for a series of other volatile organic substances such as aldehydes and alcohols, in addition to true hydrocarbons (Horowitz, 1982). Hydrocarbons are emitted from a wide variety of natural sources as well as man-made sources. Examples include plant and animal metabolism, transportation (especially light-duty motor vehicles), petroleum refining, and food processing (Godish, 1991). The importance of HC in air pollution is attributed almost entirely to its chemical reactions with nitrogen dioxide in the presence of sunlight- resulting in ozone and other photochemical oxidants (Faith & Atkisson, 1972).

6.4.5. Particulates (PM)

"Particulate matter", or simply "particulates", are very small solid particles and/or liquid droplets in the air (Godish, 1991). These cover a wide range of small substances, including such materials as smoke, metallurgical dust and fumes, smog, fly-ash, windblown dust, and mists (Horowitz, 1982). Particles range in size from roughly 0.001 μm ($1 \mu\text{m} = 10^{-6} \text{ m}$) to 500 μm (Wark & Warner, 1981). Transportation is a major contributor to particulates emissions through diesel fuel exhaust. These include substances such as unburned hydrocarbons, sulphur dioxide, and sulphuric acid. Depending on the size and composition of the particle, there could be adverse effects on human health (CSI, 1991). Recent studies show that atmospheric particulate matters can lead to respiratory cancer and may contribute to the development of chronic bronchitis (Godish, 1991). It is

useful to mention here that particulate matter is known as *aerosol* in its suspended form in the air. It is a nuisance and can impair visibility (as an aerosol). Also, it causes corrosion and soiling of surfaces as a settled matter (Faith & Atkisson, 1972).

6.4.6. Carbon Dioxide (CO₂)

Complete combustion of fossil and other hydrocarbon fuels for automobiles, ship, trucks, air plane, and trains results in CO₂ (National Academy of Science, 1992). It is the major component of greenhouse gases. Its importance lies in the fact that high concentrations of CO₂ contribute to the phenomenon of "global warming" -an environmental issue which is receiving considerable international attention (CSI, 191). Scientists believe that as the CO₂ level and other greenhouse gases increase, they could change the earth's climate. CO₂ acts like the panes of glass in a greenhouse; it allows the sun radiation to enter the earth's atmosphere but then traps it, and prevents heat from escaping into space. Increasing CO₂ levels, may trap enough heat in the atmosphere to warm it and thereby, eventually increase the earth's mean temperature. This, in turn, could lead to differential effects such as producing floods in some areas and drought in other places (CSI, 1991).

Although there are many factors such as ambient air and engine temperatures, control technology, vehicle speed, vehicle age, etc. that affect emission rates, from a transportation planning perspective, the total volume of emissions can be reduced by reducing vehicle kilometres of travel (VKT) and reducing the emission rate (i.e.,

emissions/vehicle-km) (CSI, 1991).

The rest of this chapter deals with the estimation of VKT for the case study. Based on emission rates for the 2011 vehicle fleet, the fuel consumption and volume of emissions for various scenarios are estimated.

However, before moving to the next section, it is useful to say a few words about the dispersion or migration of pollutants. From a global perspective, pollutants can circulate both horizontally and vertically in the atmosphere over time, due to the wind effects, temperature and pressure differences between the poles and the equator, etc. At the local level, in urban areas, a phenomenon called "heat island" can result due to the existence of houses, large buildings, and factories. This phenomenon may result in a self-contained circulatory system within the urban area which requires a strong wind for its break up (Wark & Warner, 1981). Thus, in an urban area (especially in high density CBD), polluted air containing CO, PM and other pollutants can remain for a considerable amount of time.

6.5. VEHICLE KILOMETRES OF TRAVEL ESTIMATION

To be able to estimate the emissions for each of the scenarios, it is first necessary to obtain their corresponding VKTs. Two major vehicular modes of travel are used for this study: private auto and bus. Different methodologies are used to calculate VKT for each of these modes of travel.

6.5.1. Automobile Kilometres of Travel (AKT) Estimation

To estimate the distance travelled by Kanata residents, first a 258x258 distance matrix for the year 2011 corresponding to the travel time matrix is obtained from the Transportation Department of RMOC. A program (Basic), like the one used for the estimation of 2011 district-to-district travel time, is developed and used to aggregate the distance travelled into the 29-district system. Intra-district travelled distances for the study area are calculated by the same method described in Section 5.2.1. Tables 6.1 and 6.2 show the automobile distance matrices for trips made from districts outside Kanata to Kanata, and for trips made within Kanata respectively. The program listing is included in Appendix D.1.

6.5.1.1. Automobile Load Factor

To convert person trips to automobile trips it is necessary to apply the automobile occupancy rate. The 1986 O-D survey shows that the average occupancy rate for afternoon peak hour trips is 1.35 (RMOC, 1990). However, this figure is for all trip purposes and it is reasonable to assume that the occupancy rate for HBW trip purpose would be less than the overall average. Based on conversation with RMOC staff, it is found that the occupancy rate for morning HBW trips is 1.20. This number is then adopted for afternoon trips as well (it is also assumed that this would be the case for 2011 as well).

Having estimated the travel distance, occupancy rate, and person trip interchange results, first, bicycle and transit trips are deducted from the person trips to yield the

Table 6.1 Distance (in kilometres) Travelled By Automobile For Trips Destined To Kanata in 2011

FROM DISTRICT	TO DISTRICT :									
	19	20	21	22	23	24	25			
1	21.5	29.8	22.5	21.6	22	25.2	23			
2	23.1	31.5	24.2	23.4	23.9	27	24.8			
3	26.8	35.4	27.7	26.9	27.3	30.5	28.5			
4	24.3	32.5	25.9	25.4	26.1	28.7	26.4			
5	31.8	42.5	32.3	31	31.5	34.9	35.4			
6	16.9	25.1	17.9	17.1	17.5	20.7	18.3			
7	16.3	24	18	17.7	18.5	20.9	17.9			
8	10.9	18.9	12.2	11.6	12.3	15	12.2			
9	15.8	21.1	17.9	17.9	19.3	20.8	16.1			
10	20.3	20.4	21.7	22.5	24.1	23.3	16.2			
11	37.3	46	38.4	37.3	37.6	41	39.5			
12	43.8	52.1	45.2	44.3	44.7	47.9	45.8			
13	36.5	41.6	38.3	38.3	39.2	40.9	36.4			
14	25.4	30.7	27.3	27.3	28.2	30	25.5			
15	7.5	15.4	8.6	7.9	9	11.6	9			
16	37.7	46.1	38.6	37.7	38.2	41.4	39.2			
18	42.4	50.7	43.3	42.4	42.7	46.1	43.8			

Table 6.2 Distance (in km.) Travelled By Automobile For Trips Made Within Kanata in 2011

TO	19	20	21	22	23	24	25
FROM							
19	1.03	8.42	3.15	5.06	6.66	5.17	3.40
20	7.94	1.98	10.52	13.84	14.4	9.75	8.31
21	3.21	10.5	3.13	3.11	5.3	4.96	7.43
22	4.50	13.17	2.85	1.46	3.14	6.65	6.36
23	6.91	14.42	5.45	2.77	1.6	7.94	8.98
24	5.08	9.6	4.81	6.86	7.72	4.73	8.58
25	3.45	8.77	6.27	6.89	8.58	8.61	2.08

resulting automobile trips. Next, the AKTs for each of the scenarios are calculated by multiplying the above figures for each pair of districts. Tables 6.3 and 6.4 show the calculation of AKT for trips between Kanata and the rest of the Region and trips that remain within Kanata respectively, for the Null scenario.

6.5.2. Bus Kilometres of Travel (BKT) Estimation

Because transit service follows a designated route, it is not possible to obtain a district-to-district distance matrix in the same way as described in the previous section. Rather, this is done manually using the System Map of OCTranspo. To do so, first, highway district boundaries are drawn on this map. Then, for each of the districts, a centroid is assigned as a representative of job concentrations for that district¹⁸. Centroids in the study area are located in such a way that for each district they are close to the vicinity of both residential and employment areas. For most of the districts, this location approximately coincides with that district's centre of gravity. To connect each centroid in the study area to the rest of centroids (1 through 18), it is assumed that transit trips travel via proposed transitway where possible, and that they follow a reasonable route to reach their destinations. To estimate distance travelled by bus within Kanata, the corresponding pair of centroids are inter-connected following the current transit route layouts.

By dividing the average distance travelled by bus in the study area (excluding

¹⁸ The selection of the centroid location for each district is made using 1992 "OTTAWA-HULL & ENVIRONS" map (JLC Repro Graphic, 1992) obtained from RMOC. Different land uses (e.g., residential, industrial, and governmental offices) are specified on this map. By selecting the appropriate centroid location for a district on this map, it is then transferred to the OCTranspo System Map.

Table 6.3 Calculation of Automobile Kilometres of Travel (AKT) For Trips Between Kanata and The Rest of The Region

From :	To	Dist. (km)	P. trips	Tr. trips	Auto trip	AKT [(Col.2 × Col.5)/1.2]
1 :	19	21.5	183.9	124.1	59.8	1071.4
1 :	20	29.8	280.3	189.2	91.1	2262.3
1 :	21	22.5	320.6	216.4	104.2	1953.8
1 :	22	21.6	65.3	44.1	21.2	381.6
1 :	23	22	165.4	111.7	53.8	986.3
1 :	24	25.2	2	1.3	0.6	12.6
1 :	25	23	621.2	419.3	201.9	3869.8
2 :	19	23.1	54.2	36.6	17.6	338.8
2 :	20	31.5	87.7	59.2	28.5	748.1
2 :	21	24.2	94.5	63.8	30.7	619.1
2 :	22	23.4	19.3	13	6.3	122.9
2 :	23	23.9	48.8	32.9	15.8	314.7
2 :	24	27	0.6	0.4	0.2	4.5
2 :	25	24.8	183.1	123.6	59.5	1229.7
3 :	19	26.8	24.8	13.4	11.4	254.6
3 :	20	35.4	40.2	21.7	18.5	545.8
3 :	21	27.7	43.3	23.4	19.9	459.4
3 :	22	26.9	9.4	5.1	4.3	96.4
3 :	23	27.3	22.3	12.1	10.3	234.3
3 :	24	30.5	0.3	0.1	0.1	2.5
3 :	25	28.5	83.9	45.3	38.6	916.8
4 :	19	24.3	59.8	21.5	38.3	775.6
4 :	20	32.5	102.8	37	65.8	1782.1
4 :	21	25.9	98.2	35.4	62.9	1357.6
4 :	22	25.4	20	7.2	12.8	270.9
4 :	23	26.1	47.7	17.2	30.5	663.4
4 :	24	28.7	0.6	0.2	0.4	9.6
4 :	25	26.4	214.6	77.2	137.3	3020.6
5 :	19	31.8	26.1	8.2	17.8	471.7
5 :	20	42.5	42.2	13.3	28.9	1023.5
5 :	21	32.3	45.4	14.3	31.1	837.1
5 :	22	31	9.3	2.9	6.3	162.8
5 :	23	31.5	23.4	7.4	16.1	422.6
5 :	24	34.9	0.3	0.1	0.2	5.8
5 :	25	35.4	88	27.7	60.5	1778.9
6 :	19	16.9	112.1	50.4	61.6	867.5
6 :	20	25.1	170.8	76.9	94	1966.2
6 :	21	17.9	184	82.8	101.2	1509.6
6 :	22	17.1	39.8	17.9	21.9	312.1
6 :	23	17.5	95	42.7	52.2	761.3
6 :	24	20.7	1.1	0.5	0.6	10.4
6 :	25	18.3	378.6	170.4	208.2	3175.1
7 :	19	16.3	19.2	8.6	10.5	142.6
7 :	20	24	35	15.7	19.2	384
7 :	21	18	31.5	14.2	17.3	259.5
7 :	22	17.7	6.4	2.9	3.5	51.6
7 :	23	18.5	15.3	6.9	8.4	129.5
7 :	24	20.9	0.2	0.1	0.1	1.7
7 :	25	17.9	68.8	30.9	37.8	563.9
8 :	19	10.9	35.5	16	19.5	177.1
8 :	20	18.9	57.4	25.9	31.6	497.7
8 :	21	12.2	61.9	27.8	34	345.7
8 :	22	11.6	12.6	5.7	6.9	66.7
8 :	23	12.3	30.1	13.5	16.5	169.1

Table 6.3 Cont'd.

From :	To	Dist.(km)	P.trips	Tr. trips	Auto trip	AKT [(Col.2 × Col.5)/1.2]
8 :	24	15	0.4	0.2	0.2	2.5
8 :	25	12.2	119.9	54	65.9	670
9 :	19	15.8	29.7	8	21.7	285.7
9 :	20	21.1	57.5	15.5	42	738.5
9 :	21	17.9	45.9	12.4	33.5	499.7
9 :	22	17.9	9.4	2.5	6.8	101.4
9 :	23	19.3	19.8	5.3	14.4	231.6
9 :	24	20.8	0.3	0.1	0.2	3.5
9 :	25	16.1	113.1	30.5	82.5	1106.9
10 :	19	20.3	70.8	19.1	51.7	874.6
10 :	20	20.4	174.4	47.1	127.3	2164.1
10 :	21	21.7	116.3	31.4	84.9	1535.3
10 :	22	22.5	22.3	6	16.3	305.6
10 :	23	24.1	47.2	12.7	34.4	690.9
10 :	24	23.3	0.7	0.2	0.5	9.7
10 :	25	16.2	322.9	87.2	235.7	3182
11 :	19	37.3	15.7	3.5	12.2	379.2
11 :	20	46	27	6.1	20.9	801.2
11 :	21	38.4	27.4	6.2	21.2	678.4
11 :	22	37.3	5.6	1.3	4.3	133.7
11 :	23	37.6	13.3	3	10.3	322.7
11 :	24	41	0.2	0	0.1	3.4
11 :	25	39.5	53.1	12	41.2	1356.2
12 :	19	43.8	20.9	4.7	16.2	591.3
12 :	20	52.1	35.9	8.1	27.8	1207
12 :	21	45.2	34.3	7.7	26.6	1001.9
12 :	22	44.3	7	1.6	5.4	199.4
12 :	23	44.7	17.7	4	13.7	510.3
12 :	24	47.9	0.2	0	0.2	8
12 :	25	45.8	70.5	15.9	54.7	2087.7
13 :	19	36.5	6	1.1	4.9	149
13 :	20	41.6	12.3	2.2	10.1	350.1
13 :	21	38.3	9.8	1.8	8	255.3
13 :	22	38.3	2	0.4	1.6	51.1
13 :	23	39.2	4.5	0.8	3.7	120.9
13 :	24	40.9	0.1	0	0	0
13 :	25	36.4	24.1	4.3	19.8	600.6
14 :	19	25.4	39.3	7.1	32.2	681.6
14 :	20	30.7	76.2	13.7	62.5	1599
14 :	21	27.3	64.6	11.6	52.9	1203.5
14 :	22	27.3	12.4	2.2	10.2	232.1
14 :	23	28.2	27.8	5	22.8	535.8
14 :	24	30	0.4	0.1	0.3	7.5
14 :	25	25.5	149.8	27	122.8	2609.5
15 :	19	7.5	97.2	43.7	53.5	334.4
15 :	20	15.4	148.2	66.7	81.5	1045.9
15 :	21	8.6	169.5	76.3	93.2	667.9
15 :	22	7.9	36.7	16.5	20.2	133
15 :	23	9	82.4	37.1	45.3	339.8
15 :	24	11.6	1	0.5	0.6	5.8
15 :	25	9	348.7	156.9	191.8	1438.5
16 :	19	37.7	25.6	16.1	9.5	298.5
16 :	20	46.1	39	24.6	14.4	553.2
16 :	21	38.6	44.6	28.1	16.5	530.8
16 :	22	37.7	9.1	5.7	3.4	106.8
16 :	23	38.2	23	14.5	8.5	270.6

Table 6.3 Cont'd.

From :	To	Dist. (km)	P. trips	Tr. trips	Auto trip	AKT [(Col.2 x Col.5)/1.2]
16	: 24	41.4	0.3	0.2	0.1	3.5
16	: 25	39.2	86.5	54.5	32	1045.3
17	: 19	17.4	17.4	0	17.4	252.3
17	: 20	17	51.3	0	51.3	726.8
17	: 21	17.9	32.2	0	32.2	480.3
17	: 22	18.9	6.2	0	6.2	97.7
17	: 23	18.8	14.7	0	14.7	230.3
17	: 24	17.7	0.2	0	0.2	3
17	: 25	18.7	62.4	0	62.4	972.4
18	: 19	42.4	75.4	47.5	27.9	985.8
18	: 20	50.7	122	76.9	45.2	1909.7
18	: 21	43.3	131.5	82.8	48.6	1753.7
18	: 22	42.4	28.4	17.9	10.5	371
18	: 23	42.7	72	45.4	26.7	950.1
18	: 24	46.1	0.8	0.5	0.3	11.5
18	: 25	43.8	254.7	160.5	94.2	3438.3
19	: 26	168.2	0.4	0	0.4	56.1
19	: 27	165.7	3.1	0	3.1	428.1
19	: 28	98.5	0.9	0	0.9	73.9
19	: 29	88	1.6	0	1.6	117.3
20	: 26	176.6	0.7	0	0.7	103
20	: 27	162.2	11	0	11	1486.8
20	: 28	99.5	2.3	0	2.3	190.7
20	: 29	96.7	2.7	0	2.7	217.6
21	: 26	169.2	0.7	0	0.7	98.7
21	: 27	166	5.4	0	5.4	747
21	: 28	99.9	1.5	0	1.5	124.9
21	: 29	89.3	2.6	0	2.6	193.5
22	: 26	168.3	0.2	0	0.2	28.1
22	: 27	168.8	1.1	0	1.1	154.7
22	: 28	100.9	0.3	0	0.3	25.2
22	: 29	88.5	0.5	0	0.5	36.9
23	: 26	168.7	0.4	0	0.4	56.2
23	: 27	169.4	2.6	0	2.6	367
23	: 28	102	0.7	0	0.7	59.5
23	: 29	89.1	1.2	0	1.2	89.1
24	: 26	172	0	0	0	0
24	: 27	164.7	0	0	0	0
24	: 28	101.2	0	0	0	0
24	: 29	91.9	0	0	0	0
25	: 26	169.7	1.5	0	1.5	212.1
25	: 27	168.3	11.9	0	11.9	1669
25	: 28	97.1	3.8	0	3.8	307.5
25	: 29	90.2	5.3	0	5.3	398.4
Totals=		-	8436.9	3892.5	4544.4	96674.4

Table 6.4 Calculation of Automobile Kilometres of Travel (AKT) For Trips Within Kanata

From	To	Dist. (km)	P. trips	Tr. trips	Bike Trip	Auto Trip	AKT ¹
19	: 20	8.4	16.2	2.5	0	13.7	95.8
19	: 21	3.1	16.4	3	1.4	12	31.3
19	: 22	5.1	2.8	0.6	0.2	2	8.3
19	: 23	6.7	6.3	1.2	0	5.1	28.1
19	: 24	5.2	0.1	0	0	0.1	0.4
19	: 25	3.4	33.8	7.6	2.9	23.2	66
20	: 21	10.5	52.5	11.7	0	40.8	358.2
20	: 22	13.8	8.9	2	0	6.9	79.7
20	: 23	14.4	20.1	4.4	0	15.7	187.8
20	: 24	9.8	0.4	0	0	0.4	3.3
20	: 25	8.3	129.4	30.8	0	98.6	682.5
21	: 22	3.1	28.7	8	2.5	18.2	47.2
21	: 23	5.3	57.2	17	5	35.2	155.5
21	: 24	5	0.9	0.1	0.1	0.7	3
21	: 25	6.3	228.1	54.1	0	174	913.7
22	: 23	3.1	54.1	12.6	4.7	36.7	96.1
22	: 24	6.7	0.6	0	0	0.5	3
22	: 25	6.4	159.7	26.8	0	132.9	705.2
23	: 24	7.9	0.8	0.1	0	0	4.7
23	: 25	9	191.9	37.6	0	154.3	1154.8
24	: 25	8.6	0	0	0	0	0
20	: 19	7.9	32	6.6	0	25.4	168.2
21	: 19	3.2	80.8	18.3	7	55.5	148.6
22	: 19	4.5	47.3	7.9	4.1	35.3	132.5
23	: 19	6.9	60.3	11.7	0	48.7	280.2
24	: 19	5.1	0	0	0	0	0
25	: 19	3.5	35	9.3	3	22.7	65.3
21	: 20	10.5	116.1	24.2	0	91.9	804.1
22	: 20	13.2	72.1	10.1	0	61.9	679.4
23	: 20	14.4	92	15.5	0	76.5	918.6
24	: 20	9.6	0	0	0	0	0
25	: 20	8.8	63.9	13.8	0	50.1	365.9
22	: 21	2.9	104.8	19.6	9.1	76.1	180.9
23	: 21	5.4	125.9	31	11	84	381.1
24	: 21	4.8	0	0	0	0	0
25	: 21	6.3	51	11.7	0	39.2	205.1
23	: 22	2.8	32.6	9.2	2.8	20.5	47.4
24	: 22	6.9	0	0	0	0	0
25	: 22	6.9	9.8	2.4	0	7.4	42.4
24	: 23	7.7	0	0	0	0	0
25	: 23	8.6	20.7	4.8	0	15.9	113.4
25	: 24	8.6	0.3	0	0	0.3	2.1
19	: 19	1	10	2	0.9	7.2	6.1
20	: 20	2	171.9	45.8	15	111.2	183.5
21	: 21	3.1	149.7	44.3	13	92.3	240.7
22	: 22	1.5	24.1	6.5	2.1	15.5	18.9
23	: 23	1.6	87.7	24.1	7.6	56	74.9
24	: 24	4.7	0	0	0	0	0
25	: 25	2.1	150.3	44.8	13.1	92.3	160.1
Totals=			2547.2	583.7	105.5	1857.6	9844.3

Note: 1) (Col.2 x Col.6)/1.2

intra-districts ones) by the average distance travelled by car in the study area (excluding intra-districts ones) it is found that bus trips are approximately 11% longer than car trips. This trend is assumed to be the case for intra-district bus trips as well. Therefore, in estimating intra-district travel distances by bus, the corresponding intra-district automobile distances are increased 11% to reflect the effect of specific routes that buses take.

Tables 6.5 and 6.6 illustrate the transit distance matrices for trips between districts outside Kanata and Kanata, and for trips within Kanata respectively. Appendix E.1 provides the assumed bus itineraries that are used to connect each of the districts in the study area to the rest of the Region.

6.5.2.1. Bus Load Factors

In order to determine the load factors for converting transit person trips to bus trips, contacts are made to the Planning Department of OCTranspo. Because no projections are made for the year 2011 at this time, the current trend is assumed to be the case for the horizon year. Based on telephone conversations, it is concluded that for HBW trips, the following load factors are used:

- 80% for express routes serving Kanata, and
- 40% for local routes within Kanata.

A load factor of 100% corresponds to a fully seated bus with a 50-seat capacity. Therefore, the bus load factors are assumed to be 40 and 20 persons/bus for express and local routes respectively. Table 6.7 illustrates the calculation of BKT for the Null scenario for transit trips between Kanata and the rest of the Region, while Table 6.8 shows BKT

Table 6.5 Distance (in kilometres) Travelled By Bus For Trips Destined To Outside Kanata in 2011

From Dist.	Centroid Location in the District	To District:							
		19	20	21	22	23	24	25	
1	Transitway station: Bank & Slater	23.4	27.4	25.9	23.9	25.9	25.9	24.2	
2	Middle point between Ottawa U. & Carleton U.	25.6	30.7	29.5	27.5	29.5	29.5	26.4	
3	St. Laurant Shopping centre	30.5	34.5	33	31	33	33	31.3	
4	General Hospital	22.9	36.3	34.8	32.8	34.8	34.8	23.7	
5	N.R.C.	36.6	40.6	39.1	37.1	39.1	39.1	37.4	
6	Ottawa Royal Hospital	17.3	22.4	19.8	17.8	19.8	19.8	18.1	
7	Merivale Industrial Park	18.8	26.2	21.3	19.3	21.3	21.3	19.6	
8	Pine Crest	12.2	19.6	14.7	12.7	14.7	14.7	13	
9	Industrial Land (close to Rideau River)	19.6	29	24.1	22.1	24.1	24.1	20.4	
10	Baahaven Mall	22.9	30.2	25.4	23.4	25.4	25.4	23.7	
11	Orleans Complex	42.9	47	45.4	43.4	45.4	45.4	43.7	
12	Industrial Land	49.8	53.8	52.3	50.3	52.3	52.3	50.6	
13	Leitrim (Arena)	34.0	40.1	36.5	35.3	37.3	37.3	34.8	
14	C.F.B.	30.7	36.8	33.2	31.5	33.5	33.5	31.5	
15	K-Mart Mall	5.6	11.7	12.7	10.7	12.7	12.7	6.4	
16	Gatineau	31.6	35.2	33.7	31.7	33.7	33.7	32.4	
18	Place du Portage	24.1	27.7	26.2	24.2	26.2	26.2	24.9	

Table 6.6 Distance (in kilometres) Travelled For Trips Made By Bus Within Kanata in 2011

TO FROM	19	20	21	22	23	24	25
19	1.2	8.1	5.3	6.2	8.2	6.0	4.0
20	8.1	2.2	10.3	13.5	15.7	10.7	8.9
21	5.3	10.3	3.5	4.6	5.1	4.8	7.6
22	6.2	13.5	4.6	1.6	3.9	8.4	7.7
23	8.2	15.7	5.1	3.9	1.8	9.7	9.9
24	6.0	10.7	4.8	8.4	9.7	5.2	8.0
25	4.0	8.9	7.6	7.7	9.9	8.0	2.3

for within-Kanata trips.

Table 6.9 illustrates the results of AKT and BKT calculations for both within-Kanata trips and Kanata-to-the rest of the Region trips under each scenario.

6.6. FUEL CONSUMPTION AND EMISSIONS ESTIMATIONS

It is reasonable to expect that fuel consumption and emission rates for vehicles in 2011 will be different from what they are today due to emission control standards and technological improvements in automobile and bus manufacturing. In a report for Transport Canada, Khan (1990) undertook a study to provide the fuel economy and emission projections for automobile and intercity bus. The results of his findings, as these relate to this research and the assumptions that were made, are described below:

6.6.1. Fuel Consumption Projections

Automobile fuel consumption for urban application in 2010 is assumed to be 9lit/100 km, compared to the current rate of 11.3 lit/100km . This projection is based on the analysis of fuel economy capabilities of domestic manufacturers. In this analysis, it is assumed that there is a five year lag between the new car fleet and the over-the-road fleet, and that the over-the-road fuel consumption estimate is 14 percent more than the new car fleet average of five years prior to the year 2010 (Khan, 1990).

The fuel consumption rate of intercity bus for years beyond 2000 is projected to be 90% of the present rate due to technological improvements. Although Khan's study does not deal with the urban transit bus case, it is reasonable to assume that

Table 6.7 Calculation of Bus Kilometres of Travel (BKT) For Trips Between Kanata and The Rest of The Region

From : To	Dist. (km)	% of Tran. ¹	P. Trips	Transit Trip ²	BKT ³
1 : 19	23.4	0.675	183.9	124.1	72.6
1 : 20	27.4		280.3	189.2	129.6
1 : 21	25.9		320.6	216.4	140.1
1 : 22	23.9		65.3	44.1	26.3
1 : 23	25.9		165.4	111.7	72.3
1 : 24	25.9		2	1.3	0.9
1 : 25	24.2		621.2	419.3	253.7
2 : 19	25.6	0.675	54.2	36.6	23.4
2 : 20	30.7		87.7	59.2	45.4
2 : 21	29.5		94.5	63.8	47
2 : 22	27.5		19.3	13	8.9
2 : 23	29.5		48.8	32.9	24.3
2 : 24	29.5		0.6	0.4	0.3
2 : 25	26.4		183.1	123.6	81.6
3 : 19	30.5	0.54	24.8	13.4	10.2
3 : 20	34.5		40.2	21.7	18.7
3 : 21	33		43.3	23.4	19.3
3 : 22	31		9.4	5.1	3.9
3 : 23	33		22.3	12.1	10
3 : 24	33		0.3	0.1	0.1
3 : 25	31.3		83.9	45.3	35.5
4 : 19	72.9	0.36	59.8	21.5	12.3
4 : 20	36.3		102.8	37	33.6
4 : 21	34.8		98.2	35.4	30.8
4 : 22	32.8		20	7.2	5.9
4 : 23	34.8		47.7	17.2	14.9
4 : 24	34.8		0.6	0.2	0.2
4 : 25	23.7		214.6	77.2	45.8
5 : 19	36.6	0.315	26.1	8.2	7.5
5 : 20	40.6		42.2	13.3	13.5
5 : 21	39.1		45.4	14.3	14
5 : 22	37.1		9.3	2.9	2.7
5 : 23	39.1		23.4	7.4	7.2
5 : 24	39.1		0.3	0.1	0.1
5 : 25	37.4		88	27.7	25.9
6 : 19	17.3	0.45	112.1	50.4	21.8
6 : 20	22.4		170.8	76.9	43
6 : 21	19.8		184	82.8	41
6 : 22	17.8		39.8	17.9	8
6 : 23	19.8		95	42.7	21.2
6 : 24	19.8		1.1	0.5	0.3
6 : 25	18.1		378.6	170.4	77.1
7 : 19	18.8	0.45	19.2	8.6	4.1
7 : 20	26.2		35	15.7	10.3
7 : 21	21.3		31.5	14.2	7.5
7 : 22	19.3		6.4	2.9	1.4
7 : 23	21.3		15.3	6.9	3.7
7 : 24	21.3		0.2	0.1	0
7 : 25	19.6		68.8	30.9	15.2
8 : 19	12.2	0.45	35.5	16	4.9
8 : 20	19.6		57.4	25.9	12.7
8 : 21	14.7		61.9	27.8	10.2
8 : 22	12.7		12.6	5.7	1.8
8 : 23	14.7		30.1	13.5	5
8 : 24	14.7		0.4	0.2	0.1

Table 6.7 Cont'd.

From : To	Dist. (km)	% of Tran.	P. Trips	Transit Trip ²	BKT ³
8 : 25	13		119.9	54	17.5
9 : 19	19.6	0.27	29.7	8	3.9
9 : 20	29		57.5	15.5	11.3
9 : 21	24.1		45.9	12.4	7.5
9 : 22	22.1		9.4	2.5	1.4
9 : 23	24.1		19.8	5.3	3.2
9 : 24	24.1		0.3	0.1	0
9 : 25	20.4		113.1	30.5	15.6
10 : 19	22.9	0.27	70.8	19.1	10.9
10 : 20	30.2		174.4	47.1	35.6
10 : 21	25.4		116.3	31.4	19.9
10 : 22	23.4		22.3	6	3.5
10 : 23	25.4		47.2	12.7	8.1
10 : 24	25.4		0.7	0.2	0.1
10 : 25	23.7		322.9	87.2	51.7
11 : 19	42.9	0.225	15.7	3.5	3.8
11 : 20	47		27	6.1	7.1
11 : 21	45.4		27.4	6.2	7
11 : 22	43.4		5.6	1.3	1.4
11 : 23	45.4		13.3	3	3.4
11 : 24	45.4		0.2	0	0
11 : 25	45.7		53.1	12	13.1
12 : 19	49.9	0.225	20.9	4.7	5.8
12 : 20	53.8		35.9	8.1	10.9
12 : 21	52.3		34.3	7.7	10.1
12 : 22	50.3		7	1.6	2
12 : 23	52.3		17.7	4	5.2
12 : 24	52.3		0.2	0	0.1
12 : 25	50.6		70.5	15.9	20.1
13 : 19	34	0.18	6	1.1	0.9
13 : 20	40.1		12.3	2.2	2.2
13 : 21	36.5		9.8	1.8	1.6
13 : 22	35.3		2	0.4	0.3
13 : 23	37.3		4.5	0.8	0.8
13 : 24	37.3		0.1	0	0
13 : 25	34.8		24.1	4.3	3.8
14 : 19	30.7	0.18	39.3	7.1	5.4
14 : 20	36.8		76.2	13.7	12.6
14 : 21	33.2		64.6	11.6	9.6
14 : 22	31.5		12.4	2.2	1.8
14 : 23	33.5		27.8	5	4.2
14 : 24	33.5		0.4	0.1	0.1
14 : 25	31.5		149.8	27	21.2
15 : 19	5.6	0.45	97.2	43.7	6.1
15 : 20	11.7		148.2	66.7	19.5
15 : 21	12.7		169.5	76.3	24.2
15 : 22	10.7		36.7	16.5	4.4
15 : 23	12.7		82.4	37.1	11.8
15 : 24	12.7		1	0.5	0.1
15 : 25	6.4		348.7	156.9	25.1
16 : 19	31.6	0.63	25.6	16.1	12.7
16 : 20	35.2		39	24.6	21.6
16 : 21	33.7		44.6	28.1	23.7
16 : 22	31.7		9.1	5.7	4.5
16 : 23	33.7		23	14.5	12.2
16 : 24	33.7		0.3	0.2	0.1
16 : 25	32.4		86.5	54.5	44.1

Table 6.7 Cont'd.

From : To	Dist. (km)	% of Tran.	P. Trips	Transit Trip	BKT ³
17 : 19	0	0	17.4	0	0
17 : 22	0		6.2	0	0
17 : 23	0		14.7	0	0
17 : 20	0		51.3	0	0
17 : 21	0		32.2	0	0
17 : 24	0		0.2	0	0
17 : 25	0		62.4	0	0
18 : 19	24.1	0.63	75.4	47.5	28.6
18 : 20	27.7		122	76.9	53.2
18 : 21	26.2		131.5	82.8	54.2
18 : 22	24.2		28.4	17.9	10.8
18 : 23	26.2		72	45.4	29.7
18 : 24	26.2		0.8	0.5	0.3
18 : 25	24.9		254.7	160.5	99.9
Total=			8374.2	3892.5	2359.6

Notes:

- 1) It is obtained from Table 5.6 after the corresponding cells in that figure are multiplied by 0.9. It goes without saying that assuming a specific transit share from a district to Kanata means that the same number would be the case for all comprising districts in Kanata.
- 2) This column is obtained by multiplying Col. 3 by Col. 4.
- 3) BKT for each pair of district is calculated using the following formula:

$$(\text{Col.2} \times \text{Col.5})/40$$

where the denominator is the bus load factor.

Table 6.8 The Null Scenario Calculation of Bus Kilometres of Travel (BKT) For Trips Within Kanata

From : To	Dist. (km)	Transit Trip	BKT
19 : 20	8.1	2.5	1
19 : 21	5.3	3	0.8
19 : 22	6.2	0.6	0.2
19 : 23	8.2	1.2	0.5
19 : 24	6	0	0
19 : 25	4	7.6	1.5
20 : 21	10.3	11.7	6
20 : 22	13.5	2	1.4
20 : 23	15.7	4.4	3.5
20 : 24	10.7	0	0
20 : 25	8.9	30.8	13.7
21 : 22	4.6	8	1.8
21 : 23	5.1	17	4.3
21 : 24	4.8	0.1	0
21 : 25	7.6	54.1	20.6
22 : 23	3.9	12.6	2.5
22 : 24	8.4	0	0
22 : 25	7.7	26.8	10.3
23 : 24	9.7	0.1	0
23 : 25	9.9	37.6	18.6
24 : 25	8	0	0
20 : 19	8.1	6.6	2.7
21 : 19	5.3	18.3	4.9
22 : 19	6.2	7.9	2.4
23 : 19	8.2	11.7	4.8
24 : 19	6	0	0
25 : 19	4	9.3	1.9
21 : 20	10.3	24.2	12.5
22 : 20	13.5	10.1	6.9
23 : 20	15.7	15.5	12.2
24 : 20	10.7	0	0
25 : 20	8.9	13.8	6.1
22 : 21	4.6	19.6	4.5
23 : 21	5.1	31	7.9
24 : 21	4.8	0	0
25 : 21	7.6	11.7	4.5
23 : 22	3.9	9.2	1.8
24 : 22	8.4	0	0
25 : 22	7.7	2.4	0.9
24 : 23	9.7	0	0
25 : 23	9.9	4.8	2.4
25 : 24	8	0	0
19 : 19	1.2	2	0.1
20 : 20	2.2	45.8	5
21 : 21	3.7	44.3	8.2
22 : 22	1.6	6.5	0.5
23 : 23	3	24.1	3.6
24 : 24	5	0	0
25 : 25	2.5	44.8	5.6
Total=		583.9	186.1

Note: BKT for internal trips in the study area is obtained using the following formula:

$$[(\text{Col.2} \times \text{Col.3})/20]$$

where "20" is the bus load factor for local routes within Kanata.

improvements in the urban bus would be on par with the intercity bus. Therefore, the same trend is assumed for the urban transit case. In a recent report, RMOC (1992a) indicates a fuel consumption rate of 59.2 lit/100 km for the 1989 OTranspo fleet. Consequently, for its 2011 fleet, the fuel consumption is assumed to be: $0.9 \times 59.2 = 53.3$ lit/100 km

6.6.2. Emission Rates Projections

The approach used in Khan's study for the development of emission rates (e.g., gm/veh.km) relies upon actual (reported) magnitude of various pollutants measured from highway vehicles. Projections for future fleets take into account technological improvements and emission controls. The current as well as projected emissions for light-duty gasoline fuelled vehicles (i.e., automobile), are illustrated in Table 6.10. The projected levels of emissions which call for the reduction of various air pollutant levels indicate government initiatives and regulations for controlling pollutants from the source (Khan, 1990).

For heavy-duty vehicles such as a bus, available information from Transport Canada is used to determine current over-the-road emission levels. They are also shown in Table 6.10. In this table, there are proposed reductions in NO_x and PM levels (Khan, 1990).

A note on fuel consumption and emission estimates is relevant to make here.

The reader should consider that the above fuel consumption and emission estimates are projections and that there is no guarantee that these estimates would occur in that horizon

Table 6.9 The Automobile- and Bus-Kilometres of Travel Estimates for Future Scenarios

SC EN AR IO	Within-Kanata Trips		Kanata --> Outside Trips		AKT		BKT	
	AKT	BKT	AKT	BKT	Total ¹ (km)	Percent Change ²	Total ³ (km)	Percent Change ²
Null	9844.3	186.1	96695.1	2359.6	106539	-	2545.7	-
A1	10476	198.9	94817.6	2312	105294	-1.17	2510.9	-1.37
A2	10291	211	//	//	105109	-1.34	2523.0	-0.89
A3	10132	221.7	//	//	104950	-1.49	2533.7	-0.47
B1	10991	205.1	93898.9	2288.6	104890	-1.55	2493.7	-2.04
B2	10391	230.9	//	//	104290	-2.11	2519.5	-1.03
B3	10216	242.6	//	//	104115	-2.27	2531.2	-0.57
C1	11091	211.3	92993.3	2265.7	104084	-2.30	2477.0	-2.70
C2	10453	252.8	//	//	103446	-2.90	2518.5	-1.07
C3	10270	265.2	//	//	103263	-3.08	2530.9	-0.58
D1	10913	207	93824.3	2285.8	104737	-1.69	2492.8	-2.08
D2	10668	222.2	//	//	104492	-1.92	2508.0	-1.48
D3	10756	218.2	//	//	104580	-1.84	2504.0	-1.64
D4	10533	233.1	//	//	104357	-2.05	2518.9	-1.05
D5	10365	244.6	//	//	104189	-2.21	2530.4	-0.60

NOTES:

- 1) Col.2 + Col.4
- 2) With respect to the Null scenario
- 3) Col.3 + Col.5

Table 6.10 Current and Future Light and Heavy Duty Vehicles Emissions Levels
(Khan, 1990)

		Exhaust Emissions (gr/veh. km)				
		CO	NO _x	HC	PM	CO ₂
AUTOMOBILE	Current	2.11	0.62	0.25	0.12	249
	Future¹	2.11	0.25	0.16 ²	0.05	199
BUS	Current	5.6	15.5	2.2	3.2	1552.8
	Future¹	5.6	12.9	2.2	0.53	1397.5 ³

Notes:

- 1- Year 2000 over-the-road fleet
- 2- Non-methane hydrocarbons
- 3- This reflects 10% increase in fuel efficiency of future transit bus.

year. However, in this study because the fuel savings and emission reductions of alternative land use scenarios (if any) are compared to a "null" scenario, any inaccuracy in the above projections will not affect the results. On the other hand, these projections are based on the advanced technologies that are expected to take place in future model cars. For instance, the technological improvements such as electronic transmission control, multi-point fuel injection, aerodynamic improvements, and superior rolling resistant tires are a few examples of projected advancements resulting in fuel efficiency. Many of these technologies are already available in new cars. In terms of emission reductions, some of the above technologies as well as catalytic converters in car exhausts will be applied to future car fleets (Khan, 1990; Godish, 1991).

6.7. FUEL CONSUMPTION AND EMISSIONS RESULTS

The vehicle kilometres of travel estimation results shown in Table 6.9 and fuel consumption and emission rate estimates obtained in Sec. 6.6, are used to produce the final results of fuel consumption and emission estimates for the various future scenarios. These are shown in Table 6.11.

Because the main purpose of this study is to assess "gross or total emissions" under each scenario, the emission rates listed in Table 6.10, which are usually considered as indicators of "air quality", are grouped as follows:

Automobile Emissions = 2.57 gm/km

Bus Emissions = 21.23 gm/km

However, in the above aggregation, the CO₂ emissions are excluded because all

Table 6.11 Fuel Consumption and Aggregated Emission Estimates of Future Scenarios

SCEN ARIO	Aggregated Emissions		Fuel Consumption		Aggregated Emissions	
	Kanata¹ (kg)	Percent Change²	Total³ (Lit.)	Percent Change	Total⁴ (kg)	Percent Change
Null	29.25	--	10945	--	327.8	--
A1	31.15	+6.50	10815	-1.19	323.9	-1.20
A2	30.67	+4.85	10805	-1.28	323.7	-1.25
A3	30.75	+5.13	10795	-1.37	323.5	-1.30
B1	32.60	+11.4	10769	-1.61	322.5	-1.62
B2	31.61	+8.07	10729	-1.97	321.5	-1.92
B3	31.41	+7.38	10720	-2.06	321.3	-1.92
C1	32.99	+12.8	10668	-2.35	320.1	-2.35
C2	32.23	+10.2	10653	-2.67	319.3	-2.59
C3	32.02	+9.47	10643	-2.76	319.1	-2.66
D1	32.44	+10.9	10755	-1.74	322.1	-1.74
D2	32.13	+9.85	10741	-1.86	321.8	-1.83
D3	32.28	+10.4	10747	-1.81	321.9	-1.80
D4	32.02	+9.47	10735	-1.92	321.7	-1.86
D5	31.83	+8.82	10726	-2.00	321.7	-1.92

NOTES:

- 1) [Col.2 of Table 6.9 × 0.00257] + [Col.3 of Table 6.9 × 0.02123]
- 2) With respect to the Null scenario
- 3) [Col.6 of Table 6.9 × 0.09] + [Col.8 of Table 6.9 × 0.533]
- 4) [Col.6 of Table 6.9 × 0.00257] + [Col.8 of Table 6.9 × 0.02123]

other pollutants are at least related to the "quality of air" in terms of their effects on humans, animals, and vegetation, whereas CO₂ has only long term global effects and its behaviour is complex and unpredictable as compared to other pollutants. Also, as shown in Table 6.12, all pollutants except CO₂ are emitted in fairly comparable quantities.

On the other hand, it is clear that different pollutants have different impacts on air quality. Therefore, to have a more meaningful comparison of land use scenarios, Table 6.12 demonstrates the emission results by air pollutant type for each of the future scenarios.

The important point in both tables is that as the number of employment opportunities increase in Kanata, the total levels of aggregated as well as individual pollutant emissions and fuel consumption for all HBW trips produced in Kanata decrease accordingly.

In addition, a comparison of the "aggregated emission" results (i.e., Col.6 of Table 6.11) and each of the individual air pollutant emissions listed in Table 6.12 show that lumping CO, NO_x, HC, and PM results in somewhat less reliable estimates of emissions. For instance, NO_x emissions in Table 6.12 show that although they decrease as the number of employments increase, within each scenario they increase as the number of BKTs increase. This is in contrast with the trend observed in "aggregated air pollutants". However, overall, both approaches provide consistent results in terms of their decreasing trend with the increase in job opportunities in Kanata.

The lumped emissions and fuel consumption estimates for some selected future scenarios (i.e., within each scenario those with highest level of transit service) are also

Table 6.12 Emission Estimates of Future Scenarios by Air Pollutant Type

SC EN AR IO	CO Emissions			NO _x Emissions			HC Emissions			PM Emissions			CO ₂ Emissions		
	Total ¹ (kg)	Percent Change ⁶		Total ² (kg)	Percent Change ⁶		Total ³ (kg)	Percent Change ⁶		Total ⁴ (Lit.)	Percent Change ⁶		Total ⁵ (kg)	Percent Change ⁶	
Null	239.1	-		59.5	-		22.65	--		6.68	--		24758.9	--	
A1	236.2	-1.20		58.7	-1.28		22.37	-1.24		6.60	-1.20		24462.5	-1.20	
A2	235.9	-1.33		58.8	-1.09		22.37	-1.24		6.59	-1.35		24442.6	-1.28	
A3	235.6	-1.45		58.9	-1.00		22.37	-1.24		6.59	-1.35		24425.9	-1.34	
B1	235.3	-1.60		58.4	-1.82		22.27	-1.67		6.57	-1.65		24358.1	-1.62	
B2	234.2	-2.06		58.6	-1.50		22.23	-1.85		6.55	-1.95		24274.7	-1.95	
B3	233.9	-2.17		58.7	-1.34		22.22	-1.89		6.55	-1.95		24256.2	-2.03	
C1	233.5	-2.35		58.0	-2.52		22.10	-2.40		6.52	-2.40		24174.3	-2.36	
C2	232.4	-2.81		58.3	-1.88		22.09	-2.45		6.51	-2.54		24105.4	-2.64	
C3	233.9	-2.93		58.5	-1.68		22.09	-2.45		6.50	-2.69		24086.3	-2.72	
D1	235.0	-1.73		58.3	-1.90		22.24	-1.80		6.56	-2.00		24326.4	-1.75	
D2	234.5	-1.91		58.5	-1.68		22.24	-1.80		6.55	-1.95		24298.8	-1.86	
D3	234.7	-1.85		58.4	-1.82		22.24	-1.80		6.56	-1.80		24310.8	-1.81	
D4	234.3	-2.00		58.6	-1.50		22.24	-1.80		6.56	-1.80		24287.2	-1.90	
D5	234	-2.13		58.7	-1.34		22.24	-1.80		6.55	-1.95		24269.8	-1.97	

NOTES:

- 1) [Col.6 of Table 6.9 × 0.00211] + [Col.8 of Table 6.9 × 0.0056]
- 2) [Col.6 of Table 6.9 × 0.00025] + [Col.8 of Table 6.9 × 0.0129]
- 3) [Col.6 of Table 6.9 × 0.00016] + [Col.8 of Table 6.9 × 0.0022]
- 4) [Col.6 of Table 6.9 × 0.00005] + [Col.8 of Table 6.9 × 0.00053]
- 5) [Col.6 of Table 6.9 × 0.199] + [Col.8 of Table 6.9 × 1.3975]
- 6) With respect to the Null scenario

depicted in Figure 6.1.

**Figure 6.1 Emissions and Fuel Consumption Schemes
for Various Future Scenarios**

CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1. SUMMARY

The purpose of this research was to demonstrate to what extent a better match between jobs and housing could reduce the environmental consequences of travel demand on a transportation system and thus improve the resulting air quality.

Data on the level of transportation service and socioeconomic characteristics of the RMOC and of the City of Kanata were collected. Scenarios were developed, demonstrating possible future employment schemes in the study area. Travel demand models based on P.M. peak hour for "home-based work" trips were applied to estimate travel demand for each of the scenarios. This involved obtaining trip generation, trip distribution, and modal split data for the 1986 observed base case, calibrating the demand model against the observed situation, and finally its application to the horizon year travel demand forecasts.

Based on the result of travel demand analysis, estimates of vehicle kilometres of travel for two major modes of travel, private auto and bus, were made. For each of the scenarios, fuel consumption and emissions were calculated, using the demand VKT

figures.

7.2. CONCLUSIONS

From an examination of energy consumption and emission results obtained through the use of methodology explained earlier, a number of conclusions are drawn:

- The most important finding of this research was that providing a better match between jobs and housing (in the form of more employment opportunities) would encourage more intra-satellite city trips that would otherwise be destined outwards. Subsequently, the VKTs, fuel consumption and emissions for the whole region would be reduced.
- Considering the level of aggregation that was used for estimation of the emissions and fuel consumption, it seems that the alternative future scenarios did not have an appreciable effect on the resulting air quality in the Region. On the other hand, although the 3% reduction in total aggregated (or even individual pollutant) emissions is a meagre saving, this methodology demonstrated that accommodating more job opportunities in a sub-region (i.e., redirecting of approximately 1.2% of the Region's total employment in 2011 to Kanata) would result in the regional fuel savings and emission reductions.
- In Chapter VI it was projected that the fuel consumption rate would decrease by approximately 20% between now and 2011 due to improvements in technology. Comparing this with a 3% (at most) reduction in fuel consumption due to land use re-arrangements, it can be concluded that controlling the fuel consumption (and

emissions) from the source (i.e., motor vehicle) would be the most effective way to reduce energy consumption and air pollution in urban areas.

- As job opportunities in the study area increased, both AKT and BKT for within-Kanata trips increased, but they decreased accordingly for trips destined to other districts outside Kanata.
- Total automobile kilometres travelled (AKT) by Kanata residents decreased accordingly as the number of jobs increased. The AKT decreased 3.07% from 106,539 km in Null scenario to 103,263 km in scenario C3.
- Although the emissions for trips that remained within the study area increased as more jobs were accommodated, from a regional perspective, this increase could be justified by the overall decrease in emissions.
- A Comparison of scenarios B3 and D5 (with the same jobs/housing ratio) demonstrated that the scenario with an even distribution of jobs in the study area (B3) would yield slightly less internal trips, and better air quality and fuel saving results than the concentration scenario D5. The emissions in Kanata itself were also higher in scenario D5 than in scenario B3 by approximately 1.5%. This conclusion, however, is not definitive since this study followed an aggregate approach. The proximity of results might change if a more disaggregate and finer approach is adopted.

It should be also pointed out that other studies have shown or proposed that a centralized urban structure (i.e., concentrating most developments in the central, built-up areas) would use the least energy and produce the least air pollution levels provided that

no bedroom communities are built outside the high density urban area. The satellite cities concept (i.e., concentrating developments in a few number of self-contained communities in addition to the central area) would be the second best in this regard, due to their impacts on shortening the journey distances (Roseland, 1992; UMA Consultants, 1993; Transportation Association of Canada, 1993). In addition, these studies agree that a widely dispersed urban area which has physical separation between different land uses is the least energy efficient.

In short, land use planning has a medium to long term potential for improving energy consumption and air quality by reducing the demand on the transportation system, basically through reducing travel distances. However, this solution must first surmount the trend of decentralized low density bedroom communities associated with high journey distances.

Furthermore, despite deploying many tools and techniques (e.g., transportation demand management, infrastructure capacity expansion, land use planning, new fuel and vehicle technologies) for reducing traffic congestion and air pollution, none of these can individually achieve a sufficient reduction in energy consumption and air pollution. They are more likely to be successful if integrated and implemented together as part of a broad-based strategy to support the resulting benefits of each other.

7.3. RECOMMENDATIONS FOR FURTHER STUDY

Further study is needed on the subject of this thesis due to the complex nature of the problem. Such a study would potentially supplement and enhance the findings of this

research. More reliable data on the level of service variables such as trip times and on travel modes such as bicycle and transit trips would refine the results provided in this study.

The relationship between land use and transportation, however, should be viewed from a broader perspective. In this regard, the location of housing versus location of jobs is of great importance. Studies of residential location choice have indicated that living close to the workplace is not the highest priority for most people. There are many socio-economic factors that influence where people live and work, namely affordability of housing, quality of neighbourhood, multiple-worker households, ethnic and racial mix, availability of recreational facilities, etc. (Giuliano, 1991). Therefore, in examining the impacts of land use patterns on traffic patterns, the integration of transportation models with land use models that have the ability to take into account most of the above factors is suggested for further study.

As mentioned in Chapter II, there are two other urban centres in the Region namely Orleans and Nepean which will accommodate most of the future growth in the RMOC. It goes without saying that Kanata is only a window of the whole picture. If the same approach was used to examine the travel patterns and resulting air quality in those communities as well, then the overall environmental quality gains in the Region would eventually be substantial.

The extent to which bicycle facilities should be developed or improved to increase the energy efficiency of the urban area's transportation system should be considered for further study. The historic information on bicycle trips are incomplete. As seen in an

earlier chapter, many assumptions were made in order to forecast future bicycle trips. Therefore, more comprehensive bicycle surveys and the development of appropriate models with the ability to incorporate bicycle trips as a mode of travel are necessary.

As mentioned in Chapter VI, the magnitude of air pollutants released from motor vehicle exhaust depends not only on the number of kilometres driven but also on many other factors: ambient air and engine temperatures, vehicle speed, change cycles, meteorological conditions, etc. Furthermore, the effects of trip end emissions are important. For instance, a significant amount of HC emissions is due to evaporative effects and cold starts at the trip ends (Fleet & DeCorla-Souza, 1991). Although emission factors are appropriate for macro-level analysis, the use of more detailed macroscopic models at the network level would yield refined results. Also, improvements to the methodology developed in this study will enhance the results of the emission estimates. For instance, it is logical to assume that emissions from buses operating on the transitway is less than those operating with mixed traffic on city streets. Therefore, developing a methodology that differentiates between these two categories of emission will improve the results.

In addition, performing a sensitivity analysis is suggested to investigate the effects of changes in key variables such as travel distances, fuel price, automobile and bus load factors, and fuel consumption rates and emission factors on the resulting fuel consumption and emission estimates.

The results of this study also imply that to encourage modal shifts toward more efficient ones, drastic modifications of both the transportation system and traveller's behaviour are necessary. However, such measures can take the predictions out of the

existing demand model's range. The study of traveller response to such changes in supply is recommended.

REFERENCES

- AJH Associates (1992a). Reference Manual: General Network Editor for Windows.
Version 4.0. CT: Author
- AJH Associates (1992b). Reference Manual: Quick Response System II for Windows.
Version 3.5. CT: Author
- Bae, C. C. (1993). Air quality and travel behaviour. Untying the knots. Journal of the American Planning Association, 59, 65-74
- Cambridge Systematics Inc. (1991). Transportation control measure information documents (Draft). Washington, D.C.: U.S.Environmental Protection Agency, Office of Mobile Sources.
- Cannon, J. S. (1990). The health costs of air pollution. New York: The American Lung Association.
- Chinitz, B. (1990). Growth management. Good for the town, bad for the nation?. Journal of the American Planning Association, 56, 3-8.
- Cohn, L.F., & McVoy, G.R. (1982). Environmental analysis of transportation systems.
U.S.A: John Wiley & Sons, Inc.
- Cumming-Cockburn Ltd. (1992). The Ottawa-Carleton cyclist profile survey (Tech. Rep.).
Ontario: Regional Municipality of Ottawa: Carleton, Transportation Environment Action Plan (TEAP).
- DeCorla-Souza, P., & Schoeneberg, R. (1992). The transportation-air quality connection: Perceptions and realities, ITE 1992 Compendium of Technical Papers. 62nd Annual Meeting (pp. 157-162). Washington, D.C.: ITE

Delcan Corporation (1991). Conceptual strategic transit service plan. (Tech. Rep. No.2).

Ottawa, Ontario, CT: Author

Evrensel, N. (1989). Land use planning and control of air pollution. Unpublished master's thesis, University of Nevada, Reno.

Faith, W.L., & Atkisson, A.A., Jr. (1972). Air pollution (2nd ed.). U.S.A: John Wiley & Sons, Inc.

Fleet, C.R., & DeCorla-Souza, P. (1991). VMT for air quality purposes. In R.L. Wayson (Ed.), Transportation Planning and Air Quality: Proceedings of the National Conference, Urban Transportation Division of ASCE. (pp. 126-141). Santa Barbara, California: ASCE

Giuliano, G. (1991). Is jobs-housing balance a transportation issue?. Transportation Research Record No. 1305. Washington, DC: National Research Council, Transportation Research Board.

Godish, T. (1991). Air quality (2nd ed.). Michigan: Lewis Publishers, Inc.

Gordon, D. (1991). Steering a new course: Transportation, energy, and the environment. Washington, D.C.: Island Press

Hanson, M.E. (1992). Automobile subsidies and land use: Estimates and policy responses. Journal of the American Planning Association, 58, 60-71.

Harvey, G., & Deakin, E. (1992). A manual for transportation-air quality modelling for Metropolitan Planning Organizations (Revised Draft). U.S.A: National Association of Regional Councils.

Horowitz, J.L. (1982). Air quality analysis for urban transportation planning.

Massachusetts: MIT Press.

Hutchinson, B.G. (1974). Principles of urban transportation systems planning. U.S.A:

McGraw-Hill Inc.

JLC Repro (Cartograph). (1992). Ottawa-Hull & Environs. [Map]. Ottawa, Canada.

Khan, A.M. (1981). Urban public transit efficiency: Economic and energy factors. Journal of Advanced Transportation. 15, 213-230.

Khan, A.M. (1990). Energy and environmental factors in intercity passenger transportation (Research Report). Ottawa, Ontario: Transport Canada.

Khisty, C.J. (1990). Transportation Engineering: An Introduction. U.S.A: Prentice-Hall, Inc.

Kurtzweg, J.A., & Weig, D.W. (1969). Determining air pollution emission from transportation systems. National Air Pollution Control Administration.

Marshall-Macklin-Monaghan Ltd. (1992). Bicycle policy: Review and update (Tech. Rep.). Ontario: Ministry of transportation, Ontario.

May, J.H., & Scheuernstuhl, G.J. (1991). Sensitivity analysis for land use, transportation, and air quality. Transportation Research Record No. 1312. Washington, D.C.: National Research Council, Transportation Research Board.

Meyer, M.D., & Miller, E.J. (1984). Urban transportation planning: A decision-oriented approach. U.S.A.: McGraw-Hill Inc.

National Academy of Sciences (1992). Policy implications of greenhouse warming: Mitigation, adaption, and the science base. Washington, D.C.: National Academy Press.

Purvis, C.L. (1991). Air quality impacts of a Regional HOV system. 1991 ITE Compendium of Technical Papers. 61st Annual Meeting. (pp. 590-596).

Regional Municipality of Ottawa-Carleton (1988). Official plan of the Regional Municipality of Ottawa-Carleton (Volume I: Text). Ottawa, Ontario: RMOC, Transportation Department.

Regional Municipality of Ottawa-Carleton (1990). Travel forecast model documentation (Internal Report). Ottawa, Ontario: RMOC, Transportation Department.

Regional Municipality of Ottawa-Carleton (1991). 258-Zone land use data for 1986 and 2011 [Machine-readable data file]. Ottawa, Ontario: RMOC, Transportation Department.

Regional Municipality of Ottawa-Carleton (1992a). System status report. Ottawa, Ontario: RMOC, Transportation Department.

Regional Municipality of Ottawa-Carleton (1992b). Travel in the National Capital Area. A summary of the 1986 National Capital Area travel Origin-Destination survey undertaken by TRANS. Ottawa, Ontario: RMOC, Transportation Department.

Roberts, J.S. (1975). Energy, land use and growth policy: Implications for Metropolitan Washington. Washington, DC: Metropolitan Washington Council of Governments.

Roseland, M. (1992). Toward sustainable communities. National round table on the environment, CT: Author

Scheuermstuhl, G.J., & May, J.H. (1991). Land use, transportation and air quality relationships. In R.L. Wayson (Ed.), Transportation Planning and Air Quality: Proceedings of the National Conference, Urban Transportation Division of ASCE.

(pp. 90-99). Santa Barbara, California: ASCE

Shallal, L. (1992). Class notes of Urban Transportation Planning and Management course

(Fall term 1992). Ottawa: Department of Civil and Environmental Engineering,
Carleton University.

Sosslau, A.B., et al (1978). Quick-response urban travel estimation techniques and transferable parameters: User's Guide. National Cooperative Highway Research Program Report No. 187.

Stopher, P.R., & Meyburg, A.H. (1975). Urban transportation modelling and planning. U.S.A: Lexington Books.

Southern California Association of Governments. (1989). Regional growth management plan. California, CT: Author

Transportation Association of Canada. (1993). A new vision for urban transportation. Briefing, March 1993. Ottawa: TAC.

Transportation Research Board. (1992). Environmental research needs in Transportation. Transportation Research Circular. No.389, pp.20.

UMA Consultants (1993). Discussion paper on alternatives (Draft). presented at the Regional Municipality of Ottawa-Carleton workshop on TDM, CT: Author.

U.S. Department of Commerce. (1965). Calibrating and testing a Gravity Model for any size of urban area. Washington, D.C.: U.S. Government Printing Office.

Wark, W., & Warner, C.F. (1981). Air pollution: Its origin and control (2nd ed.). U.S.A: Authors.

Willis, C., & Soots, V. (1992). The role of technology, fuel substitution and conservation

in minimizing emissions and their impacts on the environment (Report No. 90-A5142). Ontario: Ministry of Transportation.

Young, W. (1990). Land use-transportation interaction: 1969-1989. Australian Road Research. 20, 36-47.

Zehner, R. (1977). Access, travel, and transportation in new communities. Barlington: Cambridge, Mass.

APPENDIX A

The 1986 and 2011 Land Use Data

- A.1. The 1986 Land use data for the 258-zone system**
- A.2. The 2011 Land use data for the 258-zone system**

APPENDIX A.1

ZONE	1986 POP'N	1986 # dwellin	Total Employment	Retail Employment	Other Employment
1	0	0	21959	1081	20878
2	3565	2275	11231	93	11138
3	1105	720	29490	655	28835
4	1705	765	9538	725	8813
5	190	85	1914	328	1586
6	2235	980	5686	36	5650
7	7705	3610	2230	92	2138
8	8990	4550	2144	208	1936
9	1785	750	136	13	123
10	90	35	4766	0	4766
11	9420	6115	10237	288	9949
12	2645	1710	6487	758	5749
13	5770	2575	2138	227	1911
14	0	0	350	51	299
15	730	150	1054	0	1054
16	45	30	450	0	450
17	8370	3775	3723	586	3137
18	870	415	5474	224	5250
19	4760	2080	1616	236	1380
20	7550	3105	1982	346	1636
21	0	0	407	0	407
22	3655	1715	1463	107	1356
23	4220	1710	497	155	342
24	3650	1310	1370	120	1250
25	0	0	2206	7	2199
26	95	30	3169	2	3167
27	0	0	1387	0	1387
28	12675	5425	1796	300	1496
29	0	0	1053	344	709
30	0	0	837	0	837
31	4625	1790	1824	74	1750
32	185	100	4018	0	4018
33	6520	2685	1963	266	1697
34	0	0	971	6	965
35	3880	1955	1430	235	1195
36	0	0	9458	0	9458
37	2860	1205	1603	349	1254
38	2910	1305	1128	110	1018
39	2895	1440	2051	487	1564
40	4205	1675	1954	231	1723
41	5510	1885	3041	567	2474
42	0	0	2017	1576	441
43	5395	2360	2010	182	1828
44	3275	1790	168	5	163
45	5545	2985	1524	317	1207
46	0	0	632	492	140
47	11650	5655	1501	212	1289
48	6480	2090	291	14	277
49	6580	2835	275	55	220
50	0	0	1707	1513	194
51	5040	1645	372	45	327
52	0	0	901	0	901
53	9930	3790	1498	115	1383
54	3835	1350	180	0	180
55	0	0	2594	374	2220

ZONE	1986 POP'N	1986 # dwelln	Total Employment	Retail Employment	Other Employment
56	0	0	1170	69	1101
57	9720	3815	590	84	506
58	185	75	3407	128	3279
59	0	0	434	302	132
60	0	0	1750	0	1750
61	6435	2280	732	125	607
62	4545	1360	353	26	327
63	0	0	4498	2115	2383
64	6330	2455	217	13	204
65	10205	3715	420	15	405
66	0	0	4558	136	4422
67	8390	3395	1132	105	1027
68	0	0	7	0	7
69	4970	1980	745	69	676
70	0	0	7437	0	7437
71	0	0	158	0	158
72	0	0	1530	633	897
73	3725	1510	632	152	480
74	330	165	2418	758	1660
75	5585	2255	1390	48	1342
76	0	0	575	383	192
77	13355	5130	594	59	535
78	35	0	675	0	675
79	190	0	5231	2	5229
80	5500	3055	565	42	523
81	0	0	16	0	16
82	505	160	2171	0	2171
83	215	170	5980	355	5625
84	4055	1430	568	17	551
85	8305	3140	538	43	495
86	660	375	378	291	87
87	4100	1730	404	28	376
88	3100	1290	6898	726	6172
89	395	135	3192	433	2759
90	0	0	4555	0	4555
91	0	0	2855	1599	1256
92	9345	3525	1533	439	1094
93	2850	975	1562	858	704
94	5595	2115	1346	473	873
95	7560	3560	4431	703	3728
96	10870	4765	1780	387	1393
97	2035	635	200	1	199
98	5185	2085	753	53	700
99	3350	1195	1273	16	1257
100	5900	2590	866	465	401
101	0	0	817	0	817
102	3775	1480	1015	9	1006
103	3050	1070	535	91	444
104	0	0	0	0	0
105	0	0	512	391	121
106	0	0	2119	0	2119
107	12780	3755	819	79	740
108	0	0	1201	65	1136
109	7470	2745	1072	265	807
110	6515	2015	464	59	405
111	0	0	3270	130	3140
112	6570	2685	2078	746	1332
113	3655	1115	106	0	106
114	0	0	121	0	121

ZONE	1986 POP'N	1986 # dwellin	Total Employment	Retail Employment	Other Employment
115	6075	2095	397	41	356
116	8665	3040	1175	380	795
117	10400	3340	939	63	876
118	4695	1390	4766	19	4747
119	0	0	2489	80	2409
120	440	150	5643	420	5223
121	7815	2335	427	38	389
122	0	0	243	0	243
123	14380	4385	1361	206	1155
124	15	5	344	0	344
125	8745	2940	5869	1050	4819
126	4455	1405	133	5	128
127	0	0	3497	0	3497
128	270	75	1266	0	1266
129	2389	695	10	0	10
130	8740	2740	784	88	696
131	5873	1842	715	170	545
132	1396	427	206	8	198
133	11797	3789	1918	192	1726
134	6964	2149	1000	260	740
135	874	268	1003	49	954
136	13200	3980	594	214	380
137	742	230	208	25	183
138	10270	3230	1725	358	1367
139	11195	3495	1823	244	1579
140	701	217	30	10	20
141	1494	458	-	0	0
142	10700	3135	1525	190	1335
143	4572	1389	161	69	92
144	1273	364	10	10	0
145	8198	2469	970	110	860
146	1619	481	1192	0	1192
147	2109	660	27	0	27
148	9155	2876	1045	497	548
149	2580	901	135	27	108
150	783	244	130	30	100
151	2364	994	108	108	0
152	1215	479	623	135	488
153	4853	2037	1760	239	1521
154	207	117	15841	1531	14310
155	5387	2226	2476	119	2357
156	1637	586	64	0	64
157	0	0	32	0	32
158	1053	581	6445	2836	3609
159	10977	4303	1418	226	1192
160	0	0	1031	0	1031
161	16385	6975	1482	483	999
162	150	70	4756	1631	3125
163	0	0	838	0	838
164	10425	4146	902	0	902
165	5891	1730	519	188	331
166	6997	2280	280	141	139
167	8030	2925	1316	146	1170
168	1218	443	292	227	65
169	4827	1562	246	201	45
170	1805	600	298	110	188
171	79	20	3722	1128	2594
172	5027	1794	1459	298	1161
173	10605	3285	274	124	150

ZONE	1986 POP'N	1986 # dwelln	Total Employment	Retail Employment	Other Employment
174	2321	791	454	292	162
175	5135	1564	148	43	105
176	309	100	119	36	83
177	5366	1625	775	167	608
178	2325	728	168	30	138
179	2717	941	783	48	735
180	8820	3130	2425	157	2268
181	2745	881	433	119	314
182	3955	1302	570	123	447
183	5394	1883	845	173	672
184	3908	1412	642	129	513
185	4353	1438	671	129	542
201	0	6	5002	2498	2504
202	9491	2570	942	293	649
203	4080	1185	80	13	67
204	268	84	930	606	324
205	708	200	35	10	25
206	0	0	457	115	342
207	17	5	3796	20	3776
208	16	5	0	0	0
209	17	5	1085	15	1070
210	10	3	0	0	0
211	17	5	0	0	0
212	6	2	0	0	0
213	21	7	30	0	30
214	12	4	0	0	0
215	33	11	39	0	39
216	896	276	310	35	275
217	2540	905	482	100	382
218	925	294	120	16	104
219	980	311	210	16	194
220	9027	2630	1175	546	629
221	697	170	10	0	10
222	24	7	10	0	10
223	38	11	5	0	5
224	442	112	152	0	152
225	63	19	20	0	20
226	305	93	71	0	71
227	450	152	19	3	16
228	255	87	0	0	0
229	12	4	0	0	0
230	575	188	1669	42	1627
231	130	44	1015	75	940
232	0	0	0	0	0
233	0	0	358	56	302
234	0	0	0	0	0
235	3843	1265	215	7	208
236	3465	995	1413	361	1052
237	5770	1802	626	159	467
238	7702	2175	187	15	172
239	4322	1215	190	23	167
240	962	316	26	5	21
241	25	8	10	0	10
242	180	55	60	0	60
243	106	32	35	3	32
244	152	46	25	0	25
245	660	202	120	10	110
246	150	47	80	28	52
247	435	134	30	0	30

ZONE	1986 POP'N	1986 # dwelln	Total Employment	Retail Employment	Other Employment
248	2266	650	90	40	50
249	3310	1145	1088	658	430
250	2040	680	734	77	657
251	2205	646	50	10	40
252	5875	2020	1277	677	600
253	7471	2305	245	105	140
254	561	248	550	50	500
255	483	225	6194	30	6164
256	885	250	493	30	463
257	5289	1565	611	245	366
258	6713	2244	375	70	305
	806,469	298,197	409,268	51,405	357,863

APPENDIX A.2

ZONE	2011 POP'N	2011 # dwelling	Total Employment	Retail Employment	Other Employment
1	0	0	28176	1121	27055
2	4170	3475	16446	180	16266
3	954	830	31440	725	30715
4	1398	1165	12500	1600	10900
5	194	155	3019	500	2519
6	1888	1180	5750	50	5700
7	6970	4100	2230	92	2138
8	7905	5100	2144	225	1919
9	1860	1200	136	13	123
10	46	35	4766	0	4766
11	8740	7600	11800	375	11425
12	4030	3100	8300	815	7485
13	5163	2950	2550	227	2323
14	0	0	350	51	299
15	400	150	1135	0	1135
16	4257	2365	3210	230	2980
17	8352	4640	5584	700	4884
18	2250	1250	5474	224	5250
19	4050	2250	1616	236	1380
20	5751	3195	1982	346	1636
21	0	0	407	0	407
22	4024	2515	1263	107	1156
23	3168	1760	497	155	342
24	2784	1465	1003	120	883
25	0	0	2539	10	2529
26	396	180	3375	10	3365
27	1540	700	2440	45	2395
28	11498	5475	1796	300	1496
29	0	0	1334	450	884
30	0	0	850	0	850
31	3982	1810	1824	74	1750
32	0	0	4219	0	4219
33	5988	2785	1963	266	1697
34	0	0	971	6	965
35	4689	2605	1716	275	1441
36	0	0	9882	0	9882
37	3001	1405	1890	350	1540
38	2619	1355	1128	110	1018
39	4053	2240	2051	487	1564
40	3785	1725	2230	231	1999
41	4213	1915	3050	567	2483
42	0	0	2150	1650	500
43	5504	2560	2010	182	1828
44	3222	1790	168	5	163
45	5256	3285	1595	330	1265
46	0	0	880	625	255
47	10856	5855	1551	250	1301
48	6393	2459	291	14	277
49	6758	3235	275	55	220
50	0	0	2350	2000	350
51	4236	1765	1600	50	1550
52	0	0	1171	0	1171
53	8415	3825	1498	115	1383
54	10865	4100	5000	250	4750

ZONE	2011 POP'N	2011 # dwelling	Total Employment	Retail Employment	Other Employment
55	0	0	2650	375	2275
56	0	0	1440	69	1371
57	8613	3915	590	84	506
58	140	65	3700	135	3565
59	0	0	900	600	300
60	0	0	2000	0	2000
61	5472	2280	732	125	607
62	3264	1360	353	26	327
63	0	0	5200	2500	2700
64	5658	2460	220	15	205
65	9556	4015	506	20	486
66	0	0	5800	200	5600
67	8162	3710	1132	105	1027
68	0	0	20	0	20
69	4511	2005	745	69	676
70	0	0	7550	0	7550
71	0	0	158	0	158
72	0	0	1770	700	1070
73	3040	1600	632	152	480
74	248	165	2475	775	1700
75	5738	2550	1390	46	1342
76	0	0	600	400	200
77	11925	5300	594	59	535
78	0	0	680	0	680
79	0	0	7380	75	7305
80	7755	4700	565	42	523
81	0	0	48	10	38
82	494	260	2171	0	2171
83	333	180	6054	425	5629
84	3410	1550	568	17	551
85	6762	3145	538	43	495
86	563	375	460	300	160
87	3546	1730	404	28	376
88	2980	1490	8561	775	7786
89	250	125	5100	460	4640
90	0	0	4700	0	4700
91	0	0	3950	2000	1950
92	6885	3825	1533	439	1094
93	2613	1375	7000	950	6050
94	5104	2320	1346	473	873
95	7806	4435	6400	750	5650
96	11904	6265	2200	410	1790
97	2230	885	200	0	200
98	4658	2740	760	70	690
99	6889	3626	1550	100	1450
100	7922	4660	1010	500	510
101	0	0	817	0	817
102	4998	2380	1085	45	1040
103	5956	2770	4300	120	4180
104	0	0	4200	600	3600
105	0	0	3600	425	3175
106	0	0	2225	0	2225
107	11043	3930	850	80	770
108	0	0	2300	100	2200
109	8262	3345	1272	265	1007
110	6294	2375	6450	75	6375
111	0	0	8280	320	7960
112	5406	2845	2078	746	1332
113	2712	1130	106	0	106

ZONE	2011 POP'N	2011 # dwelling	Total Employment	Retail Employment	Other Employment
114	0	0	2300	1850	450
115	11527	5240	278	29	249
116	8856	3690	1750	500	1250
117	11664	4860	1050	63	987
118	7052	3280	6200	50	6150
119	0	0	3800	80	3720
120	605	275	9400	600	8800
121	6588	2635	427	38	389
122	0	0	243	0	243
123	12259	4715	1361	206	1155
124	14	5	400	0	400
125	8350	3340	6200	1100	5100
126	3822	1470	133	5	128
127	0	0	8000	0	8000
128	325	125	1276	0	1276
129	21350	7445	1117	279	838
130	8522	2990	875	150	725
131	5488	1860	750	175	575
132	3517	1272	416	44	372
133	21552	7925	3148	394	2754
134	12832	4600	2000	100	1900
135	2206	780	1646	100	1546
136	19893	6980	760	300	460
137	4590	1430	555	170	385
138	13740	5020	2450	602	1848
139	20440	7425	3000	471	2529
140	14274	4680	11199	860	10339
141	2395	921	550	40	510
142	8775	3250	3750	300	3450
143	10167	3389	339	102	237
144	7950	2650	541	320	221
145	14938	5210	1800	175	1625
146	9378	3460	2500	80	2420
147	5806	2020	2700	550	2150
148	8000	2850	1460	612	848
149	9200	3220	325	85	240
150	4514	1705	907	60	847
151	11159	4110	1440	475	965
152	2795	1350	845	160	685
153	7000	3320	3000	475	2525
154	200	112	22226	1840	20386
155	8490	4020	3000	175	2825
156	2160	900	200	0	200
157	0	0	1700	0	1700
158	1755	900	7750	3300	4450
159	10320	4800	1420	235	1185
160	750	300	1135	0	1135
161	13800	6900	1630	575	1055
162	1310	675	7150	2100	5050
163	237	110	975	0	975
164	7000	2905	1325	150	1175
165	11267	3930	850	325	525
166	6937	2680	330	191	139
167	8624	3320	1573	258	1315
168	2295	850	2500	2500	0
169	4538	1650	5000	250	4750
170	11982	4260	3500	225	3275
171	60	20	3900	1150	2750
172	6793	2750	1750	362	1388

ZONE	2011 POP'N	2011 # dwelling	Total Employment	Retail Employment	Other Employment
173	11103	3550	486	136	350
174	6950	2565	700	365	335
175	6598	2175	176	53	123
176	275	100	3600	200	3400
177	7980	2800	1090	235	855
178	2700	750	225	60	165
179	3341	1300	1530	80	1450
180	11500	4600	3450	210	3240
181	3438	1250	590	165	425
182	4384	1600	705	160	545
183	5125	2075	1050	215	835
184	3888	1600	990	205	785
185	5824	2157	965	190	775
201	0	0	5750	2800	2950
202	7857	2857	803	302	501
203	3822	1365	4292	60	4232
204	150	80	10200	2750	7450
205	439	169	0	0	0
206	4752	1980	10825	2400	8425
207	0	0	9978	200	9778
208	10233	3355	436	150	286
209	442	138	5121	102	5018
210	7220	2329	303	61	242
211	8534	2753	413	62	351
212	30	10	1	0	1
213	39	13	2	1	1
214	15	5	1	0	0
215	45	15	2	1	1
216	4288	1606	2005	402	1603
217	4640	1738	4526	664	3862
218	4733	1777	302	201	101
219	2339	879	167	133	33
220	7364	2630	6683	471	6212
221	608	190	19	0	19
222	5119	1625	5158	750	4408
223	31	11	7361	1194	6167
224	11172	3960	4396	400	3996
225	17243	5474	821	246	575
226	6334	1950	5485	600	4885
227	17844	5895	826	253	573
228	239	90	10	0	10
229	14	5	3	0	3
230	494	190	2287	147	2140
231	9792	3200	3300	665	2635
232	4940	2246	119	12	107
233	0	0	2070	80	1990
234	0	0	3300	150	3150
235	4614	1678	472	178	294
236	2886	1110	2470	275	2195
237	9763	3331	466	148	318
238	7592	2489	200	20	180
239	5917	1940	225	35	190
240	7219	2367	308	40	268
241	10558	3439	360	60	300
242	8134	2465	5300	135	5165
243	16514	5310	9312	600	8712
244	4932	1605	3997	100	3897
245	5505	1805	1605	150	1455
246	0	0	2935	200	2735

ZONE	2011 POP'N	2011 # dwelling	Total Employment	Retail Employment	Other Employment
247	3875	1250	175	75	100
248	5794	2155	160	50	110
249	4310	1650	1576	696	880
250	4963	2086	1260	203	1057
251	8204	3249	199	76	123
252	5236	2000	1577	777	800
253	7563	2670	400	169	231
254	755	378	1315	215	1100
255	605	310	6859	195	6664
256	5606	2035	768	105	663
257	6487	2329	965	448	517
258	8013	3111	575	70	505
	1,157,697	479,832	672,276	81,685	590,591

APPENDIX B

Programs Lists for Calculations of Travel Times in 1986 and 2011

- B.1. Program list and resulting travel time table of the 29-district system for the 1986
Base case**
- B.2. Program list and resulting travel time table of the 29-district system for the 2011
Null scenario**

APPENDIX B.1

```
10 DIM Z(258), ZN(29), ZZ$(29), TMP1(30), TMP2(30), MTOD(29,29), MTIM(29,29),  
    PH$(52), PK$(30)  
20 L=0  
30 FOR I=1 TO 29  
40 READ ZZ$(I),ZN(I)  
50 FOR J=1 TO ZN(I)  
60 L=L+1  
70 READ Z(L)  
80 NEXT J  
90 NEXT I  
100 A=0 : B=0  
110 L=0  
120 FOR I=1 TO 29  
130 FOR K=1 TO ZN(I)  
140 L=L+1  
150 TMP1(K)=Z(L)  
160 NEXT K  
170 LL=0  
180 FOR J=1 TO 29  
190 FOR K=1 TO ZN(J)  
200 LL=LL+1  
210 TMP2(K)=Z(LL)  
220 NEXT K  
230 FOR M=1 TO ZN(I)  
240 S=TMP1(M)  
250 OPEN "ODOBS.TXT" FOR INPUT AS #1  
260 G=1  
270 FOR F=1 TO 700  
280 INPUT #1,C$  
290 IF C$="" GOTO 390  
300 K=INSTR(C$,CHR$(32))  
310 E$=MID$(C$,1,K-1)  
320 EE=VAL(E$)  
330 IF G=1 GOTO 350  
340 IF EE<>S AND PK$(G-1)<>CHR$(32) GOTO 390  
350 IF EE <> S GOTO 380  
360 PK$(G)=C$  
370 G=G+1  
380 NEXT F  
390 CLOSE  
400 IF G=1 GOTO 830
```

```
410 OPEN "PMPH.TXT" FOR INPUT AS #1
420 INPUT #1,C$,DDS
430 IF S=1 GOTO 470
440 FOR F=1 TO (S-1)*52
450 INPUT #1,C$
460 NEXT F
470 FOR F=1 TO 52
480 INPUT #1,PH$(F)
490 NEXT F
500 CLOSE
510 FOR N=1 TO ZN(J)
520 IF TMP1(M)=TMP2(N) GOTO 820
530 FOR P=1 TO G-1
540 V=LEN(PK$(P))
550 FOR Q=1 TO V
560 IF MID$(PK$(P),Q,1)<>":" GOTO 650
570 R$=MID$(PK$(P),Q-3,3)
580 RR=VAL(R$)
590 IF RR>TMP2(N) GOTO 820
600 IF RR<TMP2(N) GOTO 650
610 W$=MID$(PK$(P),Q+1,5)
620 WW=VAL(W$)
630 A=A+WW
640 GOTO 680
650 NEXT Q
660 NEXT P
670 GOTO 820
680 FOR NN=1 TO 52
690 V=LEN(PH$(NN))
700 FOR Q=1 TO V
710 IF MID$(PH$(NN),Q,1)<>":" GOTO 800
720 R$=MID$(PH$(NN),Q-3,3)
730 RR=VAL(R$)
740 IF RR>TMP2(N) GOTO 820
750 IF RR<TMP2(N) GOTO 800
760 X$=MID$(PH$(NN),Q+1,5)
770 XX=VAL(X$)
780 B=B+XX*WW
790 GOTO 820
800 NEXT Q
810 NEXT NN
820 NEXT N
830 NEXT M
840 IF A<>0 THEN AVGTIM=B/A ELSE AVGTIM=0
```

```

850 IF I=J THEN MTIM(I,J)=.75*AVGTIM ELSE MTIM(I,J)=AVGTIM
860 MTOD(I,J)=A
870 A=0:B=0
880 NEXT J
890 NEXT I
900 OPEN "OTTDATA" FOR OUTPUT AS #1
910 FOR I=1 TO 28
920 FOR J=I+1 TO 29
930 PRINT #1, I;" ";J;
940 PRINT #1, TAB(33);MTIM(I,J);TAB(44);MTIM(J,I)
950 NEXT J
960 NEXT I
970 CLOSE
980 OPEN "FREQ.TXT" FOR OUTPUT AS #1
990 OPEN "TIMEFREQ.TXT" FOR OUTPUT AS #2
1000 FOR I=1 TO 29
1010 FOR J=1 TO 29
1020 PRINT #1,MTOD(I,J)
1030 PRINT #2,MTIM(I,J)
1040 NEXT J
1050 NEXT I
1060 CLOSE
1070 OPEN "NEWZONE.TXT" FOR OUTPUT AS #1
1080 OPEN "INTRA.TXT" FOR OUTPUT AS #2
1090 L=0
1100 FOR I=1 TO 29
1110 PRINT#1,"ZONE";I;" ";
1120 PRINT #2,I;" ";I;MTIM(I,I)
1130 FOR K=1 TO ZN(I)
1140 L=L+1
1150 PRINT #1,Z(L);
1160 NEXT K
1170 PRINT #1,
1180 NEXT I
1190 CLOSE
1200 DATA "1",14,1,2,3,11,12,13,14,15,16,17,18,19,20,21
1210 DATA "2",12,4,5,6,7,8,9,10,22,23,24,25,201
1220 DATA "3",10,90,91,92,93,94,95,96,97,98,100
1230 DATA "4",22,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89
1240 DATA "5",10,99,101,102,103,104,105,106,107,108,109
1250 DATA "6",22,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,57,58
1260 DATA "7",9,59,60,61,62,63,64,65,66,67
1270 DATA "8",11,46,47,48,49,50,51,52,53,54,55,56
1280 DATA "9",5,120,121,122,123,124

```


1290 DATA "10",10,135,136,137,138,221,222,223,224,225,226
1300 DATA "11",11,110,142,143,202,204,234,235,236,237,246,247
1310 DATA "12",10,144,145,203,238,239,240,241,242,243,244
1320 DATA "13",5,139,141,230,231,245
1330 DATA "14",16,111,112,113,114,115,116,117,118,119,140,205,227,228,229,232,233
1340 DATA "15",4,125,126,127,128
1350 DATA "16", 27, 156, 157, 162, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174,
175, 176,177,178,179,180,181,185,248,249,250,251,252,253
1360 DATA "17",3,132,133,134
1370 DATA "18", 26, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 158, 159, 160,
161,163,164,182,183,184,186,187,254,255,256,257,258
1380 DATA "19",1,130
1390 DATA "20",4,216,217,218,219
1400 DATA "21",3,206,210,211
1410 DATA "22",1,131
1420 DATA "23",3,207,208,209
1430 DATA "24",4,212,213,214,215
1440 DATA "25",2,129,220
1450 DATA "26",2,188,189
1460 DATA "27",4,190,191,193,194
1470 DATA "28",5,192,195,196,197,200
1480 DATA "~9",2,198,199
1490 END

Inter-district travel times in 1986

A : B	A --> B	B --> A
1 : 2	7.994295	9.182052
1 : 3	11.62756	10.27751
1 : 4	15.09994	11.23428
1 : 5	21.32538	14.55
1 : 6	12.6846	10.76418
1 : 7	16.13676	15.08826
1 : 8	21.02677	0
1 : 9	23.9518	0
1 : 10	40.69599	55.96
1 : 11	28.25749	18.9114
1 : 12	35.71932	23.37006
1 : 13	47.98677	22.06
1 : 14	19.9401	19.82
1 : 15	26.28649	0
1 : 16	22.4719	15.09
1 : 17	53.42012	0
1 : 18	23.15042	8.718703
1 : 19	34.71	0
1 : 20	40.4708	0
1 : 21	0	0
1 : 22	33.215	26.24
1 : 23	35.26666	27.76667
1 : 24	32.59334	0
1 : 25	35.69289	26.942
1 : 26	0	0
1 : 27	0	0
1 : 28	0	0
1 : 29	0	0
2 : 3	10.73281	7.616182
2 : 4	16.58474	10.59633
2 : 5	19.8322	15.35245
2 : 6	14.549	12.24429
2 : 7	17.12304	16.13822
2 : 8	22.79804	19.56
2 : 9	26.05546	19.70954
2 : 10	43.87002	0
2 : 11	26.10092	0
2 : 12	35.27576	0
2 : 13	38.44067	0
2 : 14	20.86844	0
2 : 15	26.17	21.45
2 : 16	19.92853	13.89342
2 : 17	48.62991	0
2 : 18	21.76657	9.519089
2 : 19	35.82337	0
2 : 20	41.78867	0
2 : 21	0	0
2 : 22	0	0
2 : 23	0	0
2 : 24	33.99333	0
2 : 25	37.91739	0
2 : 26	0	0
2 : 27	0	0
2 : 28	0	0
2 : 29	0	0
3 : 4	13.72136	13.14252
3 : 5	15.4083	8.76823

A : B	A --> B	B --> A
3 : 6	16.7278	17.74162
3 : 7	0	19.74
3 : 8	25.35	26.47
3 : 9	29.1	24.7
3 : 10	42.95036	0
3 : 11	70.39592	18.2271
3 : 12	30.0031	0
3 : 13	0	0
3 : 14	21.2528	0
3 : 15	28.85	27.14
3 : 16	22.46749	25.2857
3 : 17	57.53	0
3 : 18	21.83974	14.57226
3 : 19	38.785	32.61
3 : 20	43.94867	0
3 : 21	0	0
3 : 22	0	0
3 : 23	0	0
3 : 24	0	0
3 : 25	0	0
3 : 26	0	0
3 : 27	0	0
3 : 28	0	0
3 : 29	0	0
4 : 5	18.0639	18.21642
4 : 6	16.37834	17.06102
4 : 7	13.57018	0
4 : 8	24.12886	0
4 : 9	24.81222	0
4 : 10	33.67563	0
4 : 11	24.13688	15.7204
4 : 12	32.55394	19.49964
4 : 13	42.61494	41.67
4 : 14	14.95905	13.10799
4 : 15	30.82	0
4 : 16	28.92645	24.9229
4 : 17	60.5248	48.5
4 : 18	29.82805	17.90045
4 : 19	0	0
4 : 20	42.09815	37.55645
4 : 21	0	0
4 : 22	0	33.47
4 : 23	0	35.00334
4 : 24	0	0
4 : 25	40.6755	0
4 : 26	0	274.3
4 : 27	0	0
4 : 28	0	0
4 : 29	0	0
5 : 6	21.10557	24.66847
5 : 7	0	34.97
5 : 8	28.23	0
5 : 9	0	40.01
5 : 10	68.98001	0
5 : 11	18.54032	14.31981
5 : 12	25.34168	14.5146
5 : 13	50.48017	0
5 : 14	28.76	0
5 : 15	0	0
5 : 16	37.02987	19.64

A : B	A --> B	B --> A
8 : 11	0	0
8 : 12	0	0
8 : 13	0	0
8 : 14	24.35	24.80778
8 : 15	11.00134	10.47862
8 : 16	0	0
8 : 17	36.5525	0
8 : 18	45.92	23.44203
8 : 19	20.07	0
8 : 20	0	0
8 : 21	0	0
8 : 22	19.11	18.67871
8 : 23	20.62	19.84083
8 : 24	20.16833	0
8 : 25	22.3634	0
8 : 26	0	0
8 : 27	0	0
8 : 28	0	0
8 : 29	0	0
9 : 10	23.82177	0
9 : 11	42.89741	34.87
9 : 12	0	0
9 : 13	47.1	0
9 : 14	16.89603	22.33
9 : 15	12.94	12.86
9 : 16	0	31.57
9 : 17	46.09752	0
9 : 18	37.1085	26.79217
9 : 19	0	0
9 : 20	30.55756	0
9 : 21	0	0
9 : 22	20.81	24.034
9 : 23	23.28667	25.77867
9 : 24	28.81	0
9 : 25	28.5198	0
9 : 26	0	0
9 : 27	0	0
9 : 28	0	0
9 : 29	0	0
10 : 11	62.72421	0
10 : 12	0	0
10 : 13	52.8703	56.67787
10 : 14	40.7095	38.87829
10 : 15	19.02	20.80088
10 : 16	0	0
10 : 17	50.88	29.92
10 : 18	73.1143	52.49741
10 : 19	26.31	0
10 : 20	0	26.70022
10 : 21	0	0
10 : 22	0	28.89
10 : 23	0	30.17334
10 : 24	0	0
10 : 25	23.0861	0
10 : 26	0	0
10 : 27	0	0
10 : 28	0	152
10 : 29	0	0
11 : 12	15.19401	16.3918
11 : 13	25.6798	36.70466

A : B	A --> B	B --> A
11 : 14	0	31.74471
11 : 15	0	39.58
11 : 16	0	31.00578
11 : 17	0	65.12
11 : 18	0	32.48904
11 : 19	0	0
11 : 20	0	51.56
11 : 21	0	0
11 : 22	0	0
11 : 23	0	0
11 : 24	0	0
11 : 25	0	0
11 : 26	0	282.6
11 : 27	0	0
11 : 28	0	0
11 : 29	0	91.9
12 : 13	65.46501	37.49372
12 : 14	0	40.39401
12 : 15	0	0
12 : 16	0	42.90567
12 : 17	0	0
12 : 18	44.37707	39.63126
12 : 19	0	0
12 : 20	0	0
12 : 21	0	0
12 : 22	0	0
12 : 23	0	0
12 : 24	0	0
12 : 25	0	0
12 : 26	0	0
12 : 27	0	0
12 : 28	0	0
12 : 29	108.656	85.45403
13 : 14	28.44643	32.82566
13 : 15	0	0
13 : 16	0	0
13 : 17	0	0
13 : 18	66.85	40.12948
13 : 19	0	59.84001
13 : 20	0	0
13 : 21	0	0
13 : 22	0	0
13 : 23	0	0
13 : 24	0	0
13 : 25	0	0
13 : 26	0	0
13 : 27	0	0
13 : 28	0	.08.9
13 : 29	0	119.1544
14 : 15	0	0
14 : 16	36.21258	38.79
14 : 17	0	56.59
14 : 18	40.86548	24.13873
14 : 19	0	0
14 : 20	0	0
14 : 21	0	0
14 : 22	37.98	0
14 : 23	40.45667	0
14 : 24	0	0
14 : 25	0	0

A : B	A --> B	B --> A
19 : 26	0	0
19 : 27	0	0
19 : 28	0	0
19 : 29	0	0
20 : 21	0	0
20 : 22	0	20.90202
20 : 23	0	22.98652
20 : 24	0	15.39071
20 : 25	0	14.81222
20 : 26	0	0
20 : 27	0	137.2244
20 : 28	0	109.96
20 : 29	0	0
21 : 22	0	0
21 : 23	0	0
21 : 24	0	0
21 : 25	0	0
21 : 26	0	0
21 : 27	0	0
21 : 28	0	0
21 : 29	0	0
22 : 23	8.377334	8.247
22 : 24	12.99333	0
22 : 25	17.09072	13.63989
22 : 26	0	0
22 : 27	0	0
22 : 28	0	0
22 : 29	0	0
23 : 24	14.71	0
23 : 25	19.20677	16.3213
23 : 26	0	0
23 : 27	0	0
23 : 28	0	0
23 : 29	0	0
24 : 25	0	0
24 : 26	0	0
24 : 27	0	0
24 : 28	0	0
24 : 29	0	0
25 : 26	0	0
25 : 27	0	0
25 : 28	0	0
25 : 29	0	0
26 : 27	0	0
26 : 28	0	0
26 : 29	0	0
27 : 28	0	0
27 : 29	0	0
28 : 29	0	0

Note: A travel time of "zero" for any pair of district means that there was no observed trip for that pair during the observation period.

Intra-district travel times in 1986

1	:	1	4.640032
2	:	2	4.606895
3	:	3	6.282824
4	:	4	8.733136
5	:	5	9.549209
6	:	6	6.877174
7	:	7	7.103257
8	:	8	5.947513
9	:	9	6.165
10	:	10	17.79893
11	:	11	6.753273
12	:	12	6.845019
13	:	13	22.5075
14	:	14	11.11197
15	:	15	6.712612
16	:	16	12.23189
17	:	17	33.13386
18	:	18	8.654
19	:	19	4.77
20	:	20	5.828087
21	:	21	8.350
22	:	22	5.040
23	:	23	5.139375
24	:	24	9.920
25	:	25	6.169125

APPENDIX B.2

```
10 DIM Z(258),ZN(29),ZZ$(29),TMP1(30),TMP2(30),MTIM(29,29),PH$(52)
20 L=0
30 FOR I=1 TO 29
40 READ ZZ$(I),ZN(I)
50 FOR J=1 TO ZN(I)
60 L=L+1
70 READ Z(L)
80 NEXT J
90 NEXT I
100 B=0:L=0
110 FOR I=1 TO 29
120 FOR K=1 TO ZN(I)
130 L=L+1
140 TMP1(K)=Z(L)
150 NEXT K
160 LL=0
170 FOR J=1 TO 29
180 FOR K=1 TO ZN(J)
190 LL=LL+1
200 TMP2(K)=Z(LL)
210 NEXT K
220 IF I=J AND I=19 THEN MTIM(I,J)=3.305:GOTO 540
230 IF I=J AND I=22 THEN MTIM(I,J)=2.6:GOTO 540
240 FOR M=1 TO ZN(I)
250 S=TMP1(M)
260 OPEN "PMPH2011.TXT" FOR INPUT AS #1
270 INPUT #1,CS,DD$
280 IF S=1 GOTO 320
290 FOR F=1 TO (S-1)*52
300 INPUT #1,CS
310 NEXT F
320 FOR F=1 TO 52
330 INPUT #1,PH$(F)
340 NEXT F
350 CLOSE
360 FOR N=1 TO ZN(J)
370 IF TMP1(M)=TMP2(N) GOTO 510
380 FOR NN=1 TO 52
390 V=LEN(PH$(NN))
400 FOR Q=1 TO V
410 IF MID$(PH$(NN),Q,1)<>":" GOTO 490
```

```

420 R$=MID$(PH$(NN),Q-3,3)
430 RR=VAL(R$)
440 IF RR<TMP2(N) GOTO 490
450 X$=MID$(PH$(NN),Q+1,5)
460 XX=VAL(X$)
470 B=B+XX
480 GOTO 510
490 NEXT Q
500 NEXT NN
510 NEXT N
520 NEXT M
530 IF I=J THEN MTIM(I,J)= 0.75*B/(ZN(I)*(ZN(J)-1)) ELSE MTIM(I,J)=
      B/(ZN(I)*ZN(J))
540 B=0
550 NEXT J
560 NEXT I
570 OPEN "OTDTA11" FOR OUTPUT AS #1
580 FOR I=1 TO 28
590 FOR J=I+1 TO 29
600 PRINT #1, I;" ";J;
610 PRINT #1, TAB(33);MTIM(I,J);TAB(44);MTIM(J,I)
620 NEXT J
630 NEXT I
640 CLOSE
650 OPEN "INTRA11.TXT" FOR OUTPUT AS #2
660 FOR I=1 TO 29
670 PRINT #2,I;" ";I;MTIM(I,I)
680 NEXT I
690 CLOSE
700 DATA "1",14,1,2,3,11,12,13,14,15,16,17,18,19,20,21
710 DATA "2",12,4,5,6,7,8,9,10,22,23,24,2  01
720 DATA "3",10,90,91,92,93,94,95,96,97,98,100
730 DATA "4",22,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89
740 DATA "5",10,99,101,102,103,104,105,106,107,108,109
750 DATA "6",22,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,57,58
760 DATA "7",9,59,60,61,62,63,64,65,66,67
770 DATA "8",11,46,47,48,49,50,51,52,53,54,55,56
780 DATA "9",5,120,121,122,123,124
790 DATA "10",10,135,136,137,138,221,222,223,224,225,226
800 DATA "11",11,110,142,143,202,204,234,235,236,237,246,247
810 DATA "12",10,144,145,203,238,239,240,241,242,243,244
820 DATA "13",5,139,141,230,231,245
830 DATA "14",16,111,112,113,114,115,116,117,118,119,140,205,227,228,229,232,233
840 DATA "15",4,125,126,127,128

```

850 DATA "16", 27, 156, 157, 162, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174,
175, 176, 177, 178, 179, 180, 181, 185, 248, 249, 250, 251, 252, 253
860 DATA "17",3,132,133,134
870 DATA "18", 26, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 158, 159, 160,
161, 163, 164, 182, 183, 184, 186, 187, 254, 255, 256, 257, 258
880 DATA "19",1,130
890 DATA "20",4,216,217,218,219
900 DATA "21",3,206,210,211
910 DATA "22",1,131
920 DATA "23",3,207,208,209
930 DATA "24",4,212,213,214,215
940 DATA "25",2,129,220
950 DATA "26",2,188,189
960 DATA "27",4,190,191,193,194
970 DATA "28",5,192,195,196,197,200
980 DATA "29",2,198,199
990 END

Inter-district travel times in 2011

A : B	A --> B	B --> A
1 : 2	8.145598	8.182901
1 : 3	12.76686	11.45922
1 : 4	12.1958	11.2476
1 : 5	17.47097	15.4593
1 : 6	11.23429	10.2039
1 : 7	15.37314	13.36358
1 : 8	19.97059	15.3412
1 : 9	22.14171	17.0488
1 : 10	34.85622	27.1823
1 : 11	22.55327	18.4172
1 : 12	30.57736	24.8282
1 : 13	30.07586	25.5484
1 : 14	21.05319	18.2719
1 : 15	25.4125	18.7367
1 : 16	43.05406	23.8675
1 : 17	61.04166	42.0333
1 : 18	43.57923	29.681
1 : 19	33.90857	24.2607
1 : 20	46.70107	32.5058
1 : 21	34.95167	25.1452
1 : 22	34.63	25.3135
1 : 23	33.99881	27.7023
1 : 24	38.96018	26.423
1 : 25	36.93107	26.8046
1 : 26	276.4964	206.185
1 : 27	296.4303	270.786
1 : 28	144	135.53
1 : 29	96.46679	91.421
2 : 3	11.28299	10.22531
2 : 4	12.19549	11.05015
2 : 5	16.22928	14.4884
2 : 6	13.42883	12.21166
2 : 7	17.04718	14.9609
2 : 8	22.11674	17.3288
2 : 9	23.7385	18.5947
2 : 10	36.42343	28.718
2 : 11	21.88301	18.0605
2 : 12	29.84125	24.4765
2 : 13	29.52	24.8573
2 : 14	21.43032	18.4132
2 : 15	27.57375	20.74
2 : 16	42.45875	23.3616
2 : 17	63.06334	43.9608
2 : 18	44.16748	30.3152
2 : 19	35.95333	26.272
2 : 20	48.42688	34.4283
2 : 21	37.09056	27.1566
2 : 22	36.80917	27.3241
2 : 23	36.25194	29.713
2 : 24	41.14458	28.4358
2 : 25	38.82834	28.8066
2 : 26	276.0792	205.658
2 : 27	298.3979	272.76
2 : 28	144.3489	136.142
2 : 29	95.86417	90.8462
3 : 4	12.94009	12.55698
3 : 5	11.53465	11.1838

A : B

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A --> B

16.89351
 21.01667
 25.68391
 27.724
 40.4183
 17.88942
 25.7894
 28.2038
 23.11285
 31.12075
 43.57427
 66.73268
 45.97489
 39.62
 52.39051
 40.66367
 40.337
 39.707
 44.673
 42.647
 277.195
 302.1301
 145.0166
 92.48699
 15.39395
 14.94343
 15.38932
 22.09206
 21.45691
 34.02232
 19.22419
 26.93023
 24.93662
 17.41576
 27.61955
 47.881
 62.46455
 49.14643
 35.15272
 46.39353
 36.72637
 36.80091
 36.92621
 40.99523
 37.46182
 281.4682
 297.3841
 140.3567
 92.29612
 20.61259
 24.27289
 29.22455
 30.4972
 42.9837
 14.58845
 21.67477
 28.1124
 24.5373
 34.666
 48.63727

B --> A

16.7885
 19.5132
 21.8263
 23.314
 33.3563
 15.8735
 22.348
 25.165
 20.9535
 25.22
 25.8833
 48.5183
 33.54
 30.74
 38.9864
 31.6266
 31.79
 34.1966
 32.9042
 33.28
 208.1
 277.27
 138.575
 89.11889
 15.3453
 14.66
 14.5032
 19.1567
 18.1543
 28.1517
 17.2965
 23.5515
 22.0836
 15.6182
 22.672
 30.075
 45.4125
 36.2653
 28.234
 35.7455
 29.119
 29.2881
 31.7137
 30.3967
 30.5584
 212.413
 274.48
 134.365
 89.3138
 21.1196
 23.4095
 26.0564
 26.919
 37.034
 12.82225
 18.4801
 25.4172
 22.5287
 29.45
 31.4388

A : B	A --> B	B --> A
5 : 17	69.97267	52.7483
5 : 18	50.91075	39.0449
5 : 19	43.122	34.97
5 : 20	55.39476	43.2172
5 : 21	44.16467	35.8573
5 : 22	43.895	36.02
5 : 23	43.26567	38.4276
5 : 24	48.17425	37.1347
5 : 25	46.119	37.51
5 : 26	282.27	213.71
5 : 27	305.4075	281.498
5 : 28	146.0504	140.544
5 : 29	89.93149	87.033
6 : 7	11.56789	11.02328
6 : 8	14.6304	11.6474
6 : 9	17.109	13.6573
6 : 10	29.6781	23.8853
6 : 11	25.7557	23.2604
6 : 12	33.72563	29.6527
6 : 13	31.77191	28.6447
6 : 14	21.40254	19.4036
6 : 15	20.01552	15.0886
6 : 16	47.16956	29.0433
6 : 17	55.63698	38.3596
6 : 18	45.96212	32.379
6 : 19	28.37955	20.6
6 : 20	41.14603	28.931
6 : 21	29.5106	21.57
6 : 22	29.18318	21.7431
6 : 23	28.73591	23.8654
6 : 24	33.56193	22.8518
6 : 25	31.36227	23.212
6 : 26	280.4864	211.468
6 : 27	290.9507	267.216
6 : 28	141.5258	134.611
6 : 29	99.04866	95.81771
7 : 8	14.00765	12.28976
7 : 9	12.73718	10.82673
7 : 10	25.24056	21.1859
7 : 11	26.91516	25.8372
7 : 12	34.37	31.8886
7 : 13	28.73756	26.5268
7 : 14	18.12095	16.5973
7 : 15	19.55055	15.8468
7 : 16	50.88402	33.798
7 : 17	54.11778	38.4174
7 : 18	49.98923	37.1528
7 : 19	26.82889	21.4422
7 : 20	37.38972	28.6902
7 : 21	28.52815	22.3277
7 : 22	28.68556	22.4955
7 : 23	29.06519	24.9429
7 : 24	32.85611	23.6052
7 : 25	28.78889	23.5755
7 : 26	284.1833	216.177
7 : 27	288.8528	267.67
7 : 28	137.5871	132.404
7 : 29	98.41945	96.343
8 : 9	13.4702	12.97536
8 : 10	22.89944	20.2274

A : B	A --> B	B --> A
8 : 11	30.61686	31.627
8 : 12	38.571	37.9771
8 : 13	33.62473	33.1447
8 : 14	22.90404	23.0614
8 : 15	11.97255	10.27102
8 : 16	52.73639	38.0644
8 : 17	47.41212	33.4612
8 : 18	51.09831	40.5561
8 : 19	19.76546	15.9154
8 : 20	32.26113	23.9356
8 : 21	21.14036	16.8624
8 : 22	21.02818	17.0409
8 : 23	21.2297	19.1493
8 : 24	25.31319	18.152
8 : 25	22.58137	18.0136
8 : 26	286.0591	220
8 : 27	282.3968	262.469
8 : 28	136.6569	132.9
8 : 29	102.1577	102.109
9 : 10	19.22746	17.4899
9 : 11	30.10782	31.4081
9 : 12	37.44339	37.201
9 : 13	29.4264	29.334
9 : 14	18.14198	18.5238
9 : 15	17.0505	16.1303
9 : 16	54.51787	40.5368
9 : 17	50.85401	37.7353
9 : 18	53.28439	43.2222
9 : 19	23.452	21.38
9 : 20	32.1455	26.65
9 : 21	25.632	22.8973
9 : 22	26.034	23.1
9 : 23	27.646	25.5533
9 : 24	30.2025	24.21
9 : 25	24.069	.45
9 : 26	287.83	222.9
9 : 27	284.826	267.396
9 : 28	134.498	131.738
9 : 29	101.244	101
10 : 11	40.16054	43.8783
10 : 12	47.4629	49.6627
10 : 13	35.77201	37.017
10 : 14	25.30765	27.803
10 : 15	21.34088	22.9137
10 : 16	64.66948	53.234
10 : 17	50.22734	41.4103
10 : 18	63.39975	55.8293
10 : 19	27.213	27.31
10 : 20	32.2805	29.5422
10 : 21	29.36834	29.1243
10 : 22	29.935	29.69
10 : 23	31.54933	32.0403
10 : 24	32.6635	30.482
10 : 25	24.92635	24.4193
10 : 26	297.985	235.6
10 : 27	282.8085	271.34
10 : 28	134.1164	133.455
10 : 29	111.154	113.543
11 : 12	15.22336	13.81688
11 : 13	27.54514	27.0147

A : B	A --> B	B --> A
11 : 14	25.4314	25.6019
11 : 15	37.08568	34.077
11 : 16	54.13798	38.3305
11 : 17	71.96881	56.9718
11 : 18	55.92756	45.6375
11 : 19	45.20182	39.6
11 : 20	56.32228	47.3315
11 : 21	46.49486	40.496
11 : 22	46.37273	40.6663
11 : 23	45.91243	43.0745
11 : 24	50.62341	41.7752
11 : 25	47.53364	42.0831
11 : 26	287.7546	220.609
11 : 27	307.1636	285.927
11 : 28	146.8809	143.627
11 : 29	86.38683	85.5259
12 : 13	32.46194	33.21
12 : 14	31.21576	32.8789
12 : 15	43.45275	42.0782
12 : 16	60.54592	46.2972
12 : 17	78.153	64.7796
12 : 18	62.33662	53.6181
12 : 19	51.441	47.62
12 : 20	62.12125	55.08
12 : 21	52.813	48.5133
12 : 22	52.749	48.68
12 : 23	52.32366	51.1023
12 : 24	56.9825	49.7932
12 : 25	53.523	50.011
12 : 26	294.185	228.5
12 : 27	313.2775	293.835
12 : 28	152.411	150.438
12 : 29	82.83051	83.4
13 : 14	21.49824	22.6514
13 : 15	38.13	36.82
13 : 16	61.61911	47.6623
13 : 17	69.67801	57.2986
13 : 18	63.27731	53.9498
13 : 19	45.014	42.28
13 : 20	53.27901	47.41
13 : 21	46.99867	43.52
13 : 22	47.306	43.74
13 : 23	48.18201	46.1913
13 : 24	51.1045	44.85
13 : 25	45.39301	42.46
13 : 26	295.26	229.9
13 : 27	303.32	286.432
13 : 28	137.8732	135.815
13 : 29	96.545	96.038
14 : 15	27.63109	26.0801
14 : 16	55.60278	39.7023
14 : 17	60.10833	46.9337
14 : 18	56.09859	44.8654
14 : 19	34.3725	31.582
14 : 20	42.61001	36.7435
14 : 21	36.4023	32.8166
14 : 22	36.72875	33.017
14 : 23	37.86208	35.4645
14 : 24	40.60734	34.1271
14 : 25	34.6775	31.739

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A --> B

289.175
 293.8625
 135.1021
 96.5522
 56.13064
 42.745
 54.56307
 14.62875
 27.77512
 15.79358
 14.899
 15.97767
 20.23006
 17.49125
 289.45
 278.1545
 137.0315
 105.625
 79.1846
 43.3777
 52.10741
 64.94436
 53.15125
 52.58371
 51.95285
 57.16102
 55.13408
 246.2185
 314.65
 162.0696
 113.0897
 77.82988
 27.00667
 29.14417
 27.32556
 28.16333
 27.89056
 28.08083
 29.32167
 312.7667
 274.7892
 154.197
 128.4
 54.5577
 67.39453
 55.60334
 55.04423
 54.41347
 59.61202
 57.58635
 283.0539
 317.1029
 166.1993
 120.0315
 19.43
 41.551668
 11.599
 13.16167
 12.92575
 10.1495

B --> A

222.09
 276.24
 131.605
 95.46029
 43.4278
 30.9408
 45.8856
 12.524
 20.4737
 13.71883
 13.84925
 15.3363
 15.0718
 14.5133
 225.887
 259.432
 135.05
 107.558
 79.4288
 49.6619
 61.6511
 69.8978
 62.5361
 62.7051
 65.1056
 63.8159
 64.19641
 196.07
 308.181
 172.397
 127.208
 81.637
 37.3
 33.6941
 37.5633
 38.9
 38.6976
 36.452
 38.5
 261.666
 268.883
 162.278
 147
 60.18
 68.4261
 61.0675
 61.235
 63.2501
 62.345
 62.7257
 225.676
 306.706
 172.19
 128.991
 14.8592
 8.3
 11.76
 13.52499
 10.127
 9.47

A : B	A --> B	B --> A
19 : 26	295	234
19 : 27	272.1525	254.48
19 : 28	142.01	141.12
19 : 29	111.2	115.4
20 : 21	16.65033	21.8991
20 : 22	19.8425	25
20 : 23	20.68	26.7558
20 : 24	15.98688	19.8182
20 : 25	15.35938	18.8137
20 : 26	303.225	247.42
20 : 27	262.0813	253.484
20 : 28	144.0985	146.158
20 : 29	118.675	126.487
21 : 22	8.768334	8.84533
21 : 23	11.52656	11.98022
21 : 24	12.54858	9.97058
21 : 25	13.61983	12.84233
21 : 26	295.8334	235.616
21 : 27	273.605	255.112
21 : 28	143.6393	142.902
21 : 29	112.0335	116.783
22 : 23	8.300667	8.20233
22 : 24	15.345	12.66
22 : 25	15.13	14.1
22 : 26	296	27
22 : 27	277.35	258.117
22 : 28	143.934	143.76
22 : 29	112.2	116.7
23 : 24	16.33833	13.40191
23 : 25	17.57667	15.7773
23 : 26	298.4167	234
23 : 27	278.2142	258.968
23 : 28	146.3907	144.91
23 : 29	114.65	116.616
24 : 25	15.41813	17.07
24 : 26	297.15	239.612
24 : 27	270.49	254.266
24 : 28	144.6605	145.71
24 : 29	113.35	120.962
25 : 26	297.55	237
25 : 27	274.3825	259.6
25 : 28	140.08	140.56
25 : 29	113.55	117.7

Intra-district travel times in 2011

1	:	1	6.079738
2	:	2	6.933518
3	:	3	7.166892
4	:	4	8.515975
5	:	5	7.584291
6	:	6	7.365955
7	:	7	7.600541
8	:	8	7.267647
9	:	9	7.500588
10	:	10	15.16698
11	:	11	9.311487
12	:	12	10.199251
13	:	13	21.21674
14	:	14	12.180007
15	:	15	7.13
16	:	16	18.38079
17	:	17	40.22625
18	:	18	33.87691
19	:	19	7.305
20	:	20	6.93625
21	:	21	8.32125
22	:	22	6.6
23	:	23	6.216875
24	:	24	11.22325
25	:	25	8.294875

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OF / DE

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**PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT**

PRECISION™ RESOLUTION TARGETS

APPENDIX C

Results of Person Trips Simulations in 1986 and 2011

- C.1. Actual and simulated person trips results for the whole Region in 1986**
- C.2. (Simulated) person trips results for the whole Region in 2011 for the Null scenario**
- C.3. Person trips results of alternative future scenarios for Kanata area**
- C.4. Transit trips results of alternative future scenarios for Kanata area**

APPENDIX C.1

THE 1986 OBSERVED INTER-DISTRICT PERSON TRIPS

1 : 2	780	225
1 : 3	1808	186
1 : 4	1592	387
1 : 5	845	44
1 : 6	1726	420
1 : 7	1091	115
1 : 8	1148	0
1 : 9	571	0
1 : 10	597	46
1 : 11	1448	40
1 : 12	802.9801	55
1 : 13	314.6	24.8
1 : 14	1073.4	37.2
1 : 15	225	0
1 : 16	1775	93
1 : 17	265.16	0
1 : 18	1951.99	468.0001
1 : 19	134	0
1 : 20	117	0
1 : 22	50.4	56
1 : 23	21.6	24
1 : 24	.8400001	0
1 : 25	339	40
2 : 3	519	132
2 : 4	744	294
2 : 5	538	216
2 : 6	575	413
2 : 7	201	73
2 : 8	306	26
2 : 9	97	109
2 : 10	272	0
2 : 11	730.9999	0
2 : 12	220	0
2 : 13	49	0
2 : 14	325	0
2 : 15	40	50
2 : 16	1182	123
2 : 17	31.13	0
2 : 18	658	291.05
2 : 19	89	0
2 : 20	14.4	0
2 : 24	.42	0
2 : 25	54	0
3 : 4	264	923
3 : 5	247	248
3 : 6	337	525
3 : 7	0	49
3 : 8	51	46
3 : 9	30	49
3 : 10	83	0
3 : 11	334	63.00001
3 : 12	292	0
3 : 14	186	0
3 : 15	31	49
3 : 16	163	43
3 : 17	17.6	0
3 : 18	268	362

3 : 19	90	49
3 : 20	14.4	0
4 : 5	559	240
4 : 6	568	539
4 : 7	177	0
4 : 8	325	0
4 : 9	167	0
4 : 10	144	0
4 : 11	595	35
4 : 12	411.0001	55
4 : 13	109.8	83
4 : 14	935.2	271
4 : 15	31	0
4 : 16	484.0001	124
4 : 17	83.4	20.9
4 : 18	390	524
4 : 20	21.6	17.1
4 : 22	0	28
4 : 23	0	12
4 : 25	40	0
4 : 26	0	12
5 : 6	167	255
5 : 7	0	32
5 : 8	40	0
5 : 9	0	33
5 : 10	16	0
5 : 11	246	107
5 : 12	240	35
5 : 13	59	0
5 : 14	96	0
5 : 16	61	43
5 : 17	17.6	0
5 : 18	19	472.0001
5 : 20	14.4	0
5 : 27	0	33
6 : 7	709	284
6 : 8	995	145
6 : 9	522	118
6 : 10	196	46
6 : 11	383	0
6 : 12	203	0
6 : 13	20	13.2
6 : 14	422	96.8
6 : 15	271	377
6 : 16	557	43
6 : 17	307.78	19
6 : 18	716	311.05
6 : 19	84	0
6 : 20	100.8	0
6 : 22	25.2	147
6 : 23	10.8	63
6 : 24	.42	0
6 : 25	317	0
6 : 27	0	54
7 : 8	117	41
7 : 9	125	135
7 : 10	82	65
7 : 11	43	0
7 : 12	101	0
7 : 13	78	82.8
7 : 14	68	213.2
7 : 15	0	122

7 : 16	16	0
7 : 17	124.78	0
7 : 18	0	226
7 : 20	28.8	0
7 : 22	0	65.1
7 : 23	0	27.9
7 : 24	.42	0
7 : 29	0	46
8 : 9	75	184
8 : 10	65	0
8 : 14	62	126
8 : 15	156	473
8 : 17	65.16001	0
8 : 18	19	402
8 : 19	42	0
8 : 22	25.2	151.9
8 : 23	10.8	65.1
8 : 24	.8400001	0
8 : 25	31	0
9 : 10	130	0
9 : 11	35	36
9 : 13	20	0
9 : 14	194	69
9 : 15	70	72
9 : 16	0	36
9 : 17	143.14	0
9 : 18	41	292.12
9 : 20	21.6	0
9 : 22	25.2	70
9 : 23	10.8	30
9 : 24	1.26	0
9 : 25	37	0
10 : 11	70	0
10 : 13	95.00001	56.4
10 : 14	40	142.6
10 : 15	31	260
10 : 17	57	18.15
10 : 18	49	165
10 : 19	33	0
10 : 20	0	14.85
10 : 22	0	45.5
10 : 23	0	19.5
10 : 25	37	0
10 : 28	0	16
11 : 12	231.004	102.012
11 : 13	28	17.598
11 : 14	0	62.402
11 : 15	0	34
11 : 16	0	106
11 : 17	0	18.7
11 : 18	0	337.4931
11 : 20	0	15.3
11 : 26	0	36
11 : 29	0	36
12 : 13	20	16
12 : 14	0	16
12 : 16	0	68
12 : 18	35.00001	275.2
12 : 29	16	50
13 : 14	82.8	224.8
13 : 18	10.4	48
13 : 19	0	20

13 : 28	0	20
13 : 29	0	31.6
14 : 16	104	48
14 : 17	0	48
14 : 18	76.6	193
14 : 22	25.2	0
14 : 23	10.8	0
14 : 29	0	63.4
15 : 16	52	0
15 : 17	222.73	22
15 : 18	152	146
15 : 19	219	47
15 : 20	77.85001	18
15 : 22	77	0
15 : 23	33	0
15 : 24	.42	0
15 : 25	184	37
16 : 18	689.996	1878.337
16 : 25	40	0
16 : 26	17	0
17 : 18	0	95.03401
17 : 19	47	46.8
17 : 20	58.32601	68.43401
17 : 22	39.9	187.19
17 : 23	17.1	80.22
17 : 24	0	.272
17 : 25	0	8.799999
17 : 27	0	122.4
17 : 28	0	8.8
18 : 19	88	0
18 : 20	35.69101	0
18 : 22	26.6	88.19299
18 : 23	11.4	37.8
18 : 24	.42	0
18 : 25	63.12001	0
19 : 20	7.2	0
19 : 22	29.4	180.6
19 : 23	12.6	77.4
20 : 22	0	34.964
20 : 23	0	14.985
20 : 24	0	.224
20 : 25	0	7.200001
20 : 27	0	21.6
20 : 28	0	7.2
22 : 23	23.73	23.73
22 : 24	1.155	0
22 : 25	155.43	22.404
23 : 24	.495	0
23 : 25	66.606	9.600001

1986 OBSERVED INTRA-DISTRICT PERSON TRIPS

1 : 1	1672
2 : 2	426
3 : 3	398
4 : 4	908
5 : 5	511
6 : 6	1853
7 : 7	107

8 : 8	419
9 : 9	64
10 : 10	49
11 : 11	192.89
12 : 12	26.662
13 : 13	31.6
14 : 14	441.8001
15 : 15	307
16 : 16	2406.81
17 : 17	29.444
18 : 18	3905.128
19 : 19	0
20 : 20	27.738
21 : 21	0
22 : 22	55.37
23 : 23	4.52
24 : 24	0
25 : 25	10.624

THE 1986 SIMULATED DISTRICT-TO-DISTRICT PERSON TRIPS

Row A Labels

Position 1: 18
 Position 2: 23
 Position 3: 24
 Position 4: 6
 Position 5: 8
 Position 6: 21
 Position 7: 16

Row B Labels

Position 1: 5
 Position 2: 1(cbd)
 Position 3: 2
 Position 4: 3
 Position 5: 26
 Position 6: 15
 Position 7: 22

Row C Labels

Position 1: 7
 Position 2: 19
 Position 3: 9
 Position 4: 20
 Position 5: 25
 Position 6: 17
 Position 7: 4

Row D Labels

Position 1: 14
 Position 2: 11
 Position 3: 12
 Position 4: 10
 Position 5: 27
 Position 6: 13
 Position 7: 28

Row E Labels

Position 1: 29

18

A	2415.1	10.2	0.6	803.8	544.4	0.0	1323.9
B	437.2	547.6	406.5	671.4	0.0	126.1	24.2
C	388.7	115.1	210.4	47.1	128.3	100.6	655.7
D	478.7	513.8	317.2	131.0	0.0	219.4	0.0
E	0.0						

23

A	37.4	8.8	0.3	52.6	73.2	0.0	0.0
B	0.0	19.7	0.0	0.0	0.0	32.8	16.4
C	23.9	40.4	25.1	18.6	45.0	50.6	26.5
D	20.6	0.0	0.0	55.1	0.0	0.0	0.0
E	0.0						

24

A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0						

6

A	1069.4	17.9	1.2	1332.4	709.9	0.0	947.4
B	397.8	469.2	348.3	541.7	0.0	209.0	45.2
C	477.2	169.3	309.3	78.0	188.6	177.0	672.5
D	491.0	496.3	306.4	293.1	0.0	97.2	0.0
E	0.0						

8							
A	41.4	4.7	0.3	171.2	238.2	0.0	0.0
B	54.3	42.0	35.2	54.7	0.0	58.6	11.9
C	73.4	47.4	92.0	0.0	52.8	55.9	72.2
D	75.5	0.0	0.0	57.3	0.0	0.0	0.0
E	0.0						
21							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0						
16							
A	722.9	0.0	0.0	255.5	0.0	0.0	1099.0
B	285.5	196.2	164.3	189.2	0.0	57.4	0.0
C	44.5	0.0	80.1	0.0	48.8	0.0	221.3
D	100.0	280.2	136.1	0.0	0.0	0.0	0.0
E	0.0						
5							
A	87.5	0.0	0.0	147.2	99.7	0.0	118.0
B	250.3	94.4	74.4	237.8	0.0	0.0	0.0
C	175.0	0.0	162.6	8.6	0.0	18.4	162.0
D	87.7	277.0	192.8	11.7	0.0	29.8	0.0
E	0.0						
1 (cbd)							
A	2032.5	25.2	1.7	1876.1	1196.7	0.0	2289.0
B	1020.5	1357.2	893.5	1566.9	0.0	294.2	63.6
C	804.5	238.3	491.0	116.6	282.0	264.6	1530.2
D	1186.4	1273.3	786.0	494.1	0.0	264.7	0.0
E	0.0						
2							
A	772.2	0.0	0.6	595.3	379.7	0.0	923.4
B	387.7	382.0	382.7	595.3	0.0	105.3	0.0
C	271.1	80.3	155.8	37.0	89.5	120.3	485.6
D	399.7	513.7	298.6	147.7	0.0	172.6	0.0
E	0.0						
3							
A	315.2	0.0	0.0	215.6	137.5	0.0	334.4
B	213.7	146.9	130.5	328.0	0.0	35.9	0.0
C	214.1	27.4	53.1	13.4	0.0	28.6	237.3
D	163.2	300.6	164.6	64.0	0.0	0.0	0.0
E	0.0						
26							
A	0.0	0.0	0.0	0.0	0.0	0.0	107.8
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0						
15							
A	189.5	14.2	0.9	266.3	393.4	0.0	226.7
B	0.0	65.4	69.6	108.2	0.0	156.3	35.9
C	114.2	126.6	161.4	58.3	159.1	132.4	99.6
D	0.0	105.3	0.0	278.7	0.0	0.0	0.0
E	0.0						
22							
A	81.1	15.9	0.7	121.0	168.4	0.0	0.0
B	0.0	48.0	0.0	0.0	0.0	80.1	42.6
C	58.5	98.7	61.3	45.5	110.0	116.4	64.8
D	50.3	0.0	0.0	126.7	0.0	0.0	0.0
E	0.0						

7							
A	385.7	9.8	0.1	128.4	132.3	0.0	41.8
B	26.7	45.2	33.6	58.8	0.0	71.0	22.0
C	83.8	0.0	61.2	10.8	0.0	20.4	98.6
D	97.2	42.4	37.5	16.5	0.0	17.1	0.0
E	3.0						
19							
A	21.7	2.1	0.0	16.7	29.6	0.0	0.0
B	0.0	5.2	3.9	10.4	0.0	15.9	5.6
C	0.0	33.6	0.0	12.9	0.0	23.1	0.0
D	0.0	0.0	0.0	28.3	0.0	3.0	0.0
E	0.0						
9							
A	60.6	3.6	0.2	129.6	150.6	0.0	344.8
B	22.5	30.0	30.0	49.6	0.0	44.3	9.9
C	75.0	0.0	94.0	13.8	29.6	27.8	58.0
D	98.1	35.8	0.0	94.6	0.0	19.4	0.0
E	0.0						
20							
A	8.6	2.4	0.2	7.5	0.0	0.0	0.0
B	2.9	2.5	1.7	3.4	0.0	6.7	5.8
C	4.4	12.6	4.8	13.5	32.5	24.0	5.8
D	0.0	4.5	0.0	17.2	0.0	0.0	0.0
E	0.0						
25							
A	11.0	1.0	0.0	8.5	15.0	0.0	8.6
B	0.0	4.8	2.0	0.0	0.0	8.5	2.6
C	0.0	0.0	4.8	7.0	22.7	15.8	4.3
D	0.0	0.0	0.0	19.4	0.0	0.0	0.0
E	0.0						
17							
A	139.3	0.7	0.3	11.0	13.6	0.0	0.0
B	2.4	2.3	2.3	2.9	0.0	6.8	1.9
C	3.3	9.0	3.9	10.8	60.4	26.0	5.9
D	4.0	4.1	0.0	28.3	0.0	0.0	0.0
E	0.0						
4							
A	510.0	48.6	0.0	598.4	381.7	0.0	574.4
B	466.6	361.6	285.0	563.5	15.9	83.2	108.9
C	346.4	0.0	176.6	39.5	79.8	62.5	837.6
D	611.6	618.2	359.4	287.2	0.0	136.5	0.0
E	0.0						
14							
A	73.7	2.0	0.0	116.7	100.5	0.0	105.5
B	67.4	58.9	43.7	97.5	0.0	0.0	5.0
C	80.9	0.0	59.1	0.0	0.0	395.9	184.2
D	217.4	106.9	66.0	59.5	0.0	69.5	0.0
E	6.7						
11							
A	107.1	0.0	0.0	13.6	0.0	0.0	144.4
B	35.3	13.3	6.9	24.9	1.1	16.5	0.0
C	4.9	0.0	5.8	12.6	0.0	58.8	32.8
D	62.5	102.1	63.0	3.0	0.0	22.5	0.0
E	1.7						
12							
A	9.9	0.0	0.0	6.4	0.0	0.0	91.2
B	25.2	7.9	3.0	9.2	0.0	0.0	0.0
C	3.3	0.0	0.0	0.0	0.0	0.0	20.7
D	44.5	45.0	77.0	0.0	0.0	1.6	0.0
E	0.0						

10							
A	7.5	10.0	0.0	11.8	38.2	0.0	0.0
B	4.2	4.7	7.6	18.0	0.0	33.1	25.2
C	21.4	30.2	36.3	70.3	45.4	22.0	36.1
D	24.9	11.5	0.0	145.0	0.0	14.5	0.0
E	0.0						
27							
A	0.0	0.0	0.0	7.8	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	5.7	0.0	217.2	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0						
13							
A	8.4	0.0	0.0	49.6	0.0	0.0	0.0
B	10.3	28.3	8.5	0.0	0.0	0.0	0.0
C	22.6	54.7	7.1	0.0	0.0	0.0	17.5
D	42.4	42.8	42.7	10.9	0.0	68.5	0.0
E	4.6						
28							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	5.7	0.0	22.1	0.0
D	0.0	0.0	0.0	2.1	0.0	22.1	0.0
E	0.0						
29							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	18.0	0.0	0.0	0.0	0.0	0.0	0.0
D	23.5	69.9	106.1	0.0	0.0	9.5	0.0
E	0.0						

Total person trips= 79101

APPENDIX C.2

COMPUTER RESULTS OF SIMULATED DISTRICT INTERCHANGES: PERSON TRIPS

Row A Labels

Position 1: 18
 Position 2: 23
 Position 3: 24
 Position 4: 6
 Position 5: 8
 Position 6: 71
 Position 7: 16

Row B Labels

Position 1: 5
 Position 2: 1(cbs)
 Position 3: 2
 Position 4: 3
 Position 5: 26
 Position 6: 15
 Position 7: 22

Row C Labels

Position 1: 7
 Position 2: 19
 Position 3: 9
 Position 4: 20
 Position 5: 25
 Position 6: 17
 Position 7: 4

Row D Labels

Position 1: 14
 Position 2: 11
 Position 3: 12
 Position 4: 10
 Position 5: 27
 Position 6: 13
 Position 7: 28

Row E Labels

Position 1: 29

18

A	5980.8	72.0	0.8	803.8	500.4	131.5	2318.8
B	504.2	554.8	375.4	668.0	0.0	124.0	28.4
C	314.4	75.4	205.6	122.0	254.7	260.6	536.4
D	1301.5	508.4	692.1	547.5	0.0	259.2	0.0
E	0.0						

23

A	71.8	87.7	0.8	88.8	128.0	125.9	64.4
B	36.6	42.8	25.7	45.7	0.0	54.4	32.6
C	44.1	60.3	39.0	92.0	191.9	235.0	46.6
D	162.1	41.6	56.6	158.0	0.0	28.6	0.0
E	0.0						

24

A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0						

6

A	856.3	95.0	1.1	1059.6	700.4	184.0	816.5
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B	436.7	541.8	325.1	544.9	0.0	173.5	39.8
C	414.4	112.1	287.8	170.8	378.6	364.7	556.2
D	1615.8	496.5	675.9	766.4	0.0	285.4	0.0
E	0.0						
8							
A	124.3	30.1	0.4	153.8	221.8	61.9	111.6
B	63.4	78.7	47.2	79.1	0.0	55.0	12.6
C	81.2	35.5	71.7	57.4	119.9	122.6	85.7
D	280.8	72.1	98.1	228.6	0.0	49.6	0.0
E	0.0						
21							
A	75.6	57.2	0.9	93.6	135.0	149.7	67.9
B	38.6	47.9	28.7	48.1	0.0	54.0	28.7
C	49.4	80.8	43.6	116.1	228.1	233.3	52.2
D	170.9	46.6	59.7	176.8	0.0	30.2	0.0
E	0.0						
16							
A	988.2	23.0	0.3	272.8	169.9	44.6	4484.4
B	231.0	225.5	162.0	306.1	0.0	42.1	9.1
C	106.7	25.6	65.7	39.0	86.5	88.4	218.0
D	498.1	232.9	317.1	185.9	0.0	105.3	0.0
E	0.0						
5							
A	362.7	23.4	0.3	261.6	172.9	45.4	414.1
B	544.7	229.5	164.9	446.6	0.0	40.3	9.3
C	115.3	26.7	75.4	42.2	88.0	90.0	318.0
D	726.8	549.3	794.0	200.9	0.0	207.4	0.0
E	0.0						
1(cbd)							
A	2270.6	165.4	2.0	1960.2	1220.3	320.6	2441.3
B	1305.5	1619.8	972.0	1629.0	0.0	302.3	65.3
C	814.0	183.9	501.5	280.3	621.2	635.4	1566.0
D	3800.1	1397.8	1903.0	1335.2	0.0	756.7	0.0
E	0.1						
2							
A	754.6	48.8	0.6	577.7	359.7	94.5	861.5
B	460.7	477.4	343.0	610.4	0.0	83.9	19.3
C	239.9	54.2	147.8	87.7	183.1	187.3	520.4
D	1262.9	493.3	671.5	417.9	0.0	251.5	0.0
E	0.0						
3							
A	389.8	22.3	0.3	264.7	164.8	43.3	445.1
B	341.2	232.3	166.9	452.0	0.0	40.8	9.4
C	109.9	24.8	67.7	40.2	83.9	85.8	285.5
D	652.5	365.3	497.3	191.5	0.0	165.2	0.0
E	0.0						
26							
A	16.2	0.4	0.0	4.7	3.0	0.7	99.2
B	3.8	3.9	2.7	5.3	0.0	0.7	0.2
C	1.9	0.4	1.1	0.7	1.5	2.2	3.8
D	8.7	3.8	5.2	3.0	0.0	1.8	0.0
E	0.0						
15							
A	198.4	82.4	1.0	260.7	375.9	169.5	189.2
B	107.4	125.5	75.3	134.0	0.0	150.5	36.7
C	129.6	97.2	121.5	148.2	348.7	316.3	136.8
D	475.9	122.1	166.3	463.7	0.0	84.0	0.0
E	0.0						
22							

A	56.2	54.1	0.6	69.6	100.3	104.8	50.5
B	28.7	35.6	21.3	35.8	0.0	40.2	24.1
C	36.7	47.3	32.4	72.1	159.7	163.3	38.8
D	127.0	32.6	44.4	123.8	0.0	22.4	0.0
E	0.0						
7							
A	108.5	15.3	0.2	134.3	119.8	31.5	103.5
B	62.4	72.9	43.7	73.3	0.0	28.0	6.4
C	84.9	19.2	58.9	35.0	68.8	66.2	89.6
D	311.6	75.3	108.9	166.6	0.0	55.0	0.0
E	0.0						
19							
A	9.4	6.3	0.1	11.6	16.7	16.4	8.4
B	4.8	5.9	3.6	6.0	0.0	6.7	2.8
C	6.1	10.0	5.7	16.2	33.8	28.9	6.5
D	21.1	5.4	7.4	23.2	0.0	4.0	0.0
E	0.0						
9							
A	110.4	19.8	0.3	136.6	155.0	45.9	99.1
B	59.8	69.9	41.9	74.6	0.0	40.8	9.4
C	86.3	29.7	96.9	57.5	113.1	96.6	91.2
D	379.6	76.6	110.8	291.0	0.0	67.0	0.0
E	0.0						
20							
A	29.9	20.1	0.4	37.0	53.4	52.5	26.9
B	15.3	17.8	11.4	19.0	0.0	22.7	8.9
C	19.6	32.0	20.7	171.9	129.4	178.7	20.6
D	81.0	18.4	25.1	100.3	0.0	15.2	0.0
E	0.0						
25							
A	30.8	20.7	0.3	40.5	58.4	51.0	29.4
B	15.7	19.5	11.7	20.8	0.0	23.4	9.8
C	20.1	35.0	22.6	63.9	150.3	101.0	21.3
D	83.4	19.0	25.8	109.7	0.0	15.6	0.0
E	0.0						
17							
A	18.4	14.7	0.2	24.1	34.8	32.2	17.5
B	9.4	11.6	7.0	11.7	0.0	13.1	6.2
C	12.7	17.4	11.9	51.3	62.4	166.8	13.4
D	49.7	11.3	15.4	57.9	0.0	9.3	0.0
E	0.0						
4							
A	581.0	47.7	0.6	532.6	373.8	98.2	624.6
B	508.4	414.5	280.4	562.6	0.0	87.2	20.0
C	281.2	59.8	183.9	102.8	214.6	206.7	647.5
D	1668.5	613.8	835.6	489.7	0.0	352.8	0.0
E	0.0						
14							
A	236.4	27.8	0.4	259.4	218.0	64.6	239.3
B	194.8	168.6	114.1	215.6	0.0	54.0	12.4
C	154.4	39.3	128.4	76.2	149.8	144.3	263.4
D	1394.5	249.7	360.9	434.6	0.0	246.3	0.0
E	0.0						
11							
A	182.9	13.3	0.2	157.9	98.3	27.4	208.8
B	274.6	130.5	88.3	225.1	0.0	24.3	5.6
C	69.6	15.7	48.4	27.0	53.1	54.3	191.9
D	494.6	535.7	822.3	128.7	0.0	141.2	0.0
E	0.0						

12							
A	242.8	17.7	0.2	197.4	130.5	34.3	261.1
B	387.2	163.1	117.2	298.9	0.0	32.3	7.0
C	92.4	20.9	64.2	35.9	70.5	72.2	240.0
D	656.7	755.4	2112.7	171.0	0.0	211.3	0.0
E	0.0						
10							
A	183.7	47.2	0.7	227.3	308.7	116.3	165.0
B	99.5	116.2	69.8	124.1	0.0	97.2	22.3
C	143.7	70.8	171.3	174.4	322.9	311.0	151.7
D	756.2	127.5	184.3	1121.5	0.0	133.6	0.0
E	0.0						
27							
A	66.2	2.6	0.0	7.9	8.4	5.4	67.0
B	7.5	4.8	3.3	7.4	0.0	2.8	1.1
C	4.2	3.1	3.9	11.0	11.9	51.4	6.7
D	27.9	11.6	25.4	22.7	0.0	9.5	0.0
E	0.0						
13							
A	45.6	4.5	0.1	41.8	35.1	9.8	49.0
B	50.7	30.6	22.0	49.8	0.0	8.7	2.0
C	24.9	6.0	20.7	12.3	24.1	23.3	54.0
D	238.7	69.1	106.0	74.4	0.0	81.6	0.0
E	0.0						
28							
A	3.3	0.7	0.0	3.6	4.3	1.5	3.3
B	2.4	2.1	1.4	2.7	0.0	1.3	0.3
C	2.3	0.9	2.1	2.3	3.8	4.6	3.2
D	15.2	3.1	4.7	11.7	0.0	4.1	0.0
E	0.0						
29							
A	15.1	1.2	0.0	13.1	9.7	2.6	17.3
B	21.4	10.8	7.3	18.6	0.0	2.3	0.5
C	6.9	1.6	4.8	2.7	5.3	5.4	16.9
D	49.0	34.9	91.9	12.8	0.0	15.8	0.0
E	0.0						

Total person trips = 139152.3

APPENDIX C.3

COMPUTER RESULTS OF SIMULATED PERSON TRIP INTERCHANGES: SCENARIO A

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	95.1	0.8	136.5	1505.7	35.4	65.5	99.4
B	208.5						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	62.1	0.9	162.4	1597.2	31.1	87.8	125.5
B	247.9						
100							
A	760.5	9.4	1535.2	122304.8	316.7	902.5	1542.0
B	3208.0						
22							
A	53.3	0.6	103.3	1059.3	23.7	46.6	70.8
B	157.7						
19							
A	6.2	0.1	16.2	181.2	2.8	9.9	15.9
B	35.4						
20							
A	21.8	0.5	57.1	784.6	9.7	34.8	186.3
B	9						
25							
A	22.4	0.3	55.3	735.7	10.6	38.0	69.1
B	163.3						

COMPUTER RESULTS OF SIMULATED PERSON TRIP INTERCHANGES: SCENARIO B

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	98.8	0.9	141.8	1574.4	36.7	68.0	103.1
B	216.7						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	64.5	1.0	168.5	1669.2	32.3	91.2	130.1
B	257.5						
100							
A	753.1	9.3	1520.2	122095.4	313.6	894.1	1525.0
B	3179.4						
22							
A	52.9	0.6	102.6	1059.1	23.6	46.3	70.2
B	156.7						
19							
A	6.2	0.1	16.1	181.2	2.7	9.8	15.8
B	33.2						
20							
A	22.7	0.5	59.3	820.2	10.1	36.2	193.3
B	146.5						
25							
A	23.3	0.3	57.4	769.1	11.0	39.5	71.6
B	169.7						

COMPUTER RESULTS OF SIMULATED PERSON TRIP INTERCHANGES: SCENARIO C

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	102.4	0.9	146.9	1642.3	38.0	70.5	106.7
B	224.7						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	66.8	1.0	174.7	1741.9	33.5	94.5	134.7
B	267.1						
100							
A	745.9	9.2	1505.5	121836.0	310.5	885.8	1508.2
B	3151.1						
22							
A	52.6	0.6	101.6	1058.8	23.4	46.0	69.6
B	155.7						
19							
A	6.1	0.1	16.0	181.2	2.7	9.7	15.7
B	33.0						
20							
A	23.5	0.5	61.5	855.8	10.5	37.5	200.2
B	152.1						
25							
A	24.2	0.4	59.5	802.5	11.4	40.9	74.1
B	176.0						

COMPUTER RESULTS OF SIMULATED PERSON TRIP INTERCHANGES: SCENARIO D

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	106.6	0.9	153.3	1710.7	39.6	73.7	112.9
B	235.6						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	69.5	1.0	182.2	1813.7	34.9	98.8	142.4
B	280.0						
100							
A	747.1	9.2	1511.5	122023.6	311.2	891.1	1535.3
B	3179.2						
22							
A	52.5	0.6	102.0	1058.8	23.4	46.2	70.7
B	156.8						
19							
A	6.1	0.1	16.0	181.1	2.7	9.8	15.9
B	33.2						
20							
A	19.6	0.4	51.3	712.3	8.7	31.3	169.2
B	127.3						
25							
A	20.1	0.3	49.6	668.3	9.5	34.2	62.7
B	147.6						

APPENDIX C.4

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO A1

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	26.1	0.1	33.6	0.0	10.0	12.7	16.8
B	40.9						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	18.5	0.1	48.1	0.0	8.7	19.9	26.2
B	58.8						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.4	0.0	19.3	0.0	6.4	7.8	10.0
B	26.5						
19							
A	1.2	0.0	3.0	0.0	0.6	2.0	2.5
B	7.5						
20							
A	4.8	0.0	12.7	0.0	2.2	7.2	49.6
B	33.5						
25							
A	5.2	0.0	12.7	0.0	2.6	10.0	14.9
B	48.7						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO A2

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	26.8	0.1	34.7	0.0	10.2	13.2	18.7
B	42.6						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	19.1	0.1	49.6	0.0	8.9	20.6	28.9
B	60.8						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.6	0.0	19.8	0.0	6.4	8.1	11.1
B	27.5						
19							
A	1.2	0.0	3.1	0.0	0.6	2.0	2.7
B	7.7						
20							
A	5.3	0.0	14.0	0.0	2.4	7.8	56.5
B	36.4						
25							
A	5.4	0.0	13.1	0.0	2.7	10.3	16.2
B	49.9						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO A3

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	28.2	0.1	36.6	0.0	10.7	13.8	19.7
B	45.0						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	20.0	0.1	51.7	0.0	9.3	21.6	30.3
B	63.9						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	13.3	0.0	20.9	0.0	6.7	8.5	11.7
B	28.9						
19							
A	1.3	0.0	3.3	0.0	0.6	2.1	2.9
B	8.1						
20							
A	5.6	0.0	14.7	0.0	2.6	8.2	59.0
B	38.3						
25							
A	5.7	0.0	13.8	0.0	2.8	10.8	17.0
B	52.3						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO B1

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	27.1	0.1	34.9	0.0	10.4	13.2	17.4
B	42.5						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	19.2	0.1	49.9	0.0	9.0	20.6	27.1
B	61.1						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.4	0.0	19.2	0.0	6.3	7.7	9.9
B	26.3						
19							
A	1.2	0.0	3.0	0.0	0.6	1.9	2.5
B	7.5						
20							
A	5.0	0.0	13.2	0.0	2.3	7.4	51.4
B	34.9						
25							
A	5.4	0.0	13.2	0.0	2.7	10.4	15.5
B	50.6						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO B2

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	28.7	0.1	37.1	0.0	10.7	14.3	21.5
B	46.2						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	20.4	0.1	52.7	0.0	9.5	22.1	33.1
B	65.5						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.8	0.0	20.3	0.0	6.4	8.3	12.2
B	28.5						
19							
A	1.3	0.0	3.2	0.0	0.6	2.1	2.9
B	7.8						
20							
A	6.2	0.0	16.1	0.0	2.8	8.8	66.4
B	41.1						
25							
A	5.9	0.0	14.1	0.0	2.9	10.9	18.2
B	53.1						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO B3

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	30.0	0.1	39.1	0.0	11.2	15.0	22.7
B	48.7						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	21.3	0.1	55.3	0.0	9.9	23.3	34.7
B	68.7						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	13.4	0.0	21.3	0.0	6.7	8.8	13.0
B	30.1						
19							
A	1.4	0.0	3.4	0.0	0.6	2.2	3.1
B	8.3						
20							
A	6.5	0.0	16.8	0.0	2.9	9.3	69.4
B	43.1						
25							
A	6.2	0.0	14.8	0.0	3.0	11.5	19.1
B	55.4						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO C1

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	28.1	0.1	36.2	0.0	10.8	13.6	18.0
B	44.1						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	19.9	0.1	51.7	0.0	9.3	21.4	28.1
B	63.4						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.3	0.0	19.0	0.0	6.3	7.7	9.8
B	26.2						
19							
A	1.2	0.0	2.9	0.0	0.6	1.9	2.5
B	7.4						
20							
A	5.2	0.0	13.7	0.0	2.4	7.7	53.3
B	36.2						
25							
A	5.6	0.0	13.7	0.0	2.8	10.8	16.0
B	52.5						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO C2

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	32.6	0.1	48.0	0.0	12.1	16.7	31.0
B	64.1						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	25.9	0.1	70.9	0.0	12.2	28.6	50.0
B	100.7						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	13.0	0.0	24.2	0.0	6.4	8.3	15.3
B	33.5						
19							
A	1.4	0.0	3.7	0.0	0.6	2.1	3.4
B	8.5						
20							
A	8.2	0.0	22.9	0.0	3.6	10.5	77.9
B	52.8						
25							
A	7.1	0.0	19.3	0.0	3.3	11.5	22.0
B	59.8						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO 23

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	34.2	0.1	50.3	0.0	12.6	17.6	32.5
B	67.2						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	27.0	0.1	73.9	0.0	1.8	30.0	52.1
B	104.7						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	13.6	0.0	25.4	0.0	6.7	8.8	16.1
B	35.4						
19							
A	1.4	0.0	3.9	0.0	0.6	2.2	3.5
B	8.9						
20							
A	8.5	0.0	23.8	0.0	3.7	11.0	81.3
B	55.1						
25							
A	7.4	0.0	20.1	0.0	3.4	12.0	23.0
B	62.6						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO D1

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	29.3	0.1	37.7	0.0	11.2	14.3	19.0
B	46.2						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	20.7	0.1	54.0	0.0	9.7	22.4	29.7
B	66.4						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.3	0.0	19.1	0.0	6.3	7.7	10.0
B	26.3						
19							
A	1.2	0.0	2.9	0.0	0.6	1.9	2.5
B	7.5						
20							
A	4.3	0.0	11.4	0.0	2.0	6.4	45.0
B	30.3						
25							
A	4.7	0.0	11.4	0.0	2.3	9.0	13.5
B	44.0						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO D2

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	31.0	0.1	40.1	0.0	11.6	15.4	21.2
B	50.2						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	22.0	0.1	57.0	0.0	10.2	24.0	32.4
B	71.2						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.7	0.0	20.2	0.0	6.3	8.3	11.1
B	28.5						
19							
A	1.3	0.0	3.2	0.0	0.6	2.1	2.6
B	7.8						
20							
A	4.8	0.0	12.4	0.0	2.2	6.8	46.5
B	31.7						
25							
A	5.1	0.0	12.2	0.0	2.5	9.5	14.1
B	46.2						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO D3

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	30.2	0.1	39.6	0.0	11.4	15.7	19.2
B	51.2						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	21.7	0.1	55.3	0.0	10.1	25.0	29.9
B	75.5						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.5	0.0	19.9	0.0	6.3	8.0	10.0
B	27.2						
19							
A	1.3	0.0	3.3	0.0	0.6	2.0	2.6
B	7.7						
20							
A	4.3	0.0	11.5	0.0	2.0	6.7	45.0
B	31.0						
25							
A	5.2	0.0	12.9	0.0	2.4	9.3	13.8
B	44.8						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO D4

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	32.0	0.1	41.9	0.0	11.8	16.8	21.4
B	55.0						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	22.8	0.1	57.7	0.0	10.7	26.4	32.7
B	80.2						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	12.9	0.0	21.1	0.0	6.3	8.6	11.1
B	29.2						
19							
A	1.4	0.0	3.5	0.0	0.6	2.1	2.7
B	8.0						
20							
A	4.8	0.0	12.6	0.0	2.2	7.1	46.5
B	32.6						
25							
A	5.5	0.0	13.7	0.0	2.6	9.7	14.5
B	46.7						

COMPUTER RESULTS OF SIMULATED TRANSIT TRIP INTERCHANGES: SCENARIO D5

Row A Labels

Position 1: 23
 Position 2: 24
 Position 3: 21
 Position 4: 100
 Position 5: 22
 Position 6: 19
 Position 7: 20

Row B Labels

Position 1: 25

23							
A	33.4	0.1	43.9	0.0	12.4	17.6	22.5
B	57.8						
24							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
21							
A	23.8	0.1	60.5	0.0	11.1	27.7	34.3
B	84.3						
100							
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B	0.0						
22							
A	13.6	0.0	22.2	0.0	6.7	9.1	11.7
B	30.7						
19							
A	1.5	0.0	3.7	0.0	0.7	2.2	2.9
B	8.4						
20							
A	5.0	0.0	13.1	0.0	2.3	7.4	48.6
B	34.1						
25							
A	5.8	0.0	14.4	0.0	2.7	10.1	15.2
B	48.7						

APPENDIX D

Program List for Calculation of Travel Distance in 2011

- D.1. Program list and resulting automobile distance table of the 29-district system for the 2011 scenarios**

APPENDIX D.1

```
10 DIM Z(258),ZN(29),ZZ$(29),TMP1(30),TMP2(30),MTIM(29,29),PH$(52)
20 L=0
30 FOR I=1 TO 29
40 READ ZZ$(I),ZN(I)
50 FOR J=1 TO ZN(I)
60 L=L+1
70 READ Z(L)
80 NEXT J
90 NEXT I
100 B=0:L=0
110 FOR I=1 TO 29
120 FOR K=1 TO ZN(I)
130 L=L+1
140 TMP1(K)=Z(L)
150 NEXT K
160 LL=0
170 FOR J=1 TO 29
180 FOR K=1 TO ZN(J)
190 LL=LL+1
200 TMP2(K)=Z(LL)
210 NEXT K
220 IF I=J AND I=19 THEN MTIM(I,J)=1.03:GOTO 540
230 IF I=J AND I=22 THEN MTIM(I,J)=1.46:GOTO 540
240 FOR M=1 TO ZN(I)
250 S=TMP1(M)
260 OPEN "PMPKDIST.TXT" FOR INPUT AS #1
270 INPUT #1,D$,DD$
280 IF S=1 GOTO 320
290 FOR F=1 TO (S-1)*52
300 INPUT #1,C$
310 NEXT F
320 FOR F=1 TO 52
330 INPUT #1,PH$(F)
340 NEXT F
350 CLOSE
360 FOR N=1 TO ZN(J)
370 IF TMP1(M)=TMP2(N) GOTO 510
380 FOR NN=1 TO 52
390 V=LEN(PH$(NN))
400 FOR Q=1 TO V
410 IF MID$(PH$(NN),Q,1)<>"." GOTO 490
```

```

420 R$=MID$(PH$(NN),Q-3,3)
430 RR=VAL(R$)
440 IF RR<TMP2(N) GOTO 490
450 X$=MID$(PH$(NN),Q+1,5)
460 XX=VAL(X$)
470 B=B+XX
480 GOTO 510
490 NEXT Q
500 NEXT NN
510 NEXT N
520 NEXT M
530 IF I=J THEN MTIM(I,J)=.75*B/(ZN(I)*(ZN(J)-1)) ELSE MTIM(I,J)=
    B/(ZN(I)*ZN(J))
540 B=0
550 NEXT J
560 NEXT I
570 OPEN "AVGDIST.TXT" FOR OUTPUT AS #1
580 FOR I=1 TO 28
590 FOR J=I+1 TO 29
600 PRINT #1, I;" ";J;
610 PRINT #1, TAB(33);MTIM(I,J);TAB(44);MTIM(J,I)
620 NEXT J
630 NEXT I
640 CLOSE
650 OPEN "INTRADIS.TXT" FOR OUTPUT AS #2
660 FOR I=1 TO 29
670 PRINT #2,I;" ";I;MTIM(I,I)
680 NEXT I
690 CLOSE
700 OPEN "NOLBLDIS.TXT" FOR OUTPUT AS #2
710 FOR I=1 TO 29
720 FOR J=1 TO 29
730 PRINT #2, MTIM(I,J)
740 NEXT J
750 NEXT I
760 CLOSE
770 DATA "1",14,1,2,3,11,12,13,14,15,16,17,18,19,20,21
780 DATA "2",12,4,5,6,7,8,9,10,22,23,24,25,201
790 DATA "3",10,90,91,92,93,94,95,96,97,98,100
800 DATA "4",22,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89
810 DATA "5",10,99,101,102,103,104,105,106,107,108,109
820 DATA "6",22,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,57,58
830 DATA "7",9,59,60,61,62,63,64,65,66,67
840 DATA "8",11,46,47,48,49,50,51,52,53,54,55,56

```


850 DATA "9",5,120,121,122,123,124
860 DATA "10",10,135,136,137,138,221,222,223,224,225,226
870 DATA "11",11,110,142,143,202,204,234,235,236,237,246,247
880 DATA "12",10,144,145,203,238,239,240,241,242,243,244
890 DATA "13",5,139,141,230,231,245
900 DATA "14",16,111,112,113,114,115,116,117,118,119,140,205,227,228,229,232,233
910 DATA "15",4,125,126,127,128
920 DATA "16", 27, 156, 157, 162, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174,
175,176,177,178,179,180,181,185,248,249,250,251,252,253
930 DATA "17",3,132,133,134
940 DATA "18", 26, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 158, 159, 160,
161,163,164,182,183,184,186,187,254,255,256,257,258
950 DATA "19",1,130
960 DATA "20",4,216,217,218,219
970 DATA "21",3,206,210,211
980 DATA "22",1,131
990 DATA "23",3,207,208,209
1000 DATA "24",4,212,213,214,215
1010 DATA "25",2,129,220
1020 DATA "26",2,188,189
1030 DATA "27",4,190,191,193,194
1040 DATA "28",5,192,195,196,197,200
1050 DATA "29",2,198,199
1060 END

Inter-district travel distances in 2011

A : B	A --> B	B --> A
1 : 19	21.48286	21.49714
1 : 20	29.7825	30.235
1 : 21	22.46405	22.4031
1 : 22	21.56071	21.13714
1 : 23	21.98476	22.63857
1 : 24	25.2325	24.98179
1 : 25	22.97357	22.6625
2 : 19	23.14667	23.27917
2 : 20	31.53396	31.87646
2 : 21	24.2475	24.22833
2 : 22	23.4175	22.97417
2 : 23	23.87861	24.47639
2 : 24	27.03625	26.815
2 : 25	24.78125	24.35291
3 : 19	26.753	26.653
3 : 20	35.3795	35.47376
3 : 21	27.748	27.58167
3 : 22	26.851	26.326
3 : 23	27.27767	27.86667
3 : 24	30.481	30.1715
3 : 25	28.528	27.8185
4 : 19	24.28682	24.42182
4 : 20	32.53103	32.47568
4 : 21	25.86031	25.60697
4 : 22	25.38137	24.44091
4 : 23	26.05288	26.2344
4 : 24	28.74125	28.23432
4 : 25	26.35478	25.27796
5 : 19	31.814	30.279
5 : 20	42.54501	40.02725
5 : 21	32.309	31.20934
5 : 22	31.04	29.954
5 : 23	31.48533	31.48133
5 : 24	34.86025	33.8015
5 : 25	35.44299	32.093
6 : 19	16.85455	16.82227
6 : 20	25.06011	25.52352
6 : 21	17.91364	17.7744
6 : 22	17.06091	16.52182
6 : 23	17.50864	17.75833
6 : 24	20.70568	20.36295
6 : 25	18.31023	17.90364
7 : 19	16.27222	16.69778
7 : 20	23.9975	24.19667
7 : 21	18.00111	17.96037
7 : 22	17.70333	16.80334
7 : 23	18.45222	18.85074
7 : 24	20.92111	20.60416
7 : 25	17.93611	17.23111
8 : 19	10.86364	10.83109
8 : 20	18.90295	19.29387
8 : 21	12.16212	12.09603
8 : 22	11.58273	10.93673
8 : 23	12.25145	12.54724
8 : 24	15.01545	14.75932
8 : 25	12.15909	11.72073
9 : 19	15.768	15.526

9 : 20	21.0635	20.4745
9 : 21	17.88933	18.11467
9 : 22	17.874	17.212
9 : 23	19.336	19.50133
9 : 24	20.8225	21.0035
9 : 25	16.143	16.241
10 : 19	20.331	19.041
10 : 20	20.3815	20.29875
10 : 21	21.74567	21.79134
10 : 22	22.521	21.428
10 : 23	24.115	23.74667
10 : 24	23.27701	24.6035
10 : 25	16.16495	16.14615
11 : 19	37.25818	35.91546
11 : 20	46.03318	44.72159
11 : 21	38.39182	36.72637
11 : 22	37.29909	35.31364
11 : 23	37.62606	36.86879
11 : 24	40.96387	39.36386
11 : 25	39.53864	37.70863
12 : 19	43.841	43.471
12 : 20	52.09825	51.587
12 : 21	45.21733	44.53333
12 : 22	44.257	43.064
12 : 23	44.706	44.50167
12 : 24	47.904	47.21651
12 : 25	45.80551	44.9155
13 : 19	36.488	36.22
13 : 20	41.6055	41.713
13 : 21	38.326	38.29134
13 : 22	38.296	37.348
13 : 23	39.18267	39.60933
13 : 24	40.877	41.1015
13 : 25	36.413	36.609
14 : 19	25.40188	25.65625
14 : 20	30.70219	30.91063
14 : 21	27.31812	27.66813
14 : 22	27.29063	26.70063
14 : 23	28.21229	28.92063
14 : 24	30.02266	30.41437
14 : 25	25.46281	25.98187
15 : 19	7.5075	7.4295
15 : 20	15.4325	15.66563
15 : 21	8.580668	8.805166
15 : 22	7.9345	7.6525
15 : 23	8.973251	9.083167
15 : 24	11.64781	11.55219
15 : 25	8.959999	8.8575
16 : 19	37.67259	38.91185
16 : 20	46.06509	47.65047
16 : 21	38.60001	39.81863
16 : 22	37.71704	38.55185
16 : 23	38.15716	39.87481
16 : 24	41.41695	42.39825
16 : 25	39.19501	40.07945
17 : 19	17.41333	17.50333
17 : 20	17.0225	17.18667
17 : 21	17.85511	17.86311
17 : 22	18.94367	18.67367
17 : 23	18.76667	18.93856
17 : 24	17.74667	17.68583
17 : 25	18.66333	18.67

18 : 19	42.36962	43.80192
18 : 20	50.68163	52.53577
18 : 21	43.30552	44.70308
18 : 22	42.41116	43.43885
18 : 23	42.74847	44.52526
18 : 24	46.11404	47.28384
18 : 25	43.82923	44.96461
18 : 26	165.8038	166.9654
18 : 27	207.2757	207.9263
18 : 28	120.1728	121.1079
18 : 29	92.60599	94.40979
19 : 20	8.424249	7.940501
19 : 21	3.143334	3.213333
19 : 22	5.057	4.504
19 : 23	6.662333	6.911334
19 : 24	5.1695	5.0775
19 : 25	3.408	3.4525
19 : 26	168.8	168.2
19 : 27	165.93	165.68
19 : 28	98.65	98.49199
19 : 29	87.00999	88.00999
20 : 21	10.52425	10.50433
20 : 22	13.8425	13.17
20 : 23	14.39583	14.4175
20 : 24	9.752562	9.602625
20 : 25	8.306	8.76775
20 : 26	177.525	176.575
20 : 27	162.6831	162.2475
20 : 28	99.55099	99.49751
20 : 29	95.35	96.67125
21 : 22	3.112	2.853333
21 : 23	5.304777	5.446333
21 : 24	4.964166	4.810834
21 : 25	6.301834	6.212167
21 : 26	169.7	169.15
21 : 27	166.675	166.0367
21 : 28	101.2987	99.94334
21 : 29	88.03668	89.28167
22 : 23	3.138	2.770667
22 : 24	6.65125	6.859501
22 : 25	6.369	6.8945
22 : 26	168.4	168.3
22 : 27	168.9925	168.845
22 : 28	101.04	100.93
22 : 29	86.815	88.51
23 : 24	7.9415	7.72
23 : 25	8.981667	8.579168
23 : 26	169.7667	168.6833
23 : 27	170.2692	169.405
23 : 28	103.3493	101.9873
23 : 29	88.54666	89.09668
24 : 25	8.584625	8.609501
24 : 26	172.2875	171.95
24 : 27	165.2169	164.6775
24 : 28	103.1655	101.2165
24 : 29	90.6825	91.92
25 : 26	170	169.7
25 : 27	168.6675	168.275
25 : 28	97.10701	97.061
25 : 29	88.36	90.22

APPENDIX E

Assumed Bus Itineraries in 2011

- E.1 Route itineraries taken by express buses serving between Kanata and the rest of the Region**

APPENDIX E.1

From Dist.	Centroid Location in the District	Bus Itinerary
1	Transitway station: Bank & Slater	Kakulu-Transitway-CBD
2	Middle point between Ottawa U. & Carleton U.	Ottawa U: Kakulu-Transitway-Campus Carleton U: Kakulu-Robertson- Baseline-Billings Bridge-Bronson- Campus
3	St. Laurant Shopping centre	Kakulu-Transitway-St.Laurant shopping centre
4	General Hospital	Kakulu-Robertson-Billings Bridge-Riverside Dr.- hospital
5	N.R.C.	Kakulu-Transitway-Blair station-N.R.C.
6	Ottawa Royal Hospital	Kakulu-Transitway-Queensway-Carling Ave.- hospital
7	Merivale Industrial Park	Kakulu-Transitway South-Meadowsland- Viewmont
8	Pine Crest	Kakulu-Transitway-pine crest
9	Industrial Land (close to Rideau River)	Kakulu- Robertson- Baseline- Transitway south- Vaan-Slack-Merivale Rd.-Bently
10	Baarhaven Mall	Kakulu-Transitway-transitway south-Fallow field- Baarhaven Mall
11	Orleans Complex	Kakulu-Transitway-Queensway east-Orlean
12	Industrial Land	Kakulu-Transitway-Queensway east-Place d'Orlean- Dudroff
13	Leitrim (Arena)	Kakulu-Terry fox-Baseline-Walkley Rd.- Bank st.- Conroy
14	C.F.B.	Kakulu-Terry fox-Robertson-Baseline-Heron- Transitway south- C.F.B.
15	K-Mart Mall	Kakulu-Robertson- K Mart
16	Gatineau	Kakulu-Transitway-Lebreton station-bridge- Gatineau
18	Place du Portage	Kakulu-Transitway-Lebreton station-bridge- Place du portage

NOTES:

- Above itineraries are based on trip ends located in district 19. Trips from districts 20 and 25 have the following trip end locations:
District 20: Abbott Rd. & Main St. South in Stittsville
District 25: Stonehaven & Eagleson intersection
- Trips from district 2 take the following route to district 20: Kakulu-Hazeldean Mall- Robertson- Baseline-Billings Bridge-Bronson- Campus

Itineraries for Transit Trips From Districts 19,20,and 25 To Districts Outside Kanata

From Dist.	Centroid Location in the District	Bus Itinerary
1	Transitway station: Bank & Slater	KTC-Transitway-CBD
2	Middle point between Ottawa U. & Carleton U.	Ottawa U: KTC-Transitway-Campus Carleton U: KTC-Transitway South- Baseline- Billings Bridge-Bronson- Campus
3	St. Laurant Shopping centre	KTC-Transitway-St.Laurant shopping centre
4	General Hospital	KTC-Hurdman station-Smyth Station-hosp.
5	N.R.C.	KTC-Transitway-Blair station-N.R.C.
6	Ottawa Royal Hospital	KTC-Transitway-Queensway-Carling Ave.- hospital
7	Merivale Industrial Park	KTC-Transitway South-Meadowsland-Viewmont
8	Pine Crest	KTC-Transitway-pine crest
9	Industrial Land (close to Rideau River)	KTC-Transitway-transitway south-Vaan-Slack- Merivale Rd.-Bently
10	Baarhaven Mall	KTC-Transitway-transitway south-Fallow field- Baarhaven Mall
11	Orleans Complex	KTC-Transitway-Queensway east-Orlean
12	Industrial Land	KTC-Transitway-Queensway east-Place d'Orlean- Dudroff
13	Leitrim (Arena)	KTC-Terry fox-Baseline-Walkley Rd.- Bank st.- Conroy
14	C.F.B.	KTC-Terry fox-Robertson-Baseline-Heron- Transitway south- C.F.B.
15	K-Mart Mall	KTC-Moodie & Queensway- K Mart
16	Gatineau	KTC-Transitway-Lebreton station-bridge- Gatineau
18	Place du Portage	KTC-Transitway-Lebreton station-bridge- Place du portage

NOTES:

- KTC stands for Kanata Town Centre
- Above itineraries are based on trip ends located in district 21. Trips from districts 22,23 and 24 have the following trip end locations:
District 22: Leacock & Beaverbrook intersection
District 23: March & Allenby intersection
District 24: Middle point between Queensway and Richardson Rd. on the Huntmar
- For district 23, routes to districts 13 and 14 are as follows:
Dist. 13: Teron- Transitway-Baseline-Walkley station-Bank St.- Conroy
Dist. 14: Teron- Transitway-Baseline-Heron station- Transitway South to C.F.B.

Itineraries for Transit Trips From Districts 21,22,23 and 24 To Districts Outside Kanata

END

1 0-1 1-94

FIN