Effects of Neighborhood Characteristics on Sustainable Transportation Alternatives

by

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DEDICATION

I dedicate this thesis to my beloved parents without whom it's impossible for me to achieve anything.

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LIST OF ABBREVIATIONS

AADT	Average Annual Daily Traffic
ADT	Annual Daily traffic
Adjusted R^2 / $R^2_{adjusted}$	Adjusted R-square value
BRT	Bus Rapid Transit
CAD	Canadian Dollar
CARTAS	Calgary and Region Travel and Activity Survey
COV	Covariance
CO	Carbon mono-Oxide
CO_2	Carbon di-Oxide
DOT	Department of Transport
E	Elasticity, Error
EC	European Commission
EU	European Union
EXP	Exponential
GDP	Gross Domestic Product
GHG	Green House Gas
GOF	Goodness Of Fit
H_0	Null hypothesis
H_a	Alternate hypothesis
HMSO	Her Majesty's State Office
HOV	High Occupancy Vehicle
ICT	Information and Communication Technology
ILO	International Labor Organization
IMF	International Monetary Fund
IEA	International Energy Agency
IPCC	International Panel on Climate Change
L	Likelihood

LCCMT	London County Counsel and Ministry of Transport
LEDS GP	Low Emission Development Strategies Global Partnership
MRT	Mass Rapid Transit
MSR	Mean Squared due to Regression
MSE	Mean Squared due to Error
n	No of observations
n	Numerator
N	Population
NO	Nitrogen Oxides
NTD	Neo Traditional Development
OECD	Organization for Economic Cooperation and Development
OICA	Organization Internationale des Constructeurs d' Automobiles (International Organization of Motor Vehicle Manufacturers)
OLS	Ordinary Least Square
P	Denominator
P_F	No of parameters in full model
P_R	No of parameters in reduced model
POD	Pedestrian Oriented Development
Q	Proportion of population elements that don't have a particular attribute function
R^2	R-square value
SOV	Single Occupancy Vehicle
SSE	Sum of Squared Errors
SSR	Sum of Squared Residuals
SST	Sum of Squared Total
SSE_F	SSE for F-test / Full model
SSE_R	SSE for reduced model
TDM	Traffic Demand Management
TND	Traditional Neighborhood Development
TOD	Transit Oriented Development
UN	United Nations
UNEP	United Nations Environment Programme

US	United States
USA	United States of America
USD	United States Dollar
USEPA	United States Energy Protection Agency
VAR	Variance
VMT	Vehicle Miles Traveled
WEC	World Energy Council
WCED	World Commission on Environment and Development
WHO	World Health Organization
Y	Dependent variable
$\hat{Y}$	Observed dependent variable
$X_1, X_2, \ldots$	Independent variables
T_0	T-statistic value
B_0	Constant term / Regression Coefficient
B_k	Additional parameters in full model
$B_1, B_2, \ldots$	Constant term for different independent variables
Σ	Summation
ε	Disturbance Term
α	Significance level
σ	Standard deviation
i, j	Individual observations
f	Function
θ	Parameter vector estimator
$\hat{\mu}$	Maximum likelihood estimator
Π	Maximized arguments

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ABSTRACT

Traffic demand is increasing worldwide with booming economic growth. As a result, severe carbon emissions from transportation sector are highly contributing to the climate change. With the rapid increase of urban vehicles, the limited road traffic resources are becoming more and more strained. Traffic congestion and traffic safety have also become vital restrictive factors for overall development. Therefore, it is mandatory to reduce traffic congestion. To reduce emissions and continue economic growth, a sustainable and efficient transport system is indispensable. Sustainable urban transportation involves firming many features like efficiency, safety, security, convenience, low carbon, comfort, environment-friendliness etc. The characteristics of sustainable transportation are seen in several modes and alternatives such as public transit, walking, bicycling, ridesharing/carpool, teleworking/home-based office, reduction of personalized vehicles/auto ownership etc. The objective of this study is to identify the effects of different neighborhood characteristics like socioeconomic, road infrastructure, demographic and street patterns on sustainable transportation alternatives in community areas using 2011 census data and road infrastructure data of Calgary city. To develop relationships between neighborhood characteristics and sustainable transportation alternatives, linear regression model has been used. Public transit ridership, bicycling and walking have already been considered as sustainable transportation modes. However, carpool, working at home/teleworking, reduction of private vehicle usage are other alternatives which could be considered to promote sustainability. For each case, a linear regression model has been developed. In the models, sustainable alternatives were considered as the dependent variables. In the models different neighborhood characteristics has been considered as independent variables. Three different analyses have been done afterwards. The result of this study suggests that the effects of different street patterns are not identical on different alternative choices. More specifically, in reference to the irregular street pattern, other street patterns decreases the tendency of teleworking; on the contrary, the curvilinear street pattern is useful for private vehicles usage reduction. Except irregular street pattern, carpool remains indifferent for other street patterns. These findings would be helpful for the policymakers to develop new communities to promote sustainability. Moreover, different socioeconomic, demographic, land use factors such as type of roads, type and area of communities, gender, age, race, income, educational qualifications, dwelling conditions etc. play an important role in selecting different sustainable alternatives.

CHAPTER ONE: INTRODUCTION

1.1 Background

Transportation and traffic demand have been increasing worldwide, due to increasing population, income and urbanization. These increases have resulted in more congestion and environmental pollution. Reducing the negative influence of transportation on the environment and daily congestion in world capitals are issues that are very important for transportation authorities all over the world. Many negative impacts such as unexpected delays, higher transportation costs, and increased travel times have been noticed. All these undesirable traffic characteristics increase the level of air and noise pollution and also increase the number of traffic accidents. Sustainability and consistency in overall transportation system are necessary contributors to the development of a country. These must be achieved in such a manner where basic needs of individuals and society are organized and met properly without disrupting the surrounding environment. Its proper existence can help to reduce potential adverse environmental and social impacts of transportation. Proper reduction of the adverse effects of transportation only can ensure sustainability in the system.

The increase in vehicle usage deriving from urban sprawl and car ownership growth make traffic congestion more frequent and intense in both developed and developing countries. The majority of trips are single occupant vehicle trips which results in reduction of road capacity in the recent decades' causes traffic congestion. In the USA, in 2007, traffic congestion costs about 87.2 billion USD in the 437 urban areas compared to 73.1 billion USD in 2004. This represents an average delay per peak traveler of 38 hours per year. Considering all the metropolitan areas, this translates into 379 million hours of delay, 239 million gallons of fuel and 8 billion USD in delay cost (Texas Transportation Institute, 2009). Moreover, the transportation sector is still a very large consumer of energy and a major contributor to environmental pollution and global climate change. Transportation accounts for 60.1% of the total petroleum end-use consumption and 12.7% of the total energy consumption (Jia et al., 2010). Of all the modes of transportation, cars account for the largest proportion of emissions of polluting substances, such as CO_2, thereby contributing to global warming (OECD, 2002). According to Mitropoulos and Prevedouros (2014), the combination of fossil fuel such as gasoline and diesel(for the transportation of people and goods) is the second largest source of CO_2 emission (about 31% of total USA CO_2 emissions) and accounted for approximately 26% of total GHG emissions in 2011. Road transport in EU (European Union) has been estimated to be responsible for approximately 71.4% of CO_2 emissions which correspond to more than 20% of global emissions (EU, 2012). Greenhouse gas emissions for urban travel in Canada in 1997 were 215 gm per passenger-kilometer for a car or a light truck, 77 gm for urban transit, 26 gm for intercity bus travel, and, of course, 0 gm for walking or cycling (Transport Canada, 2008). Every year most of the governments are forced to initiate projects to refine and improve the surrounding environment. Because of that, a large amount of public and private investments along with valuable time are being wasted which could be more useful for other under-developed sectors instead.

All these negative impacts can be minimized by various technological inventions like eco-driving, improvement of automobile engines and the fuels they use, artificial intelligence in vehicle control. But these are not enough. Along with these, proper management and combinations of various modes of transportation are necessary. Therefore, an alternative transportation system is required for reducing adverse effects. Public transport, cycling, bike sharing and walking are the common modes of choice to reduce the auto dependency and promote sustainability of a transportation system.

Various design factors, street pattern, land use, transport infrastructure, socioeconomic and demographic features are responsible for controlling auto dependency (Pasha et al., 2016 A, 2016 B). The effects of different street patterns are not identical on different mode choices. More specifically traditional gridiron pattern is favorable for walking and cycling. On the contrary, irregular and curvilinear street patterns promote public transit usage (Pasha et al., 2016 A, 2016 B).

Different socioeconomic, demographic, land use factors also play an important role in selecting different sustainable mode choices. For example, increased number of train station enhances public transit ridership and walking. These would be helpful for the policymakers in the development of new communities for promoting sustainable transportation (Pasha M., 2016). Apart from public transport usage, cycling and walking; ride sharing, teleworking or home-based office and reduction of personalized transits can also be helpful to promote sustainability of a transportation system.

The problems of congestion, pollution, and traffic safety issues, mainly caused by a large number of travelers' trips, have become important restrictive factors in cities' development. Families who have access to a car have very different travel habits comparing to those who do not have access. The number of journeys made increases substantially when a car is acquired and some existing journeys transfer from public transport to the car. This change in behavior, especially the new trips generated, together with the increase in number of cars, is the reason for the large increase in total travel demand which is now a much-concerned issue. Wootton (1999) illustrates the change in behavior that occurs when a car is acquired. Families who do not have access to a car average about 2.5 journeys each weekday, while families with a car average about 6.4 journeys, which implies that 3.9 new journeys have been generated (in the sense of producing a completely new activity). The change is even greater when a family acquires a further car. The National Travel Survey has been suggesting that families with two or more cars make 8.7 journeys on the average weekday. There have been many studies in the UK and abroad that confirm this change of behavior (e.g. Wootton and Pick, 1997; LCCMT, 1962; West Midlands Transport Study, 1968; DOT, 1986). All have observed the same effect, though the scale of the change varies according to the location and factors involved.

Factors, other than owning a car, that affect the size of change include the number of people in the family; how many of the family members are employed; the age of family members; the number holding a driving license; the family' s income; where the family lives in; and so on. But, even when the data are disaggregated to isolate these factors, the effect is always the same. In broad terms, when the first car is acquired the total number of journeys will roughly double; about half of the journeys previously made by public transport will transfer to the car, and the number of walking and cycling journeys will fall slightly(DOT, 1986). Promotion and proper management of transportation system can be more effective than other measures to minimize the problem. Again, the efficiency of this system can be improved more by opening lanes exclusively for buses. However, during peak periods it is not uncommon to see that fewer buses in bus lanes and excessive private vehicles in other lanes, reducing the total efficiency of the road system.

According a survey done by University of California Transportation Center in 2012, prospective participants said that they would share rides primarily to save time and money and secondarily, to reduce the environmental impacts of driving. To save time, most would prefer a service that matches riders and drivers automatically, based on stated criteria, rather than one that gives the participant a list of contacts and expects them to follow up (Deakin et al., 2012).

Carpool is an important alternative to private car ownership and public transportation systems while private cars provides significant comfort and flexibility, it is very demanding on natural resources and is a major reason for congestion and traffic delays. Carpool and ridesharing are almost same. However, there is a slight difference between them. Carpool is the communal use of private vehicles where users pay the expenses of fuel and road tolls for the vehicles. Carpool reduces private vehicles usage. But in ridesharing, vehicles are provided by a company and expenses are covered by the users which may increase the number of vehicles in total in a certain area.

In the United States, the number of daily commuters is very high. According to the U.S. Census Bureau there are approximately 130 million commuters with 86% of them using a car, a truck, or a van (U.S. Department of Commerce Census Bureau, 2014). The majority of the nation's workers (76%) drive alone for an average of 25 min to get to work every day, and less than 10% carpool (McKenzie, 2014). Considering the 4 to 6 persons capacity of a passenger car, single occupant vehicles causes 60-75% unused capacity of road. High occupant vehicles and carpool decreases this unused capacity; hence decreases congestion.

Beside congestion, an increased number of private cars also creates parking problems as cars are parked for the majority of time and when they are operational, they carry only a portion of their payload. Apart from being under-utilized and extremely wasteful, private cars are a leading cause for localized pollution. Carpool de-congests roads and relaxes the pressure on parking spaces. It also reduces fuel consumption by increasing the payload, thereby reducing emissions. The International Energy Agency (2005) estimated that carpool can reduce the number of traveled distances by 12.5%. This reduction will impact fuel consumption, as the International Energy Agency estimated a 77% reduction in fuel usage, if one person is to be added to each commute. Despite such obvious advantages, the uptake of carpool has not been measured up to the expectations mainly due to the fact that traditional carpool imposes several constraints on the personal freedoms of passengers and due to the complications faced in organizing and maintaining the service under dynamically changing travel patterns (Naoum-Sawaya et al., 2015).

To understand why commuters drive to work instead of using more environmentally friendly modes of transportation, it is necessary to consider that the behavioral antecedents of car use for commuting and the intention to reduce it (Abrahamse et al., 2009). Since the mid-1970s, the phenomenon of teleworking has witnessed a great deal of attention (Nilles, 1988; Salomon, 1986; Salomon, 2000; Mokhtarian, 1990).

According to De Graaff et al. (2007), a teleworker is an individual who works mainly at home or in other places rather than the actual workplaces. So, it can be said that teleworking is a broader form of home office. Since the industrial revolution, individuals organized themselves into firms and institutions outside of household which makes telework more interesting (Mokyr, 1999). The change of work location caused an increase in specialization and was controlled by fixed capitals. Therefore, with the improvement of services, governments, non-commercial and public sectors, smaller divided groups of workers outside household became more beneficial due to the proper distribution of profits and benefits. Moreover, because of the adaptation of the advanced information and communication technology, the flexibility of workforce has increased resulting in the deviation of jobs. As a result, job sectors have been expanded and service holders can do different types of works simultaneously. In addition to that, to reduce increased commuting costs and to achieve desired better combination of working and family lives, teleworking can be a good alternative against out of home jobs.

In public service arena, teleworking has been actively promoted as a travel demand management strategy (Handy and Mokhtarian, 1995). Teleworking not only targets to reduce travel time and costs but also mitigates other transportation-related environmental impacts including traffic congestion, air pollution, and GHG emissions. However, although figures of teleworking are scarce and international comparisons are difficult to make, the general impression is that the number of teleworkers is still relatively low. Most figures show that within Europe, Finland, Sweden, and the Netherlands are the countries with relatively the largest numbers of teleworkers (De Graaff et al., 2007).

Since the advancement of the modern automation, the automobile has been considered as a major contribution that shapes social organizations, city formations, public and private investment quantity and priorities both in developed and developing worlds. Despite being more benefited, the societies where the automobile is the dominant mode of personal transportation, becoming more and more concerned about the consequences caused by the uncontrolled auto ownership. These consequences are familiar; such as auto-generated pollutant emissions, noise pollution, neighborhood intrusion and disruption associated with highway-building, fuel consumption and highway-related injuries and fatalities. Day by day, these are becoming serious public debate issues. Therefore, auto ownership and usage raise questions on the reliability and sustainability of a transportation system in developing countries which adopt the systems that a developed capitalist country has already adopted. As the most extreme example, 23.5 million new cars went on the road in China in 2014 (OICA, 2015a), a number expected to reach more than 30 million by the end of 2020 (LeBeau, 2012).

Globally, greenhouse gas emissions from the transportation sector have more than doubled since 1970 and around 80% of this increment has been estimated coming from road vehicles (IPCC, 2014). The overall increase in ownership of private vehicles is a reality. No matter if the car ownership is low, as in Asia or South America, or very high, as in Europe and North America, the trends show that people are buying more cars every day and are using them (Poudenx, 2008). According to the European Union Green Paper on Urban Mobility (2007), 1% of the European Union (EU) GDP is lost every year because of congestion. Also, the transportation sector is responsible for 40% of CO_2 and other GHG emissions and 70% of other pollutant emissions.

Private cars are a major source of GHG emissions and are the prime cause of congestion, noise and air pollution (Barla et al., 2011). Therefore there is a need for source-related measures that can reduce the environmental impact of transportation (Beckx et al., 2013). Because of the higher presence and growth rate of automobile ownership, it would be much difficult to reduce it. Reduction and control of automobile ownership should be the least effort to ensure the sustainability of a transportation system in a city. Based on this understanding, the transportation policies and investment alternatives with the aim of reducing car-induced externalities have drawn the wide attention of both politicians and researchers. For effective evaluation and selection of policy options to eradicate or reduce these problems, it is necessary to understand the factors contributing to the growth of automobile ownership.

From the above discussion, it is clear that apart from promoting public transportation, cycling and walking, increase of other sustainable transportation options such as ridesharing or carpool, working at home or teleworking are effective means in reducing private motor vehicle usage. To understand the importance of carpool, teleworking and private transit ridership, several studies have attempted to identify the factors influencing them. However, few studies have been explored the effect on ridesharing, teleworking and private vehicle ridership for different urban forms and design like Neighborhood Street Patterns (Brundell-Freij et al., 2005; Filion et al., 2003; Schwanen et al., 1998; Cervero et al., 1996; Aditjandra et al., 2012). Most of these studies showed how carpool, teleworking or home office and automobile ownership individually affect the sustainability of a transportation system of a city or a country. But this study will provide a broader view of how carpool, teleworking or home office and private car ownership together affect the sustainability of a transportation system. Factors that control all these three modes together and individually may also be found that can help policymakers to take up proper initiatives. Hence, the objective of the study is to examine the effects of street pattern on ride sharing, teleworking and automobile usage. Besides street pattern, a wide range of factors from land use, road infrastructure, socioeconomic and demographic characteristics in Calgary communities are explored in this context. Calgary is chosen as the study area because this city is growing rapidly due to the economic boom in oil and gas sector. To accommodate the increased population, the city is expanding laterally and many new communities are being built. Therefore, evidence on effects of different neighborhood design on automobile use, ride sharing and teleworking are needed to help policy maker; developers and residents make informed choices.

1.2 The Context of Neighborhood Characteristics and Sustainable Transportation

1.2.1 Sustainability

Sustainability is the process of maintaining change in a balanced fashion, in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations (James et al., 2015). For many in the field, sustainability is defined through the following interconnected domains or pillars: environment, economic and social. Sub-domains of sustainable development have been considered also: cultural, technological and political (Magee et al., 2013) Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (James et al., 2015). Brundtland Report for the World Commission on Environment and Development (1987) introduced the term of sustainable development. Sustainability implies responsible and proactive decision-making and innovation that minimizes negative impact and maintains balance between ecological resilience, economic prosperity, political justice and cultural vibrancy to ensure a desirable planet for all species now and in the future (Magee et al., 2013) Specific types of sustainability include, sustainable agriculture, sustainable architecture or ecological economics, sustainable communication and transportation etc. (Costanza et al., 1995).United Nation in 2015 sets 17 important features as sustainable development goals for future national and international development targets. Some of these features emphasizes on social, economic, natural, infrastructural, transportation and communication sectors. (UN Development Agenda, 2015).

1.2.2 Sustainable City and Community

Sustainable cities or urban sustainability means a city designed with consideration for social, economic, environmental impact and resilient habitat for existing populations, without compromising the ability of future generations to experience the same (Ranasinghe et al., 2018). These cities are inhabited by people whom are dedicated towards minimization of required inputs of energy, water, food, waste, output of heat, air pollution - CO_2, methane, and water pollution. Generally, developmental experts agree that a sustainable city should meet the needs of the present without sacrificing the ability of future generations to meet their own needs. The ambiguity within this idea leads to a great deal of variation in terms of how cities carry out their attempts to become sustainable.

A sustainable city can feed itself with minimal reliance on the surrounding countryside, and power itself with renewable sources of energy. The crux of this is to create the smallest possible ecological footprint, and to produce the lowest quantity of pollution possible, to efficiently use land; compost used materials, recycle it or convert waste-to-energy, and thus the city's overall contribution to climate change will be minimal, if such practices are adhered to.
Contrary to common belief, urban systems can be more environmentally sustainable than rural or suburban living. With people and resource located so close to one another it is possible to save energy for transportation and mass transit systems, and resources such as food. Cities benefit the economy by locating human capital in one relatively small geographic area where ideas can be generated. Having a denser, urban space would also increase people's efficiency since they wouldn't have to spend as much time commuting to places if resources are located close together, which in turn would benefit the economy since people can use this extra time on other matters; like work.

According to Shmelev et al. (2009) and Register (2006), these ecological cities are achieved through various means, such as:

- Different agricultural systems such as agricultural plots within the city (suburbs or center). This reduces the distance food has to travel from field to fork. Practical work out of this may be done by either small scale/private farming plots or through larger scale agriculture (e.g. farmscrapers).

- Renewable energy sources, such as wind turbines, solar panels, or bio-gas created from sewage. Cities provide economies of scale that make such energy sources viable.
- Various methods to reduce the need for air conditioning
- Improved public transport and an increase in pedestrianization, cycling, teleworking to reduce private car emissions. This requires a radically different approach to city planning, with integrated business, industrial, and residential zones. Roads may be designed to make driving difficult.
- Optimal building density to make public transport viable but avoid the creation of urban heat islands.
- Solutions to decrease urban sprawl, by seeking new ways of allowing people to live closer to the workspace
- Zero-emission transport
- Zero-energy building
- Sustainable urban drainage systems or SUDS
- Energy conservation systems/devices

The term "sustainable communities" has various definitions, but in essence refers to communities planned, built, or modified to promote sustainable living. Sustainable communities tend to focus on environmental and economic sustainability, urban infrastructure, social equity, and municipal government. The term is sometimes used synonymously with "green cities," "eco-communities," "livable cities" and "sustainable cities."

Different organizations have various understandings of sustainable communities; the term's definition is contested and still under construction. For example, Burlington, Vermont's Principles of Sustainable Community Development (Sustainable Communities Task Force Report, 1997) stress the importance of local control of natural resources and a thriving non-profit sector to a sustainable community. The Institute for Sustainable Communities outlines how political empowerment and social well-being are also part of the definition (Sustainable

Communities Task Force Report, 1997). Additionally, referring to communities in Shanghai and Singapore, geographer Lily Kong has paired concepts of cultural sustainability and social sustainability alongside environmental sustainability as aspects of sustainable communities (Kong, 2010). Meanwhile, the UK's 2003 Sustainable Communities Plan often abbreviates its definition of sustainable communities as "places where people want to live and work, now and in the future" (UK National Archive). Addressing the scale of sustainable communities, political scientist Kent Portney points out that the term sustainable communities has been used to refer to a broad variety of places, ranging from neighborhoods to watersheds to cities to multi-state regions (Portney, 2001).

Sustainable community initiatives have emerged in neighborhoods, cities, counties, metropolitan planning districts, and watershed districts at different scales pertaining to community needs. These initiatives are driven by various actor groups that have different methods of effectively planning out ways to create sustainable communities. Most often they are implemented by governments and non-profit organizations, but they also involve community members, academics, and create partnerships and coalitions. Non-profit organizations help to cultivate local talents and skills, empowering people to become more powerful and more involved in their own communities. Many also offer plans and guidance on improving the sustainability of various practices, such as land use and community design, transportation, energy efficiency, waste reduction, and climate friendly purchasing. Some government groups will create partnerships where departments will work together using grants to provide resources to communities like clean air and water, community planning, economic development, equity and environmental justice, as well as housing and transportation choices.

Planning process of a city's development largely depends on the development of the communities. Planning has traditionally demanded a decentralized, participatory planning process to successfully addressed local issues (i.e. environmental, geographical, social, economic, and infrastructural). Issues in decentralized levels like communities are easily solvable rather than central level like in cities. Both in developed and developing countries, every neighborhood or community in a city has different sorts of preferences based on their geographical condition, cultural norms, social beliefs, languages, economy, household size etc.

The neighborhood or some equivalent of this unit, is repeatedly referred to in proposals for urban reorganization (Simandan D., 2016).

Neighborhood, as a unit of planning, has always provided means to organize and ensure application of such decentralized planning processes to implement local planning programs and policies at the desirable de-centralized level. According to the American Planning Association (2008) a good neighborhood must have various functional attributes, multi-modal transportation (i.e. pedestrians, bicyclists, drivers, rideshares, carpoolers, public transport users) which Promotes sustainability in overall system and responds to climatic demands.

1.2.3 Sustainable Transportation and Community: Mode Choices and Alternatives

Sustainable transport refers to the broad subject of transport that is sustainable in the senses of social, environmental and climate impacts and the ability to, in the global scope, supply the source energy indefinitely. Components for evaluating sustainability include the particular vehicles used for road, water or air transport; the source of energy; and the infrastructure used to accommodate the transport (roads, railways, airways, waterways, canals and terminals). Transport operations and logistics as well as transit-oriented development are also involved in evaluation. Transportation sustainability is largely being measured by transportation system effectiveness and efficiency as well as the environmental and climate impacts of the system (Jeon et al., 2005).

Short-term activity often promotes incremental improvement in fuel efficiency and vehicle emissions controls while long-term goals include migrating transportation from fossil-based energy to other alternatives such as renewable energy and use of other renewable resources. The entire life cycle of transport systems is subject to sustainability measurement and optimization (U.S. Department of Transportation’s Research and Innovative Technology Administration, 2010).

Sustainable transport systems make a positive contribution to the environmental, social and economic sustainability of the communities they serve. Transport systems exist to provide social and economic connections, and people quickly take up the opportunities offered by increased mobility, (Schafer, 1998) with poor households benefiting greatly from low carbon transport options (Lefevre et al., 2016 A) The advantages of increased mobility need to be weighed against the environmental, social and economic costs that transport systems pose. Transport systems have significant impacts on the environment, accounting for between 20% and 25% of world energy consumption and carbon dioxide emissions (World Energy Council, 2007). The majority of the emissions, almost 97%, came from direct burning of fossil fuels (DOT, 2015). Greenhouse gas emissions from transport are increasing at a faster rate than any other energy using sector (IPCC, 2007). Road transport is also a major contributor to local air pollution and smog (USEPA, 2018).

The United Nations Environment Programme (UNEP) estimates that each year 2.4 million premature deaths from outdoor air pollution could be avoided (UNEP, 2016) Particularly hazardous for health are emissions of black carbon, a component of particulate matter, which is a known cause of respiratory and carcinogenic diseases and a significant contributor to global climate change (Lefevre et al., 2016 B). The links between greenhouse gas emissions and particulate matter make low carbon transport an increasingly sustainable investment at local level—both by reducing emission levels and thus mitigating climate change; and by improving public health through better air quality (Lefevre et al., 2016B)

The social costs of transport include road crashes, air pollution, physical inactivity (WHO, 2010), time taken away from the family while commuting and vulnerability to fuel price increases. Many of these negative impacts fall disproportionately on those social groups who are also least likely to own and drive cars (Social Exclusion Unit, UK, 2010). Traffic congestion imposes economic costs by wasting people's time and by slowing the delivery of goods and services.

Traditional transport planning aims to improve mobility, especially for vehicles, and may fail to adequately consider wider impacts. But the real purpose of transport is access – to work, education, goods and services, friends and family – and there are proven techniques to improve access while simultaneously reducing environmental and social impacts, and managing traffic congestion (Litman, 1998). Communities which are successfully improving the sustainability of their transport networks are doing so as part of a wider programme of creating more vibrant, livable, sustainable cities.

The term sustainable transport came into use as a logical follow-on from sustainable development, and is used to describe modes of transport, and systems of transport planning, which are consistent with wider concerns of sustainability. There are many definitions of the sustainable transport, and of the related terms sustainable transportation and sustainable mobility (Litman, 2009). One such definition, from the European Union Council of Ministers of Transport, defines a sustainable transportation system as one that:

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

Sustainability extends beyond just the operating efficiency and emissions. A life-cycle assessment involves production, use and post-use considerations. A cradle-to-cradle design is more important than a focus on a single factor such as energy efficiency (USEPA, 2012). Cities with overbuilt roadways have experienced unintended consequences, linked to radical drops in public transport, motorcycle, private car, walking, cycling, and teleworking. In many cases, streets became void of "life." Stores, schools, government centers and libraries moved away from central cities, and residents who did not flee to the suburbs experienced a much reduced quality of public space and of public services. Yet another impact was an increase in sedentary lifestyles, causing and complicating a national epidemic of obesity, and accompanying dramatically increased health care costs (Ewing, 2003).

There are major differences in transport energy consumption between cities; an average U.S. urban dweller uses 24 times more energy annually for private transport than a Chinese urban resident, and almost four times as much as a European urban dweller. These differences cannot be explained by wealth alone but are closely linked to the rates of walking, cycling, motorcycling, teleworking, private and public transport use and to enduring features of the city including urban density and urban design (Kenworthy, 2003).

The cities and nations that have invested most heavily in private car-based transport systems are now the least environmentally sustainable, as measured by per capita fossil fuel use (Kenworthy, 2003). The social and economic sustainability of car-based transportation engineering has also been questioned. Within the United States, residents of sprawling cities make more frequent and longer car trips, while residents of traditional urban neighborhoods make a similar number of trips, but travel shorter distances and walk, cycle and use transit more often (Ewing et al., 2001). It has been calculated that New York residents save $19 billion each year simply by owning fewer cars and driving less than the average American. A less car intensive means of urban transport is car sharing or carpooling, which is becoming popular in North America and Europe, and according to The Economist, car sharing can reduce car ownership at an estimated rate of one rental car replacing 15 owned vehicles. Car sharing has also begun in the developing world, where traffic and urban density is often worse than in developed countries. Companies like Zoom in India, Ehi in China, and Carrot in Mexico, are bringing car-sharing to developing countries in an effort to reduce car-related pollution, ameliorate traffic, and expand the number of people who have access to cars (Vijayann, 2014).

The European Commission adopted the Action Plan on urban mobility on 2009-09-30 for sustainable urban mobility. The European Commission will conduct a review of the implementation of the Action Plan in the year 2012, and will assess the need for further action. In 2007, 72% of the European population lived in urban areas, which are key to growth and employment. Cities need efficient transport systems to support their economy and the welfare of their inhabitants. Around 85% of the EU's GDP is generated in cities. Urban areas face today the challenge of making transport sustainable in environmental (CO_2, air pollution, noise) and competitiveness (congestion) terms while at the same time addressing social concerns. These range from the need to respond to health problems and demographic trends, fostering economic and social cohesion to taking into account the needs of persons with reduced mobility, families and children.

Carpooling (also car-sharing, ride-sharing and lift-sharing) is the sharing of car journeys so that more than one person travels in a car, and prevents the need for others to have to drive to a location themselves. By having more people using one vehicle, carpooling reduces each person's travel costs such as: fuel costs, tolls, and the stress of driving. Carpooling is also a more environmentally friendly and sustainable way to travel as sharing journeys reduces air pollution, carbon emissions, traffic congestion on the roads, and the need for parking spaces. Authorities often encourage carpooling, especially during periods of high pollution or high fuel prices. Car sharing is a good way to use up the full seating capacity of a car, which would otherwise remain unused if it were just the driver using the car.

In 2009, carpooling represented 43.5% of all trips in the United States (U.S. Department of Transportation's Research and Innovative Technology Administration, 2010) and 10% of commute trips (US Department of Transportation, 2014; Park et al., 2011) The majority of carpool commutes (over 60%) are "fam-pools" with family members (DeLoach et al., 2010). Carpool commuting is more popular for people who work in places with more jobs nearby, and who live in places with higher residential densities (Belz et al., 2012) Carpooling is significantly correlated with transport operating costs, including fuel prices and commute length, and with measures of social capital, such as time spent with others, time spent eating and drinking, and being unmarried. However, carpooling is significantly less likely among people who spend more time at work, elderly people, and homeowners (DeLoach et al., 2010).

According to some analysts, carpoolers to be only unrelated individuals who share responsibility for vehicle provision and driving. Other analysts distinguish between "external" carpools (unrelated individuals) and "internal" (household) carpools (Richardson and Young, 1982). Yet other analysts distinguish between carpool and car-sharing, but consider household car-sharing to be a legitimate form of ridesharing (Bonsall, 1981). The definition used here is purposefully broad; a carpooler is considered to be anyone who shares a private car with another worker. Defined in this way, 17.1% of the commuting workers (excluding those who work at home) in the NPTS sample are carpoolers and 18.5% of the workers who commute in a vehicle (excluding bicyclists) are carpoolers. Carpoolers represent 19.6% of all the private vehicle commuters (excluding bicyclists). All carpooling percentages will be expressed in terms of vehicular commuters excluding bicyclists unless otherwise stated. Carpool does not represent a singular mode of commuting but rather encompasses distinctly different commuting arrangements.

Three distinct types of carpoolers were delineated; based on previously developed categorizations as well as consideration of the important difference between carpool arrangements in which each commuter contributes to vehicular expenses and driving assistance and those in which they do not. (1) Household carpoolers: who commute together with at least one other worker from the same household; (2) External carpoolers: who share transportation with unrelated individuals and who either share driving responsibilities or drive always; (3) Carpool riders: who commute with other unrelated workers but who ride only and do not provide a vehicle. According to Delhomme and Gheorghiu (2015), carpool has successfully achieved many aspirations like controlling traffic volume, fuel usage and any associated emissions, usage of parking spots, reducing driver's fatigue, travel time and costs, providing flexibility, comfort, and more convenient service than public transports, improving social networking and interaction (Agatz et al., 20011, 2012). So, there is a possibility of having influences and relations between road infrastructures like types of the area, types of roads and intersections, presence, availability and service quality of public transportation (BRT, MRT, Light Rails etc.), the presence of various business and educational institutions and carpool. In terms of social-psychological determinants, a number of factors are likely to work together to determine users' willingness to engage in a carpool. These include the nature of trips (trip generation, distribution and termination), length of journey, time of the day and week as well as demographic determinants like users' age, gender, language, dwelling conditions, social and economic status and personality (Chowdhury et al., 2016; Malodia and Singla, 2016; Vanoutrive et al., 2012; Roy, 2016).

Work trips are major dominants of traffic congestion and air pollution during peak hours. The substitution of these trips by telecommunication (or telecommuting) has long been advocated as an approach that might reduce congestion, excessive energy consumption, and pollution. Two major types of telecommuting with respect to different special locations: home-based telecommuting or home office and regional telecommuting. Home-based telecommuting refers to an individual working from home instead of a traditional office. Regional telecommuting refers to a center set by an organization to accommodate employers who commute fewer miles from the center than to the main office which is very expensive. Telecommuting substitutes travel and benefits persons, governments, and society. Various road infrastructure, social and personal factors control telecommuting. Road infrastructure determinants could be physical environment of road network and urban form factors like population density, land use topography, availability of various types of infrastructures, connectivity of roads; mode specific factors (public transportation availability, access, flexibility, privacy, freedom, travel time and costs); trip characteristics; TDM availability (parking availability and cost, information, transit pass subsidy). Socio-demographics determinants could be trip maker's personal attributes like age, gender, income, occupation, education, marriage status etc. (Zhou, 2012). These socio-demographic and infrastructure factors not only control one but all the modes choice of transportation.

Clearly, for individuals, more benefits can be gained from car-based travels comparing to other forms of transportation modes. On the other hand, the massive use of motor cars causes serious problems for environmental quality, the quality of urban life and accessibility to various destinations. Besides, technological solutions, effective solutions for the problems associated with car use require a reduction in the volume of car-traffic based on behavior changes of individual car users (Abrahamse et al., 2009). For a long time, car usage has been predominantly explained through behavior models that focus on instrumental factors related to car use such as speed, flexibility, and convenience. However, a car is much more than a mean of transportation.

Apart from that, there are means that control car use behavior and car ownership. They can be classified as road infrastructure and socio-demographic characteristics. Various road infrastructure characteristics like types of neighbourhoods (residential, commercial and industrial area), types of intersections, types of road (local, arterial or highways), number of lanes, speed limits, density of intersections, traffic volume, street patterns (grid, cul-de-sac or mixed), road length etc. controls car use behaviour and ownership (Brundek-Freij and Ericsson, 2005). On the other hand, socio-economic characters of a neighbourhood like age, gender, income, household size, employment, marriage status, household types, number of children in a household, education level etc. also controls car use behaviour (Nurdden et al., 2007; Nolan, 2010; Bergstad et al., 2011; Crepeau, 1998)

The previous studies stated here gives a trend of analysis over time in the search for evidence of neighborhood design characteristics contributing to sustainable modes of choice. However, most of the researches were done in a distinct way considering only one or two of the features from neighborhood characteristics. For example: household income, employment and educational qualifications (Jou and Chen, 2014); parking availability, travel cost and time (Tyrinopoulos and Antoniou, 2013), socio-economic characteristics on carpool (Kaufman, 2002), employment and parking on carpool (Shoup, 1997), race and ethnicity on carpool (Charles et al., 2006), family and marital status on home office (Yap and Tng, 1990; Azeez and Supian, 1996), age, gender, occupation, income on auto ownership, housing quality and types on automobile ownership (Van Wissen and Golob, 1992); all they have studied the different aspects of neighborhood design characteristics. But almost all of the studies did not incorporate all the features of neighborhood characteristics together. Moreover, the street pattern in a community was not rigorously investigated before. Some of the studies were done by Marshal and Garick (2010) on-street pattern, traffic volume, activity level, income level, proximity to limited access, highway and downtown area; Southworth and Parthasarathy (1996) on area density level, land use, zoning patterns, suburban layouts and street scales etc.; where extensive importance on the effect of street pattern on sustainable transportation modes as well as on the neighborhood characteristics was not given. In this study socioeconomic, demographic, land use, street pattern, road infrastructures were incorporated in an integrated manner as to understand the effect of these features on sustainable transportation modes in a community.

1.3 Objective of the Study

The main objectives of this study are:

- To find out the different neighborhood characteristics such as road infrastructure, land use, socioeconomic and demographic features which may increase or decrease carpool, working at home or teleworking and private car usage to promote the sustainable transportation system.

- To find out the relationship between different community street patterns with carpool, working at home or teleworking and private car usage.

- To find out the variables and their elasticity which emphasise on transportation mode choices to promote sustainability.

1.4 Scope of the Research

The study will examine the effects of different neighborhood design characteristics on the sustainable transportation modes using linear regression model. Since one key focus of this research is on the effects of different neighborhood street pattern designs on sustainable transportation modes, it will use the neighborhood as the unit of analysis which enables the model to capture some effects of road designs. It will also be accounted for the confounding effects of non-engineering factors like neighborhood characteristics. The City of Calgary will be used as a case study and the neighborhood or unit of analysis will be defined by the different community areas in the city because most of the socioeconomic data are extracted from the population census which uses these community areas in their data collections and reporting procedures. The study will also unveil whether the significant factors are common in three case studies or same of them are particularly related to the specific case study.

Three case studies such as carpool, working at home or teleworking and automobile ownership or private car usage will be considered in the study. For each case study, a linear regression model will be developed in the analysis. The first model will study the different neighborhood characteristics affecting carpool in each community to get an overall picture. The dependent variable for this model is a percentage of the carpool. In second and third models, the dependent variable will be the percentage of home office and private vehicles (as driving alone).

1.5 Significance of the Research

With the increasing population and intensive land use, huge traffic demand is generating worldwide. As a matter of fact, severe congestion, lack of safety, environmental pollution etc. are very common phenomena nowadays. Due to this increasing number of personalized vehicles, the transportation sector has been considered as a major contribution\ of causing environmental pollution and global climate change. These negative impacts can be minimized by promoting and implementing carpool, working at home or teleworking and proper use of personalized vehicles apart from public transit use, cycling and walking. These will also help to build a more sustainable transportation system. This study will play an important role to find the factors that influence personalized vehicle usage, carpool and working at home together and individually.

1.6 Outline of the Thesis

The thesis has been organized into five chapters. After the introduction in the first chapter, the other four chapters will cover the following topics:

Chapter 2-Literature Review

In the first section of this Chapter, characteristics and definitions of a good neighborhood have been elaborated. Also, how different types of street patterns are related to neighborhood or community planning are elaborated. Moreover, different types of street patterns, their characteristics and their evolving history has been explored. In the next section, characteristics and different factors (socioeconomic, demographics, infrastructural) associated with various transportation mode and alternatives explored in previous studies have been reviewed. Important information and finding from these studies have also been documented.

Chapter 3-Data and Methodology

Chapter three describes the sources of the database used in this study as well as methodology followed in statistical analysis. This Chapter also discusses the different socioeconomic and demographic data, classification of different street pattern, auto ownership scenario in Calgary, and detailed procedure of the linear regression analysis.

Chapter 4- Analysis, Model development and Result

All the three models that are to be developed have been discussed here as well as the process of analyzing the data have been incorporated into this Chapter. Based on the analysis, three different models on carpool, telework and private vehicle usage were generated to address the objective of this research. All the results obtained from the analysis and model development have been stated here. Explanation of the results have also been discussed rigorously in this Chapter.

Chapter 5-Conclusions and Recommendations

This Chapter draws a final conclusion based on the findings of different case studies on carpool, telework and private car usage whether the variables are consistent in all case studies are explored. Limitations of this research and recommendations for different modes and alternatives have also been incorporated here. Some directions for future exploration of research in this area are also mentioned.

CHAPTER TWO: LITERATURE REVIEW

The literature review of the thesis has been organized by considering several factors. First, relevant studies that examined the relationship between neighborhood design and sustainable mode of transportation. As mentioned earlier that the walking, cycling, and public transit usage are beyond the scope of this research. Factors affecting carpool and home office or teleworking will be discussed elaborately. Besides these two factors, factors influencing private vehicle usage will also be discussed in this chapter. Second, the history and evaluation of different types of the street pattern will be discussed along with their characteristics. Third, the key findings of various published papers related to the transportation modes will be summarized to help the readers to gain some insights about the variables and contributing factors to be used.

2.1 Aspects of Neighborhoods and Street Patterns

Both in developed and developing countries, every neighborhood or community in a city has different sorts of preferences based on their geographical condition, cultural norms, social beliefs, languages, economy, household size etc. A neighborhood is a geographically localized community within a larger city, town, suburb or rural area. Neighborhoods are often social communities with considerable face-to-face interaction among members (Simandan D., 2016). Researchers have not agreed on an exact definition, but the following may serve as a starting point: "Neighborhood is generally defined spatially as a specific geographic area and functionally as a set of social networks. Neighborhoods then, are the spatial units in which face-to-face social interactions occur—the personal settings and situations where residents seek to realize common values, socialize youth, and maintain effective social control (Schuck et al, 2006). Also, the term neighborhood is often used to describe the sub-divisions of urban or rural settlements. In its purest definition, a neighborhood is the vicinity in which people live. The neighborhood or some equivalent of this unit, is repeatedly referred to in proposals for urban reorganization. It is often the smallest unit considered by urban and regional planning, reflecting the general belief of planners and others alike that neighborhoods are the building blocks of the city. Planning has traditionally demanded a decentralized, participatory planning process to successfully address local issues (i.e. environmental, geographical, social, economic, infrastructural). Neighborhood, as a unit of planning, has always provided means to organize and ensure application of such decentralized planning processes to implement local planning programs and policies at the desirable de-centralized level. It brings comprehensive planning to local levels, where transportation, housing, public facilities, etc. become interdependent systems rather than separate phenomena.

According to The American Planning Association (2008) a good neighborhood must have qualities including:

1. A variety of functional attributes that contribute to a resident's day-to-day living (i.e. residential, commercial, or mixed-uses).
2. Accommodates multi-modal transportation (i.e. pedestrians, bicyclists, drivers, ridesharing, carpooling, public transit).
3. Has design and architectural features that are visually interesting.
4. Encourages human contact and social activities.
5. Promotes community involvement and maintains a secure environment (i.e. social, natural, economic)
6. Promotes sustainability in overall system and responds to climatic demands.
7. Has a memorable character.

Neighborhood or Community development planning consists of a public participatory and usually interactive form of town or neighborhood planning and design in which diverse community members (often termed "stakeholders") contribute toward formulation of the goals, objectives, planning, fund/resource identification and direction, planned project implementations and re-evaluation of documented local planning policy. Community as well as neighborhood planning involves the formulation of long range visions, goals, policies and strategies for achieving social, economic, environmental, transportation and infrastructural sustainability within a community in order to guide future community development. Typically referred to as "long range planning", community planning differs from day to day development planning which typically focuses on the review of current development proposals to determine how they fit within community plans such as the Official Community Plan, neighborhood or sector plans and other plans and strategies. According to the Department of Community and Regional planning, Iowa State University, community planning includes:

- Land use planning
- Street zoning
- Environmental Planning
- Transportation planning
- Site planning

In the past, the main purpose of urban streets was to serve as thoroughfares for carrying people and goods from one place to another in a safe and reliable way with a minimum delay. One common network design that is able to provide a high degree of efficiency and reliability is the traditional grid design with intersecting streets that are mostly straight thoroughfares. This rectilinear design has the advantage that if any section of the road or link has reduced capacity due to congestion, vehicle collision, repair or maintenance, traffic can easily be diverted to alternative routes thereby increasing the reliability of the road network in enabling users to get from their origin to their destination. Moreover, navigation within this type of network is simple and will minimize the workload and stress on drivers, especially those who are not familiar with the neighborhood. Also, since travel is direct, straight-path travel is often possible which often reduces travel time and cost. In a simulation study, Kulash (1990) showed a 57% decrease in vehicle miles traveled (VMT) for neighborhood travel on a gridded street network.

However, the traditional grid design has several disadvantages when applied to residential areas. First, grid pattern requires a greater paved area than necessary to serve a residential community. Second, it requires the installation of a more expensive type of paving for all roads by dispersing the traffic equally throughout the area. Third, it creates an increased traffic hazard due to the increase in the potential for interactions between vehicular and pedestrian traffic. Last, it creates a monotonous and uninteresting architectural effect that may reduce some community amenities.

2.1.1 Livable Streets

Nowadays, however, urban streets are places where people walk, shop, meet, and generally engage in the diverse array of social and recreational activities that make urban living enjoyable (Dumbaugh, 2005). Urban streets not only contribute to improving the quality of life for many people but also enhance economic growth and innovation of the region (Florida, 2002) and increase the physical fitness and health of the people (Frank et al., 2003). According to Appleyard (1980), an ideal street should have the following characteristics in addition to facilitating the movement of people and goods from one place to another:

(1) The street as a sanctuary
(2) The street as a livable, healthy environment
(3) The street as a community
(4) The street as neighborly territory
(5) The street as a place for play and learning
(6) The street as a green and pleasant land
(7) The street as a unique historic place

Beyond acting as a thoroughfare, when an urban street possesses the above characteristics, it is termed as a “livable street”. This type of road has become popular recently because pedestrian travel and local needs are considered in its design. The prime feature of “livable street” is to reduce the negative externalities of motor vehicle use on neighborhood life. The road and traffic-related issues that have an impact on neighborhood life are acceptable level of traffic speed and volume, right-of-way priorities for pedestrians, pedestrian access to streets, reduction in pedestrian crashes, acceptable noise level, sufficient parking and open space (Appleyard, 1980). Most of the characteristics that defined “livable street” are missing in the traditional grid design pattern for roads.

However, most of these previous studies defined a livable street based on their aesthetic appeal of roadside features. When the issue of livability is discussed, importance is generally given to the design of roadsides. Beside the design of roadsides, the street pattern of a community area or ward surely has some influences in its livability. It is quite clear that streets in the traditional grid road design do not have the essential features required to be considered as livable streets.

2.1.2 Loops and Lollipops Design

Over the last few decades, limited access design has become the main design pattern in many suburban neighborhoods. Three forms of limited access layouts are generally considered in the residential street design: curvilinear, cul-de-sacs and loops. Loops and cul-de-sac are often found in the same development and termed as "loops and lollipops'' pattern (in this thesis "loops and lollipops" are referred as irregular road pattern). This type of design has several advantages. Residents of different communities prefer this design pattern since it offers quiet and safe streets with little fear of fast-moving vehicles. These types of streets are safer and quieter because there is hardly any through traffic and local traffic are forced to move slowly due to the design pattern of these roads. This type of design may also promote familiarity and neighborliness.

This design pattern is popular with developers because it sells well. Moreover, the infrastructure costs required in this type of design are significantly lower than the traditional interconnected grid pattern, which can require up to fifty percent more road construction. Since they carry no through traffic, they often have reduced standards for street widths, sidewalks, and curbs. For example, in Radburn, New Jersey in 1928, the introduction of cul-de-sacs reduced street area and the length of utilities, such as water and sewer lines, by 25 percent as compared to a typical gridiron street plan. Limited access roads, being disconnected, also adapt better to topography and can work around areas of high ecological or historical value.

However, the loops and lollipops pattern has been criticized on several grounds. First, it lacks the interconnectedness of other patterns like the gridiron. One must always leave the cul-de-sac via a collector street to go anywhere. Second, route choices are minimal, so one is stuck using the same path day after day. Third, since so much of the street infrastructure is devoted to semiprivate dead-end roads, a heavy load of connecting and through traffic is forced onto a relatively small collector and arterial system, contributing to suburban gridlock during peak periods of travel. Fourth, for pedestrians and cyclists, trips can be long and boring in loops and lollipops pattern, with inefficient connections to nearby destinations. Last, the pattern is difficult for a visitor to comprehend because there is little apparent structure, no unifying elements, and no clear describable pattern. Moreover, social interactions and neighborhood sense are not necessarily stronger in cul-de-sacs neighborhoods than traditional grid design neighborhoods. At the neighborhood scale, problems associated with cul-de-sacs may stem more from land use patterns than the street pattern itself. The single-use zoning of most cul-de-sac neighborhoods puts schools, jobs, and recreation and commercial centers at a distance from homes. Separation is further exacerbated by the lack of a well-connected pedestrian/bicycle network. Only rarely is there an interconnected pedestrian pathway system linking limited access road with adjacent streets, open spaces, and other neighborhoods.

2.1.3 Gridiron Street Pattern

In American planning history, street network design in the United States can be divided into two major phases (Wolfe, 1987). The first phase, lasting from the founding of the republic to World War II, was dominated by the classic gridiron pattern. Early planners in the United States relied upon the grid to provide spatial coherence to rapidly growing cities along the east coast, influenced in part by urban design considerations borrowed from Europe and by land reform in the post-Revolutionary United States (Wolfe, 1987). Grids organized the distribution of urban land in order to simplify real estate speculation and to rationalize transportation networks (Moudon and Untermann, 1987). Grids or grid-like patterns were established in many early American cities, including New York, Philadelphia, Washington, and Savannah. Gradually, this pattern expanded to major mid-western and western cities such as Chicago and San Francisco as the nation embarked on its westward expansion.

2.1.4 Decline of the Gridiron Pattern

The second phase of street network design began after World War II which rejected the grid pattern and emphasizing street hierarchy, curvilinear design, and disconnected networks (Wolfe, 1987). Discontent with certain aspects of the grid layout had begun in the nineteenth century. A diverse group of urban reformers began to associate the grid with many of the social and economic ills that plagued American cities at the end of that century. In their view, the monotony of the grid gave little attention to the open space needs of urban populations, fostered substandard housing, and allowed too little light and fresh air into the city. This judgment against the grid extended as well to aesthetic considerations: the superimposition of the grid onto undulating landscapes resulted in a loss of a sense of the natural contours of the land and increased as well the costs of construction via more earthworks (Wolfe, 1987).

The condemnation of the grid pattern as contributing to the ills of turn-of-the-century urban America was probably the result of the fact that the grid happened to be the prevailing street pattern during the industrial era. There is, in fact, no inherent reason why grids cannot allow for light and air in the same manner as more discontinuous street networks (Frank et al., 2003). Napoleon III's reconstruction of Paris during the mid-nineteenth century, for example, removed much of the city's narrow, winding street infrastructure and replaced it with the now-famous grid-like network of wide boulevards. While this reconstruction was intended to improve connectivity between major destinations within the city, it was also done to improve public health. The broad boulevards would, so Georges-Eugene Haussmann (chief architect of the city's redesign) believed, introduce more light and air into the city. The desire to improve public health through the introduction of nature into people's lives required, in Haussmann's view, the creation of a grid within the confines of the old city's boundaries (Saalman, 1971).

However, there is a major difference between Haussmann's view of the grid and American view of the grid. Because Haussman tried to solve the urban problems within existing urban boundaries whereas the other idea was to move design attention toward the suburban periphery ignoring existing urban centers. Therefore, the grid's major drawback can be pointed out in the American context is that as it was found only in the established city centers it had to be part of the reason for poor public health. This turn away from the grid can be interpreted as part of a larger movement that began to deemphasize the city as the place where the city's problems were to be solved. Rather, solutions to the ills of the industrial city began to be seen in the suburbs and in isolated, self-contained neighborhoods (Frank et al., 2003).

2.1.5 Limited Access Street Pattern

Although the basic rectilinear grid found in suburban communities remained generally unchanged until after World War II, the ideas that initiated the change emerged many decades earlier. The Garden City movement at the end of the 19th Century led to a “rediscovery” of the street system as a crucial design element and instigated a movement away from the grid toward a new pattern and scale of streets that would improve safety and increase light, air, and the sense of nature in suburban communities (Wolfe, 1987).

Raymond Unwin and Barry Parker were considered two of the advocates of Cul-de-sac and hierarchical street design when they were commissioned to design the suburban community of Hampstead Garden Suburb near London in 1904 (Southworth and Ben-Joseph, 1995). By their great effort, the “Hampstead Garden Suburban Act", a private bill was passed by Parliament in 1906, which suspended certain building regulations. The annulment of the by-law street regulations in Hampstead allowed Unwin to experiment with a variety of street forms and configurations that he believed would support the concept of a community envisioned by the Garden City movement and its founder, Ebenezer Howard (Southworth and Ben-Joseph, 1995).
For the first time, the cul-de-sac was systematically used throughout a development. Cul-de-sac is defined as the bottom of the sack, commonly refers to a dead-end street. It is a place which has no outlet except by the entrance. Moreover, the roadways in Hampstead ignored right angles and avoided regularity in every way. They meandered about aimlessly, comfortably, following the natural contour and advantages of the land. The residential streets were narrow and did not have an equal width (Southworth and Ben-Joseph, 1995). In short, they were designed to discourage traffic and kept it on the main through fares.

In the first decades of this century, Raymond Unwin directly influenced American architects and planners such as Frederic Law Olmsted, Jr., Clarence Perry, Henry Wright, and Clarence Stein for turning toward the neighborhood as the basic unit of planning for the city. Unlike the planners under Napoleon III, the American planning cohort advocated the belief that citizen’ needs for sufficient light, fresh air, and green space could not be met via designs that incorporated the grid. This group began the reorientation of urban design by changing the street network because the street network was seen as a key design element to fulfill these needs. Eventually, an alternative to grid, discontinuous street network patterns evolved in neighborhood-based planning. The work of these architects and planners created the ideals that became the bedrock of American subdivision design after World War II (Wolfe, 1987).

Planners began to categorize streets according to function and use. Interior neighborhood streets began to be designed for low traffic volume and speed and contained fewer intersections in order to discourage through traffic. Major arterials, designed to carry greater traffic volumes at higher speeds, were placed at the edges of neighborhoods in order to route through traffic around the neighborhood. Street networks became more curvilinear, which not only assisted with the goal of reducing connectivity on interior streets but also were seen as less monotonous and more natural than the grid pattern. By the 1930s, the movement's emphasis on the neighborhood had gained widespread acceptance and was put into practice in some of the most famous planning experiments in American history, including Radburn, New Jersey. During the immediate postwar period, these principles were borrowed by professional groups and government agencies and became widely used in the design of new suburbs (Wolfe, 1987).

2.1.6 Street Grid or Street Hierarchy

The older parts of most communities from Ohio west and in many communities east of that have a simple grid system of streets. There are several reasons the grid evolved. First, it created a logical subdivision of the national survey system used as a reference framework for all land from Ohio west. Second, many towns were originally laid out by railroad surveyors, who, with their engineering training, viewed the grid as a logical way to divide the rectangular parcels of land allocated to the railroads for development. Third, the grid created a simple pattern with essentially unlimited potential for expansion.

In the 1960s and 1970s, developers began to propose new developments with hierarchical street systems, designing a limited number of through streets, which provided connection through the development and to other parts of the community, and creating a number of subordinate streets that, because of their design, would handle only local traffic. The cul-de-sac (a street designed as a dead end street, usually short, with a turning circle at its end) is an easy example, but many developments included partial loops and even portions of modified grids. With a hierarchical street system, major through streets are designated in advance and designed accordingly. An extreme form of a hierarchical street system is the gated community. It is difficult to close off a grid, but putting guarded gates on a limited number of access points with in a hierarchical street system is simple. Many other developments lack gates but use a hierarchical street system to discourage through traffic. The philosophy behind the hierarchical street system is really a planning philosophy, designing certain roads for heavy traffic and creating other roads that, because of their position in the circulation system, will never carry significantly increased traffic. Today, there is a vigorous debate in planning over the merits of the grid compared with the hierarchical street system. Advocates of the grid argue that

• Because every street is a through street, the grid balances traffic loads between streets.
• The grid is pedestrian friendly because it generally provides the shortest possible distance from one point to a variety of other points
• The grid provides both rapid access and an infinite variety of alternative means of access for emergency vehicles.
• The grid is neo-traditional and associated with things such as front porches and human-scale development.

Advocates of a hierarchical street system argue that

• As the grid expands outward and streets nearer the urban core carry more traffic, the traffic load becomes so heavy that it interferes with residential uses on some streets.
• Under those circumstances, most cities improve a few streets through the grid as the major arterials and collectors, thus creating a hierarchical street system in an area that was not designed for it.
• With a grid system, the community must require rights-of-way and pavement widths that exceed current needs to allow for the fact that traffic will increase on some or all of the streets.
• With a street hierarchy, long-term traffic growth is planned, with most traffic increases occurring on streets planned for expansion.

• In a hierarchical system, traffic should never grow significantly on local streets, allowing them to be designed to an appropriate level; in contrast, the community can reserve very large rights-of-way along the major streets on which growth is expected to occur.
• The local streets in a hierarchy create ideal residential environments, much better than streets along a grid with growing traffic.
• With a street hierarchy, it is possible to plan for offices, apartments, or back yards to line the major streets, eliminating the problem of having front doors and driveways on busy streets something that occurs commonly in a grid.

A hybrid network includes elements of a grid interspersed with elements of a hierarchy.1 Planning in Kansas City, Missouri in the last part of the nineteenth century and the first half of the twentieth established a grid of traffic ways at 1-mile intervals, with an additional grid in most areas at about half-mile intervals. Within those gridded squares, however, much of the development took place with a hierarchical street design. A different type of hybrid network uses a grid or modified grid but replaces some streets on the projected grid with pedestrian and bicycle paths, thus providing more connections for pedestrians and bicycles and disrupting the driving grid to some extent in residential areas, where slower speeds and safety are more important than rapid transportation movement. One of the arguments used by advocates of a gridded street system is that it provides multiple points and routes of connection between any two locations. Connectivity is important, for a number of reasons. One reason that connectivity is important is to provide alternate routes for emergency vehicle access, in case one road is blocked by an accident or fall entrée.

Connectivity is also important for pedestrians. Disconnected streets can lead to long travel distances even between two locations that are very near each other. For someone driving a car, an extra half-mile or a mile of driving in such a situation wastes a little time and a little gas, but it does not have a major effect on that person’s life. In contrast, if someone is walking, having to go an extra half-mile or a mile not only adds minutes to the trip but is likely to discourage some people from walking at all. See Figure 2.1 for an example of the importance of such connectivity.

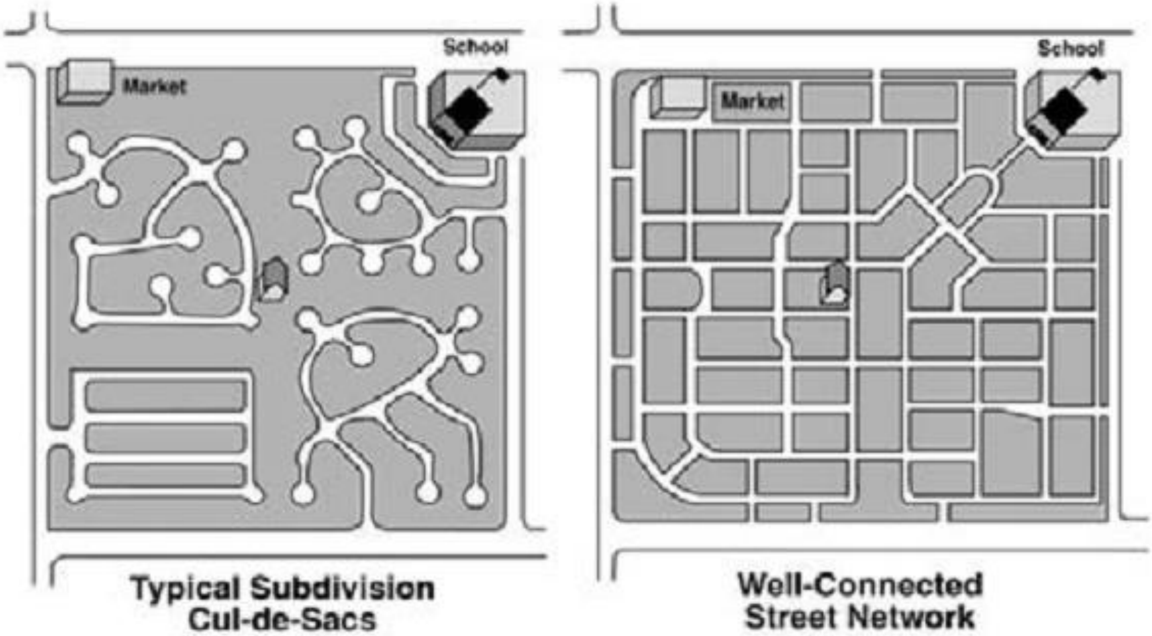


Fig. 2.1: Relative walking distance of two different street networks

[Figure 2.1 shows the relative walking distances from two homes that are equidistant from a school, based on different street lay outs. (Source: Davidson, 1998.)]

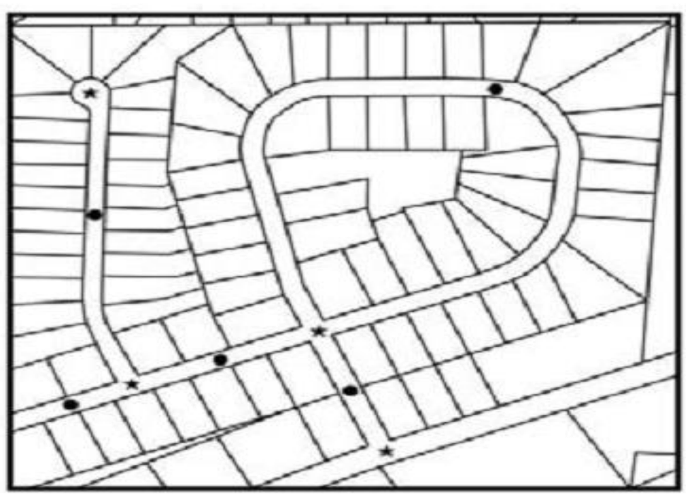


Fig. 2.2: An example of street connectivity system in North Carolina, USA

[Figure 2.2 illustrates an example of the Cary, North Carolina system of street connectivity. The town provides this explanation for this illustration: "The measure of connectivity is the number of street links divided by the number of nodes. Nodes exist at street intersections as well as cul-de-sac heads. Links are the stretches of road that connect nodes. Stub outs shall also be considered as links. In this example, there are five (5) links (circles) and four (4) nodes (stars); therefore, the connectivity index is 1.25.” (Source: Town of Cary Planning Department; drawing adapted by Ross Pierce.)]

As with most such debates, the right answer probably includes elements of both designs, resulting in a large-scale grid of through streets, with a hierarchy of more local streets in each sector of that grid. Figure 2.2 shows an alternative system for measuring connectivity, developed by the Town of Cary, North Carolina. The following are some of the considerations in crafting a solution:

• Most planners and engineers agree that developments with a single entrance and without links to adjacent developments are undesirable from a community perspective; considerations range from pedestrian routes to emergency vehicle access and to a general sense of community. The large-scale grid linking developments together at multiple levels addresses this issue.
• Some developments with hierarchical street systems include additional pedestrian and bicycle paths, providing more direct links than the street system; in some communities, those trails are wide enough and sturdy enough to handle emergency vehicles, thus offering an alternative form of ingress and egress.
• The modified hierarchy avoids the long-term conflicts that inevitably arise as traffic increases through older parts of a grid, making some formerly local streets undesirable as locations for individual residence.

2.1.7 New Urbanism

The curvilinear, disconnected street network design philosophy recently has come under a good deal of scrutiny. Planning at the neighborhood level has resulted in the creation of a set of physical barriers for movement across and between neighborhoods and different parts of the city. The separation of neighborhoods by arterials creates islands for local residents, in effect walling them off and making travel across neighborhood boundaries on foot or by bicycle dangerous (Untermann, 1987). Further, as the number of automobiles has increased in society, the car has come to dominate even the internal residential streets, also to the detriment of bicyclists and pedestrians (Wolfe, 1987).

The neo-traditional school of design, frequently referred to as “New Urbanism”, has recently challenged the design philosophy behind the disconnected street network. As the name implies, neo-traditional design deliberately attempts to recreate those characteristics of the older sections of American cities and, simultaneously, reject those design principles that are dominant considerations in contemporary suburban development. Compared with conventional suburbs, neo-traditional developments are characterized by somewhat higher densities, mixed uses, provision of public transit, accommodation of the pedestrian and bicyclist, and a more interconnected pattern of streets (Southworth, 1997).

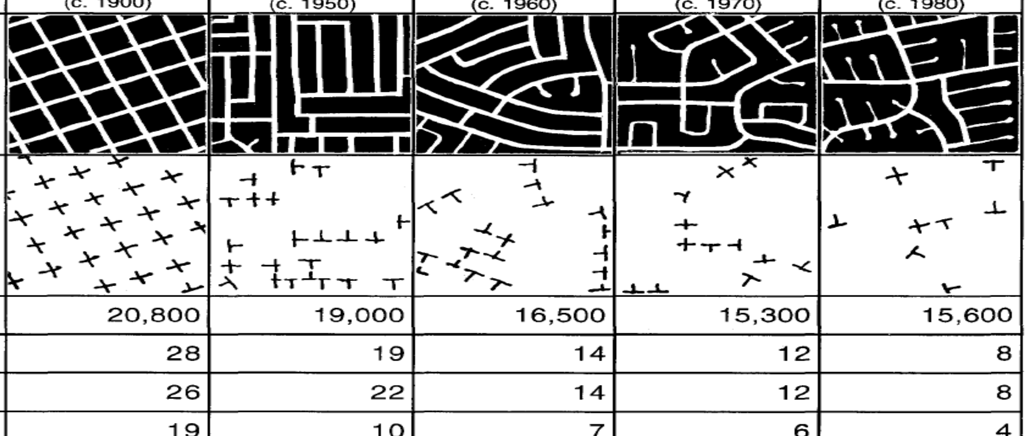
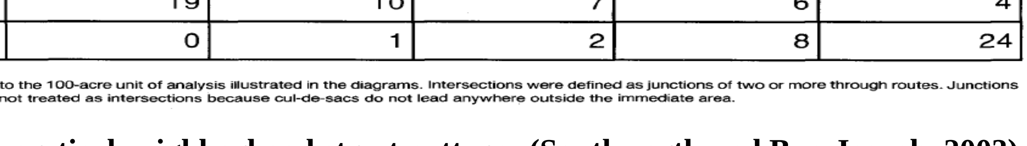
Two alternatives to the conventional low-density auto-dependent suburban track development have been proposed. One is the traditional neighborhood development (TDN) or neo-traditional development (NTD), which looks to the classic small town for its inspiration - it is walkable, has a clear civic structure, a mix of uses and housing types, and harmonious design of its buildings and spaces. The other alternative is the pedestrian pocket, sometimes referred to as pedestrian-oriented development (POD) or transit-oriented development (TOD). It is similar to the neo-traditional development in its concerns with walkability and convenient access to shopping and transit, but there is less emphasis on controlling architectural form and emulating historical styles (Southworth, 1997).

In all of these variants of neo-traditional design, the emphasis is on reducing the distances between trip origin and destination, expands public transit use and is more conducive to the formation of community sense than typical late-twentieth century subdivisions. Design schemes generally include the creation of grid-like street patterns but retain the focus on the neighborhood, including the acceptance of arterials at neighborhood boundaries (Southworth, 1997).

2.1.8 Classification of Different Street Patterns

In the successive postwar decades, planners and developers greatly expanded the street network design principles of the reform movement, increasing the degree of hierarchy, curvilinearity, and dis-connectivity in residential neighborhoods. Southworth and Owens (1993) provide a spatial analysis of the design characteristics of San Francisco Bay area suburban communities that were developed at different points in the century. The authors formulated design typologies for eight study areas at three scales: the community, neighborhood, and individual streets. Fig. 2.3 shows a typology of the different street networks found in their study areas.

As the Fig. 2.3 illustrates, over time, street network design patterns in the San Francisco Bay area transitioned from the rigidly geometric to the extremely disconnected and curvilinear and the observations are representative of broad dramatic changes in residential design over the past fifty years in different North American cities. The following five types of street pattern are examined in the study by Southworth and Owens (1993): (a) Gridiron; (b) Fragmented Parallel; (c) Warped Parallel; (d) Loops and Lollipops; and (e) Lollipops on a Stick. The characteristics of these five types of street patterns are briefly described below for better understanding their inherent properties.

	Gridiron (c. 1900)	Fragmented Parallel (c. 1950)	Warped Parallel (c. 1960)	Loops and Lollipops (c. 1970)	Lollipops on a Stick (c. 1980)
Street Patterns					
Intersections					
Lineal Feet of Streets	20,800	19,000	16,500	15,300	15,600
# of Blocks	28	19	14	12	8
# of Intersections	26	22	14	12	8
# of Access Points	19	10	7	6	4
# of Loops & Cul-de- Sacs	0	1	2	8	24

Note: This table refers to the 100-acre unit of analysis illustrated in the diagrams. Intersections were defined as junctions of two or more through routes. Junctions with cul-de-sacs were not treated as intersections because cul-de-sacs do not lead anywhere outside the immediate area.

Fig. 2.3: Theoretical neighborhood street patterns (Southworth and Ben-Joseph, 2003)

2.1.8.1 Gridiron

The open grid forms the structural core of many North American towns and cities. It is a simple system of two series of parallel streets crossing at right angles to form a pattern of equal-sized square or rectangular blocks. Grid type pattern is non-hierarchical, strongly interconnected, readily expandable, and offers a wide variety of possible routes through it and of access points in and out. Fig. 2.3 shows that this pattern has more land devoted to streets, as well as more blocks, intersections, and points of access than the other four patterns. Although the grid maximizes infrastructure costs, this pattern offers the shortest trip lengths and the largest number of route choices of any of the patterns. It also creates the most walkable neighborhood. This pattern dominated in the pre-World War II era when pedestrian travel was high, auto ownership was relatively low, and street construction standards were less automobile-oriented than they are today (Southworth and Owens, 1993).

2.1.8.2 Fragmented Parallel

The fragmented parallel pattern has been relatively popular since the 1950s. Though orthogonal in shape, this pattern varies from the traditional grid in several aspects. The blocks are reconfigured into long, narrow rectangles and L shapes. The streets, rather than being carried through, tend to corners. This limits the degree of interconnection, the choices of routes through a neighborhood, and the number of access points in and out. The long narrow blocks provide optimal frontage for residential building lots. Though this pattern has an almost equal street length as the gridiron, it reduces the number of blocks and access points compared with the grid network. Among the first kinds of neighborhoods to be built for automobile owners, this pattern reveals the diminishing value of pedestrian access and growing interest in longer blocks to provide more frontage for house lots (Southward and Owens, 1993). Due to the reduced number of access points, this pattern promotes self-contained private subdivision with limited connectivity.

2.1.8.3 Warped Parallel

The warped parallel pattern is formed when a parallel curvilinear pattern is present in the long, narrow blocks, T intersections and L corners of the fragmented parallel. Relative to fragmented parallel, it restricts the visual length of the street. This street pattern does not adopt topography since they are seen on the flat land. Leftover spaces in this pattern are filled in by occasional cul-de-sacs. The degree of connection, route choices, and access points are similar to the fragmented parallel pattern, but the curving streets make user orientation more confusing in these neighborhoods. The transition to an automobile subdivision becomes more pronounced in this pattern with significant reductions in intersections, street lengths, blocks, and access points (Southworth and Owens, 1993). As a whole, the pattern (in this thesis warped parallel and fragmented parallel road patterns are considered as a curvilinear road pattern) seems more unified and reflects a clearer conceptual basis than the fragmented parallel approach.

2.1.8.4 Loops and Lollipops

In this pattern, the parallel structure of the previous pattern is distorted by the presence of greater number of loops and cul-de-sacs. Loops and lollipops create a non-directional pattern of streets that tend to loop back on themselves. Interconnection is limited to several through streets not readily apparent in the plan. Blocks tend to be odd-shaped and frequently penetrated by street stubs. As this pattern has limited route choices and few access points, it increases privacy and the maze-like pattern is disorienting. This pattern, with its higher percentage of lots on short streets, succeeds, however, in creating quiet streets that are relatively safe for children. It limits pedestrian access because of the abundance of loops and cul-de-sacs. All these factors combine to increase auto trips and concentrate them on the few existing arterials, which result in unprecedented traffic congestion in many younger urban edge communities (Southworth and Owens, 1993). Thus, at the community scale, this pattern is proving undesirable for both the automobile driver and the pedestrian.

2.1.8.5 Lollipops on a Stick

Lollipops on a stick pattern are quite opposite to the open gridiron in terms of connectivity. This pattern is formed by branching off dead-end cul-de-sacs from a few easily recognized through streets. It maximizes privacy but interconnection is very limited. Blocks are few and large. A repeated parallel pattern of penetrating street stubs provides access to block interiors. This pattern limits intersections, route choices, and access points very much. This limited access design maximizes the number of house lots on short dead-end streets and hampers the pedestrian movement to a great extent (Southworth and Owens, 1993).

In summary, from the study by Southworth and Owens (1993) it is evident that the gridiron layout, built in neighborhoods at the turn of the century, contains the most amount of street frontage, the greatest number of intersections, the greatest number of blocks, the greatest number of access points, and the total absence of loops and cul-de-sacs. In contrast, the postwar communities examined by the authors contain street networks with fewer intersections, blocks, and access points and a greater number of loops and cul-de-sacs. In the view of the authors, these trends reflect an increasing desire to improve neighborhood traffic safety, especially for children, and increase residents' sense of privacy.

2.2 Transportation Modes and Alternatives

To make a city livable, a sustainable transportation system is an essential element of which existence can help to reduce potential adverse environmental, social and economic impacts of transportations. For the persuasion toward sustainable economic growth especially for developing countries, cities must have an effective and sustainable transportation system for both people and goods. A sustainable transport system has to allow the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem, health and with equity within and between generations (Gilbert et al., 2000). In order to endorse sustainability and efficiency in the transportation system, transportation engineers must need to consider all of the factors related to the neighborhood characteristics and land use information. Kennedy et al. (2005) defined that the process of achieving more sustainable transportation requires the suitable establishment of four pillars: effective governance of land use and transportation; fair, efficient, suitable funding; strategic infrastructure investments and attention to neighborhood design. Proper implementation, operation, maintenance and governance of various modes and alternatives of transportation together can improve a transportation system which can lead to a more livable and prosperous country. For both developed and developing countries, carpool, reduction of private vehicle usage and encouraging people for home office or teleworking could be effective as sustainable modes. In the subsequent sections, how these three modes can be effective are discussed.

2.2.1 Carpool

Regardless of size, many cities, nowadays, are suffering from severe traffic congestion and environmental pollution mostly due to the overdependence on private vehicle usage. Lower occupancy rate (number of passengers in a vehicle) is one of the main indicators of overdependence. Statics shows that occupancy rate in the USA is 1.59 (Davis et al., 2013) and 1.6 in Europe (European Environmental Agency, 2010) considering the 4 to 6 persons capacity of a standard passenger car. These figures represent 60-70% unused capacity of a car that leads to a non-sustainable transportation system. Carpool, ridesharing or communal use of private vehicles could be a good remedy along with public transportations that might yield an efficient use of this capacity. Increasing of communal use of private vehicles as well as carpool does not mean to keep individuals away from their private vehicles but to increase the occupancy rate. To understand carpool more, its definition, users' characteristics, how traffic congestion, environmental conditions, parking facilities are affected positively and merits and demerits of carpool are elaborately discussed in the next few Subsections.

2.2.1.1 Definition of Carpool

In general, carpool, car sharing and ridesharing are seemed quite same. But they are not. In fact, carpool and car sharing are different variants of ridesharing. Carpool car be conceptualized as a communal arrangement where more than one people as passenger not belonging to the same household share the use of a privately owned car for a trip or part of a trip and the passengers contribute to the owner's or driver's expenses (Ciari, 2012; Khattak and Rodriguez, 2006). In car sharing, the same vehicle is used by different persons but the vehicle is not privately owned. This vehicle is usually belongs to a car-sharing company and the users pay rents together for the trip. Moreover, the users usually do not travel together even though this can sometimes happen. Car sharing is not the communal use of a private vehicle and is designed for greater flexibility, comfort and short duration use (Steininger et al., 1996) whereas carpool is mainly for high occupancy rate which collectively leads to less traffic congestion and environmental pollution within a city area and also reduces hustle for the users using public transports for their daily trips. Carpool can be done for various types of trips although researchers have focused mostly on carpool for work, study, rarely on trips like child-related activities or taking children from/to school, leisure activities, personal activities and shopping (Delhomme et al., 2015; Bento et al., 2013; Buliung et al., 2010, 2012).

2.2.1.2 Carpool Users' Characteristics

Before examining carpooler's characteristics, it is necessary to determine just who constitute a carpooler. Carpoolers are to be considered as those who are to be unrelated individuals, who share responsibilities for vehicle provision and driving and to be related individuals who may or may not share responsibilities similar to unrelated individuals. In this regard, carpooling is of two types which are external carpool by unrelated individuals and internal carpool from same household individuals (Richardson et al., 1982). Again considering trip distribution and car sharing is as same as carpool, carpoolers are anyone who shares transportation to work in a private vehicle with another worker (Bonsall, 1981). Moreover, considering different carpool arrangements in which each commuters contributes a vehicle and driving assistance and those in which they don't, carpoolers are categorized in 3 different classes such as (1) Household carpoolers (Who commute together with at least one worker from the same household); (2) External carpoolers (who share transportation with unrelated individuals and who either share driving responsibilities or drive always); (3) carpool riders (who commute with other unrelated workers but who ride only and never provide a vehicle).

Users' age, gender, workplace, dwelling place and even type of days in a week varies carpool. According to Chung (2015), in Taipei city, Keelung city, New Taipei City, Yilan County and Taoyuan County of Taiwan, male (59.3%) prefer carpool than female (40.7%). People of age 25 to 45 are considered as working class in general of which majority (80.3%) of them are carpoolers. When public transportation facilities are less, 26.4% people use public transports while 73.6% use cars for carpool and use even motorcycles. Dwelling and working places are also two determinants for carpoolers. Employees of commercial and industrial areas mostly use carpool instead of other means of modes. Even carpool users vary by days of a week. In Taiwan, 30.2% of total population, use carpool on Thursday, 12.7-16.1% on other weekdays and 5.7-6.3% on weekends.

There are several other reasons that control carpool users. People who are concern about the adverse effects of congestion and environmental pollution prefer carpool (Deakin et al., 2012). A survey conducted by University of California Transportation Center in 2012 showed that the people who want to save time and money want more flexibility and comfort than public transportations prefer carpool. Moreover, safety and security especially for female travelers, various arrangements like waiting periods, pick up and drop off location, parking facilities, road toll, controlling the number of carpool users is necessary to promote carpool.

2.2.1.3 Factors Affecting Carpool

Carpool has been marked out as one of the most difficult forms of mode choice to achieve. Nevertheless, proper implementation of carpool in the transportation system results in various levels of success. This creative system helps the individuals and the government to achieve economic and environmental policy goals. The special flexibility offered by carpool (e.g. door to door or near door to door service) is similar to single occupancy vehicle use comparing with less flexible systems like public transports, para transits etc. with the addition of other commuter systems, involvement in the mixing of schedules, values, and norms, resource allocation make carpool formation and use a challenge over the short and long terms. The carpool alternative represents a modification of the commuters' use of existing systems within urban and regional environments. Those are systems that play an important role in ensuring economic productivity while facilitating participation in daily activities. Carpool, however, does not require a significant investment of public capital because it primarily makes use of existing infrastructure. So, the policy could be a vital role in the proper formation of carpool and its maximized implementation and outcome. Apart from that existing road infrastructure conditions, socioeconomic features, transport management, travel time, human behaviors play important role in facilitating carpool. The role of incentives an important issue for policy development and a key mechanism for encouraging changes in commuting behavior. Researchers identified some reasons for the success and failure of carpool and the motivations for taking up the practice. Commuter's decision to choice carpool as a travel mode depends on travel cost, safety and alleviating traffic congestions (Tischer and Dobson, 1979). Also, use of carpool can be increased by raising single occupancy vehicle costs (Washbrook et al., 2006). Likewise, Meyer (1999) suggested that the most effective traffic demand management policies are to be made and focused on the pricing of SOV usage. Some researchers argued on utility costs, travel time and travel costs. Savings in time are not as important as cost savings and the resolution of scheduling conflicts (Giuliano, 1992). Alternatively, the toll on driving including taxation and the elimination of free parking can vary the use of carpool (Taylor, 2006). Again, free parking or subsidy in parking only for high occupancy vehicles has tremendous potential for increasing carpool. Apart from these, environmental awareness, poor transit services between suburban areas, less traffic congestion promotes carpooling (Collura, 1994).

Kaufman (2002) emphasized that socioeconomic characteristics do not play a vital role in carpool. Furthermore, some researchers found that vehicle availability and education qualification are more important than other demographics factors or socially constructed qualities of labor force like gender (Ferguson, 1995). However, gender factuality in urban economy system indirectly influences carpool outcomes. It seems that income range of an individual or a family directly impacts on carpool. But Ferguson differs from it. He found that income has only an indirect effect on the choice to carpool in lower-income households, for income influences auto ownership and use. Morency (2007) found that the majority of passengers in carpools were from some household in Montreal. She argued that the issue of a lack of unity amongst different types of organizations is a cause for concern as there is a loss of potential carpoolers due to overlapping initiatives.

Human behavior and its process give rise to carpool. Ozanne and Mollenkoph (2009), Horowitz and sheth (1979) found that attitude of commuters is important in selecting carpool as a mode choice. They also found that perceived ease of carpool plays a role which includes a societal benefit, monetary incentives, scheduling and access to other carpoolers. So, policy should be focused on influencing attitudes. Charles et al. (2006) found that human race and ethnicity may play a role in carpool formation. Travel distance also affects carpool as a mode choice. Teal (1987) proposed that SOV drivers travel fewer distances than carpool users; therefore, the choice of carpool may also be controlled by the geography of the commute. More likely, scheduling flexibility is a significant determinant for carpool using (Tsao and Lin, 1999). They suggested that it is easier to create carpool with users who have consistent and typical work hours (e.g. 9 am to 5 pm).

Travel time is also an important factor in carpool use, for it potentially increases with an increase in carpool passengers. Increasing travel time, in response to carpool formation, could feedback into carpool decision process, leading to the dissolution of newly formed carpools and a return to SOV use. So, improving carpool infrastructure should be emphasized especially high occupancy vehicle lanes are more appeal to the policymakers (Giuliano et al., 1990).

2.2.1.4 Traffic Congestion and Carpool

With the rapid increase in the number of the urban vehicles, the limited road traffic resources are becoming more and more strained. The problem of traffic congestion, pollution and safety which are caused by a large number of travelers' trip, have also become important restrictive factors in cities' development. Developing public transportation system especially buses and exclusive lanes for buses could be a good solution. But during peak periods, it is common to see fewer buses in bus lanes and excessive private vehicles in other lanes reducing the total efficiency of the rood system.

Again, car ownership growth and increased number of single occupancy vehicles cause traffic congestion more frequent and intense in urban areas. This process results in air pollution, energy wastage and unproductive and unpleasant consumption of the time that persons have brought direct disadvantages not only for the users but also for the general economy and society at large. Congestion costs in the European Union are projected to increase by about 50% by 2050 to nearly 200 billion annually (European Commission, 2011) with a significant share of these costs attributed to urban transportation due to traffic congestion associated with automobile commuter trips. Ridesharing, carpool, and high occupancy vehicle lanes could be a good solution along with public transportation.

In modern cities, traffic congestion is intense during peak periods especially in commercial and industrial areas in working days. Cervero (1986, 1989) studied the effects of worksite characteristics on commuter mode choice. He found that the employees are most likely to share a ride if they commute long distances, work for a large company in a common area and work in non-professional and non-management positions. Teal et al. (1989), Margolin et al. (1978) also agreed with Cervero although they had different study location. They all concluded that human attitude is an important factor for determining ridesharing.

Marginal cost pricing offers the best solution for optimizing congested road traffic flow. According to the theory, road users using congested roads or single occupancy vehicle users must pay a toll in order to maximize social welfare and recompensed damage to. Time and environment. If the same amount of toll is for both SOV (Single Occupancy Vehicle) and HOV (High Occupancy Vehicle), users will be forced to use HOV as it divides the costs among the commuters. Therefore, carpool, HOV lanes and toll differentiation provide a cost-effective way to reduce traffic congestion (Turnbull et al., 1991; O' Sullivan, 1993).

2.2.1.5 Fuel Consumption, Environmental Pollution and Carpool

Transportation is a significant user of fossil fuel energy, much of which is wasted due to the slow movement of vehicles in congested conditions. Wastage of fuel can be reduced by developing more efficient engines and greater use of alternative fuels. But this strategy may not be very much effective due to excessive growth of private vehicle ownership which will lead to more traffic congestion. Reduction of vehicle counts could be a key strategy. The prime strategy for reducing vehicle counts is the introduction and expansion of public transportation services like bus rapid transit, light or heavy rail, carpool, cycling, and teleworking.

Carpool is an important alternative to private vehicle usage and public transportation system while private car provides significant comfort and flexibility. According to the US census bureau, in the USA there are approximately 130 million commuters with 86% of them using a car, a truck or a van (U.S Department of Commerce Census Bureau, 2014). The majority of the nation's workers (76%) drive alone, less than 10% use carpool (Mckenzie, 2014). So, fuel shortage in near future is for sure. Increased ridesharing or carpool in non-commercial passenger highway vehicles is a good strategy for the reduction of excessive fuel consumption (Jacobson and King, 2009). Jacobson and King (2009) showed that if no additional travel were required in a trip for ridesharing or carpool, the effect of adding one additional passenger in every 100 vehicles would lead to an annual savings of 0.80-0.82 billion gallons of fuel in the U.S.A; if one passenger were added in every 10 vehicles, the annual saving would be 7.54-7.74 billion gallons, representing 5.4% of fuel consumed by vehicles annually. Additional travel distance to pick up additional passengers reduces fuel savings but many people may see as monetary saving in purchasing fuel.

Apart from being underutilized and extremely wasteful, excessive private car ownership is a leading cause for localized pollutions. Transportation-related emissions are formed through fossil fuel incomplete combustions and evaporation and the effect on emission types and levels is determined by the number of vehicle trips, a number of active vehicles in the area, traveled distance and the condition of the vehicles. The pollutants, producing from the burning of fossil fuel by the vehicles, are mainly carbon mono oxides (CO), carbon dioxide (CO_2), nitrogen oxides (NO), hydrocarbons. These pollutants are the main source of producing smog and ozone in the atmosphere. They contain toxic air contaminants which are thought to cause serious health threats and which are present in exhaust fumes and are also emitted during refueling and greenhouse gases which contributes to global warming.

In Europe, road transport has been estimated to be responsible for approximately 71.4% if CO_2 emission, which corresponds to more than 20% of global emissions (European Union, 2012). Private car use accounts for the largest part of kilometers traveled and is considered as one of the most important contributors to air pollution (Lau et al., 2008; Mayer, 1999). Promoting eco-friendly transportation modes (such as public transportation, bicycle, walking or carpool) is becoming more and more frequent. However, even with increasing environmental awareness and concern, many road users are still car-dependent either by choice or constrained by circumstances (Stradling, 2007). One alternative route for car dependents is carpooling which has many advantages. The International Energy Agency (2005) estimated that carpool can reduce the number of kilometers traveled by 12.5%. This reduction will impact fuel consumption as the International Energy Agency (2005) estimated a 7.7% reduction in fuel use if one person was to be added to each commute. It will also help to reduce traffic congestion as well as time spent traveling and will lower CO_2 emissions (Minett and Pearce, 2011). Furthermore, it is estimated that people who carpool, for a distance of 48 km, for example, could save up to 33% of the monthly costs of commuting compared to those who choose to drive alone (TDM Encyclopedia, 2010).

2.2.1.6 Parking Demand and Carpool

In recent years, because of economic development, the private vehicle ownership growth rate has risen rapidly which makes traffic congestion an increasingly serious problem both in cities and urban areas. Excessive growth of private vehicle ownership causes a higher level of demands for purchasing along with environment pollutions, excessive fuel consumption etc. Public transports can reduce these problems but these cannot provide as much as flexibility, comfort, and freedom as private vehicles do. So, ridesharing, as well as carpool, has emerged as a productive solution for these problems.

During pick periods especially in commercial and industrialized areas, parking facilities are full to overflowing. To provide facilities, authority drains out capitals for infrastructures and waste valuable land which could be used for productive purposes. Carpool is a great solution for this kind of problem. Minett (2013) conducted a case study on how carpool affects parking facilities in five transit stations in Seattle. He found that if fully utilized carpool in those areas, parking demands were reduced by 50 spaces per day and increased ridership by 100 people per day. It would be equivalent to adding 100 parking spaces without incurring the estimated 3 million USD capital and 60000 USD annual operating costs associated with such an expansion. He also found that if fully utilized each day would short 466000 auto trips per years and regional fuel conservation would be in the order of 170000 gallons per year and greenhouse gas emission would be reduced about 1700 tons per year. To encourage people for carpool implementation of pricing policies could be useful in some areas. Raising tolls for single occupancy vehicles and lowering parking tolls for high occupancy vehicles would be effective.

2.2.1.7 Advantages and Limitations of Carpool

The existence of a sustainable transportation system in a city is a key element to make it livable. Proper distribution, management, and policies for various made choices make a transportation system sustainable. Public transportation and carpool play a vital role among the modes. Public transports are cheap but don't provide much comfort and flexibility. On the other hand, carpool provides passengers much comfort and flexibility though it is not as cheap as public transits. Apart from these, carpool is also helpful for the reduction of traffic congestion, environment pollution, fuel consumptions, and excessive parking demand. Carpool, however, does not require a significant investment of public capital because it primarily makes use of existing infrastructure. The carpool represents a modification of the commuters' use of legacy systems within urban and regional environments. Carpool leverages past capital investment in infrastructure, enabling a change in the culture of use of critical legacy systems (Garrison, 2007).

Carpool process also has some limitations also. First of all, it's about the safety and security of the users. Deakin et al. (2012) concerns about the safety and security of anonymous matching, as well as problems with stranding riders if they cannot find a match for the return trip. Moreover, program financing and program business model for ridesharing must be considered. Finally, there are concerns that dynamic ridesharing might pull drivers away from transit and non-motorized mode and into cars, a mode shift that might benefit program users but not the broader community. Registering drivers and passengers and verifying insurance and driving records can reduce safety concerns. Also, there is a psychological barrier to riding with strangers which will reduce the efficiency of carpool (Correia et al., 2011). Again, waiting for a ride for the users also reduces the efficiency of the carpool. Combination of carpool and ridesharing could be a good solution. Apart from all of these facts, the absence of dedicated lanes, proper management, policies, road pricing, parking facility pricing will reduce the efficiency of carpool which indicates an unsuccessful mode of the sustainable transportation system.

2.2.2 Telework

Since the mid of the last century, in most metropolitan areas in the world, the increasing number of vehicles creates problems like traffic congestion, environmental pollution, accidents, excessive fuel consumption, excessive capital investments for infrastructures. To influence peoples' vehicle usage with the aim of reducing these problems, a vast number of policies on travel demand management (Garling et al., 2002; Meyer, 1999), mobility management (Rye, 2002), transportation control measures (Pendyala et al., 1997), travel blending (Rose and Ampt, 2001), different travel mode choices (Public and private transportation, paratransit, walking, cycling, carpooling, ridesharing etc.) have been proposed and implemented. Among all of these, teleworking or working at home is one of the least focused modes that can reduce problems associating with traffic.Since the mid 70's, teleworking or home office has become a great deal of attention (Nilles, 1988; Salomon, 2000). Since the industrial revolution, individuals increasingly organized themselves in firms and institutions outside the location of the household (Mokyr, 1999). This shift in working location caused an increase in specialization and was mainly driven by the high fixed costs of capital. With the decline of industrial sectors and the rise of the service, government and non-commercial sectors, clustering of workers outside the household become more and more beneficial. However, with the rapid development and adaptation of information and communication technology and increase in flexibility of labor forces, workers nowadays are less constrained to work together at the same location. Working life can be much better if combined with family life. In this scenario, considering travel time and cost, safety, and security, emotional conditions working at home can be a good alternative to working out of the home. But the scenario of teleworking is not so much rich worldwide. Figures show that in the USA and within Europe; Finland, Sweden, and the Netherlands are the countries with relatively the largest number of teleworkers. According to De Graaff et al. (2007), a teleworker is an individual who works partly at home (or somewhere else than at work) and who uses information and communication technology for that purpose.

Fundamentally, teleworking or telecommuting are not same. In the Netherlands, teleworkers range from 3.3% - 6%. However, the percentage of people who are working at home will not exceed 3-4% of the total labor force (Steyaert and De Haan, 2001; De Graaff and Rietveld, 2004). These statics are not so much but still, these can be considerable. So, working at home still remains a marginal issue in spite of increasingly flexible labor force and increasing availability of various types of communication means. De Graaf (2004) agrees that teleworking increases workers income as they commute less and can do multitasks. In the next subsequent sections, factors related to home office, its sustainability, human behavior, advantages and limitation are discussed.

2.2.2.1 Factors Influencing Telework

Telework, telecommuting and virtual working are terms that often used to refer to employees who work periodically or exclusively for their employers from a remote location that is equipped with telecommunication technology to transfer work to the central firm (Hunton and Norman, 2010). Teleworking is basically both home-based and regional center based works. It can be part time or full time depending on the employer and employee demands, facilities, benefits and salary. Teleworking or working at home productivity depends on ICT access and availability, traffic availability travel modes, fuel consumption, traffic congestion, hourly earnings, contribution to GDP (Perincherry, 2009). Also, information technology training, work flexibility, organizational and personal commitment, job security, job satisfaction, human behavior and attributes, management support control teleworking.

There are other social factors that contribute to telework. Gender is a great issue for the choice of teleworking. Female favors teleworking more than a man because of taking care of children and maintaining a family. They can work during the hours when they are most productive. Women are also motivated by work flexibility, convenience, increased freedom and autonomy as well as by the stimulus and a sense of achievement which teleworking has provided them (Di Martino and Wirth, 1990; Chapman et at., 1995).

Marital status and number of children in the family play a significant role in controlling home office. Married employees tend to favor teleworking than their single counterparts (Yap and Tng, 1990; Azeez and Supian, 1996). This is largely due to time flexibility that allows work to be fitted around family commitments. Married employees do not have to travel to work daily and hence commuting time saved can be spent with family members which leads to improved family relations. So, home-based work or teleworking is a good solution for married employees who need to juggle time between work and family responsibilities (Handy and Mokhtarian, 1996). Again mothers of young children tend to opt for flexible work arrangement to increase their involvement with family and to take care of their children without sacrificing their career (Pratt, 1984). Furthermore, married employees were more receptive to admit that home-based office improves their work productivity than their unmarried employees. Therefore, teleworking may be a potential arrangement which allows married employees to combine their work and family responsibilities effectively. Again, individuals with higher level of organizational commitment will have a more favorable attitude towards teleworking than individuals with a lower level of organizational commitment. Apart from these, labor supply, leisure time, working monetary, condition wages income, individual's confidence controls teleworking. (De Graaff et al., 2007).

2.2.2.2 Sustainability of Telework and Home Office

For both infrastructural and socio-economic development of a region or country, sustainability, as well as stability in the transportation system, are important issues. These help to minimize adverse environmental and social impacts caused by the immature transportation system. Proper management of traffic demand with a minimum change in existing infrastructure can only ensure proper sustainability. In addition to public transports, reduction of private vehicles and increase in more user-friendly transportation modes, teleworking or working at home can also boost up sustainability in the transportation system. For this, well managed teleworking scheme should be considered and accepted as financially, environmentally and socially viable and reliable (James, 2004). Considering commuting cost and time, flexibility in workforce and workplaces, subsidies and environmental adverse effects, nowadays, public policy makers and planners strongly believe that home-based works or telecommuting as one of the most sustainable and competitive modes of commuting (Cox, 2004). At present, telecommuting has been actively promoted as a travel demand management strategy in compliance with US Federal Clean Air Act of the late 1980's (Handy and Mokhtarian, 1995; Dissanayake, 2008). Teleworking not only targets to reduce the amount of travel time but also to mitigate other transport related environmental impacts, including air pollution and greenhouse gas emissions.

It is a debate whether teleworking can be an alternative to working out of home or it can be complementary to other modes. If the first one is true, teleworking can contribute to urban sustainability. But if the next argument holds, the first one will not be true. Partially or entirely, the need for travel to workplaces is indisputable. Consequently, another issue that remains further investigation is about how teleworking of the household head impacts his or her non-commute travel or that of another household member. There are several approaches to measure the sustainability and impacts of teleworking on travel. The simplest way is to measure travel reduction by multiplying the frequency of telecommunicating by round-trip commute distance. Another approach is to measure actual changes in household travel under pre and post teleworking and usually includes travel changes of a control group or household members. Apart from these two, another least approach is the economic analysis of pre and post teleworking. If any of these approaches indicate effectiveness, teleworking will be sustainable in a rural or urban area. Although proper policy making and implementation also determines the level of sustainability of teleworking instead of working outside (Greene et at., 1994; Mokhtarian et al., 1995; Koenig et al., 1996; Nelson et at., 2007).

2.2.2.3 Productivity and Wage Issues of Telework

Telework has greatly increased in both popularity and use in recent years. Employers' understanding for predicted benefits that they can reap from a well-designed and implemented telework program now a days have been changed. This also changes the original driving forces act behind teleworking. Because of the rapid advancement in ICT sectors, telework changes the nature of the employer-employee relationship and may have some detrimental effects on organizations if telecommuting is not implemented strategically. Also, beneficial outcomes of teleworking mostly depend on wage issues for employees and productivity outputs for employers. Usually, individuals who work both in home and out of home for the same job will receive the same observed wage rate for both the hours they worked at home and out of home. However, those individuals who work at home most likely have a different productivity compared with the workers who work out of home. De Graaff et al. (2007) predicted that productivity difference between working out of home and at home are most likely to occur. For some workers, productivity at home may be higher than at work because they are less disturbed by colleagues. Moreover, employers may experience a positive effect. When employees work at home instead of the office, money spent for utility are saved as less workspaces are required. On the contrary, family members may interrupt workers at home. Moreover, it may be difficult for some people to combine working life with family affairs, especially having children around. Working at home decreases costs of physical workplaces, but managers' monitoring costs are increased. Furthermore, work may become less efficient where various people have to cooperated, due to higher coordination costs, when some colleagues' work at home. Working at home may be also considered as fringe benefits. Namely, employers may offer employees a trade-off between higher wages or possibilities to work at home. From a long-term view, It may be well that when people often work at home, they experience that they are less noticed on specific career opportunities or less considered by manages for promotion. De Graaff et al. (2007) focused that workers work at have wages are 19% lower than workers work out of home; only marginally significant. Moreover, this difference reduced by 80% when workers have access to an internet connection. Therefore, working at home and out of home seems to be more determined individual characteristics than by change in wage, commuting time and telecommunication connectivity. Policy to control human behavior and wage issues in both national and private sectors are necessary to promote working at home which may lead to a sustainable transportation system in a city both directly and indirectly.

2.2.2.4 Benefits and Limitations for Telework

The increase in the popularity of home-based working has some social benefits including advanced information-based economy, workers' flexibility, simultaneous participation in work life, family life and social life both for employers and employee. This increase in popularity is reflected in the fact that as much as 30% of the US labor force does not work at home at least part of the week (US Bureau of Transportation Service, 2006). Early telework Initiatives in the US were rooted in social policy issues, focused on the beneficial impact that telework would have on the environment and traffic in urban areas (Arnol, 2006). To reduce traffic congestion and to expand employment opportunities for physically disabled population, the governments of the European Union are actively promoting telework at present. Telework itself and policies to promote it are mainly designed to reduce traffic and resultant levels of pollution by alleviating a number of vehicles on the road as telework affords opportunities to secure significant social benefits by reducing the environmental impact of traffic (Harpaz, 2002). Telework was also promoted secondarily as a mean of alleviating the strain being placed on many public transportation systems (Harpaz, 2002). Less traffic on road causes less traffic congestion and pollution and most likely results in fewer traffic accident possibilities.

Comparing to the past, nowadays, employers have become keener to understand the problems that employees and job applicants with physically disabled faces. Telework can allow employers to more fully utilize the skills and abilities of such individuals. This is true not only for disabled people but also for others who may be constrained for other reasons like elderly or new parents who need or prefer to be at home with a child. According to Harpaz (2002), telework is also beneficial in individual's level. In any work structures as the absence of direct supervision is likely to increase the individuals level of responsibility within the organization and this is even more for the teleworker. Independently, work can fulfill an individual's need for autonomy, control, responsibility, and challenge. The individual's control over work Occurs when more freely and naturally. Key advantage can be achieved both for individuals and for society. For individuals, increase in autonomy, human resource capacity, savings in direct expenses, flexibility to organizations can be gained. For society, reduction in environmental damages, solutions for population having special needs, savings in infrastructure and energy can be gained through telework.

There are some limitations for employers, individuals, and society also. To individuals, limitations are possible potential isolation, lack of separation between home and work and work and family conflict. Limitations are much more for organizations and for employers: performance measurement, lack of innovative teamwork, safety and liability, the sufficiency of technology, security of information, selection of eligible employees, costs involved in the transition to new work method, training and damage to commitment are the main drawbacks for employers. For society, amount of limitation is less but it's the most severe society is faced with a danger of creating detached individuals.

By the advancement of ICT sector, teleworking has started to change the working life and living patterns of the millions around the globe dramatically. Increased work flexibility, autonomy, responsibility, and productivity are the main features of telecommuting. With all these advantages, there are also some crucial issues where new balance must be found; they are: centralization and decentralization of work, workers protection and job creation, reduction of travel distance and pollutions, reduced energy consumption, complexity of technology, working time, family time and leisure time; new work opportunities for women and disabled as against the increased marginalization of certain category of workers.

There are some facts that governments, individuals, organizations, and society should emphasize on to make home-based working more sustainable and effective. Governments can influence the speed at which telework spreads by actively promoting it with the help of rural development and creation of jobs as well as implementing new policies in regard to the continuing high cost of telecommunications. Workers and employers need to weigh up more precisely the options offered by telework. Managers are often still skeptical about the benefits of telework when compared with what they find as obstruction such as difficulties in control and supervision of teleworkers accompanied by decreasing loyalty to the company. Trade unions are worried about possible negative implications for job security for their union strength and the spreading of precarious work.

As telework is not developing as fast as predicted, there is still time in which it can usefully be organized and developed. During the 1990's and after, sufficient thought is given to the implication of the large-scale spread of telework for working conditions and the organizations of enterprises. In this regard, the ILO can certainly play a role in promoting analysis and discussion on how to direct the development of telework to the benefit of the parties concerned. Codes of practice or international guidelines could be designed to provide organizational flexibility for both managers and workers while ensuring adequate legal and social protection for teleworkers. In keeping with the mandate of ILO as a triparty organization, workers' involvement could play a central role in the development of an international standard. Information and awareness raising activities (for instance international seminars on telework, pilot studies etc.) could further engage discussion between all the parties concerned on future telework scenarios and on the suitability of various combinations of technology and human resources and how they may best be managed and organized.

2.2.3 Private Vehicle Usage

Since the last century, the automobile has been recognized as a major force shaping the social organization, city forms, public investment priorities and the habits of everyday life. Individuals, societies, and the governments, over the year, have become more concerned about the problems caused by increased auto ownership accompanied by its benefits. Pollutant emissions, fuel consumption, noise pollution, neighborhood intrusion, road safety and fatalities are the main problems that they are concerned about. Comparing to others, auto owners do not compensate equally. So, on behalf of the society, the governments must appoint and compensate the costs. Almost all auto-oriented societies have confronted these problems. To make a city livable, excessive auto ownership and its rapid expansion should be controlled. As an example, 23.5 million new cars used the roads of China in 2014 (OICA, 2015a), a number expected to reach more than 30 million by the end of 2020 (LeBeau, 2012). Globally GHG emission from the transportation sector has increased more than double since 1970 and around 80% of this increase is estimated to come from road vehicles (IPCC, 2014).

Besides these statistics, the rapid increase in private vehicles is a reality. People are buying more cars every day and are using them no matter if the car ownership is low like in Asia or South America or very high like in Europe and North America (Poudenx, 2008). According to the EU green paper on urban mobility (2007), 1% of the EU GDP is lost every year because of congestion and excessive vehicle ownership rate. Also, the transportation sector is responsible for 40% of CO_2 and other GHG emissions and 70% of other pollutant emissions. Among all the sources, excessive presence of private car private cars is a major source of GHG emission and the prime cause of congestion, excessive investments and fatalities (Barla et al., 2011). Promotion of public transportation system like BRT, MRT, carpool, bicycling, teleworking and even walking can reduce these problems. Apart from all of these, reduction of auto ownership and policies supporting it can reduce all the problems related to the transportation sector. However, without a solid understanding of the causes and factors that contribute to the growth of auto ownership, it will be very difficult to evaluate, judge and select which policy options are most likely to be effective in solving the problem. In the subsequent section, they are discussed.

2.2.3.1 Characteristics of Car Users

No doubt that private cars and their rapid growth are the major causes of congestion, pollutions and other traffic-related problems (Goodwin, 1996). To overcome these problems, certain policies car to be made and implemented. But to measure the environmental and social costs of urban transportation systems, knowledge on car use behavior is essential. With this, evaluation of transportation policies is also necessary. Various factors control the car use behavior. Mostly age, gender, occupation, income range etc. control car use behavior. As an example, females like to travel alone and don’t like to share a ride with strangers than males (Chung, 2015). Previous research has shown that workers, young people, and males are likely to drive more (Hensher, 1985; Mannering, 1983). Car use behavior is also affected by vehicle characteristics. Van Wissen and Golob (1992) determined the relationship between car usage and choice of fuel type. Household size, housing quality is another category that affects car use patterns (Borgonie et al., 2002). Land use and transport policies for public transports and others affect car use behavior at a microscopic level (Garling et al., 2002; Jakobson et. al., 2002). From behavioral and psychological points of view, personal attitudes, motives and habits also affect car use behavior

(Gardner and Abraham, 2008; Steg, 2005). Referring to the earlier research to above, the measure of car usage was not time dependent. Annual mileage and weekly car frequency are also included in this matter. A measure of annual mileage car roughly show the drivers' car use behavior, drivers with similar values of statistical car use measures may have different car use pattern. In these case, time of day of car usage is also important. Harris and Webber (2012) did an analysis of time of day car use patterns and their impact on the provision of a vehicle to grid services. It seems that peak and off-peak hours of a working day controls driver's car use behavior more than non-working days of holidays.

2.2.3.2 Effect of Car Ownership in Trip Generation and Trip Distribution

The effects of owning a car on the trip generation and distribution can be measured in individual, family, social and national level. But it seems that measuring at the family level is easier. Families who have a car have very different travel behavior comparing to those who do not have a car. Substantially, a number of journeys increases when a car is acquired and some existing journeys shift from public transport to the private cars is the reason for the increase in total travel demand. Wootton (1999) figures out the changes in behavior that occurs because of acquiring a car. Families not having a car make about 2.5 journeys in each weekday while families with a car make about 6.4 journeys which means 3.9 new journeys have been generated (in the sense of producing a completely new activity). This change is even greater when a family owns more than one car. UK national survey suggested that the families with having more than two cars, make 8.7 journeys in each weekday on average. Other researchers also confirmed that this type of changes (Wootton and Pick, 1997; LCCMT, 1962; West Midlands Transport Study, 1968; DOT, 1986). Though the change varies with the location and some factors involved, the effects are all the same. The change in the generation of trips also depends on the number of people in a family, employment, the age of the family members, number of persons holding driver's license, family's incomes, place of living, type of housing and so on. Comparing with the growth of private cars and its result, it is irrelevant to construct new roads. So, policy making and implementation on a national level to reduce the growth of private car is necessary.

2.2.3.3 Traffic Congestion, Road Pricing and Personalized Transit Usage

Traffic congestion, nowadays, has been considered one of the most challenging urban problem faced in major cities in the world. There are several ways that can reduce traffic congestion. Use of public transportation, cycling and walking for short distance, teleworking could be good solutions. Actually, traffic congestion occurs when traffic flow rate is greater than the road's traffic holding capacity. Exclusive private vehicles are the main cause of decreased traffic holding capacity on the road. So, reduction of private vehicles could be a good solution. To do so, it is necessary for management agencies to understand the travelers' choice, behavior and travel patterns so that efficient measures like pricing, policy making, and tradable credit can be advised to reduce the excessive growth of personalized vehicles. Jia et al. (2016) believe that living costs, income, number of family members, level of comfort during travel, trip generation, distribution and termination, the location of employment and housing etc. control private vehicle ownership. For example, in Singapore, because of higher car ownership and maintenance cost, most of the households have only one private car, by which household travels are made in the morning. People used to drop their children off at the school and go to their workplaces which increases traffic congestion in certain areas during certain times. Road pricing as a policy to reduce excessive car ownership could be a good remedy for decreasing traffic congestion. A survey conducted by the Texas Transportation Institute in 2007, congestion cost about 87.2 billion USD in the 437 urban areas of the US compared to 73.1 Billion USD in 2004. This represents an average delay per peak traveler of 38 hours per year, with the user from large metropolitan areas of 3 million residents or more experiencing 51 hours of delay. Due to increasing concern about global warming, climate change, and infrastructure funding crisis, the severity of traffic congestion encourages authorities to implement road pricing to stimulate demand management and revenue generation. The concept of road pricing was generated and imposed back in 1920 to 1960's. The concept was like this: charging motorists a fee that could be used to capture the extremities they impose on the system and lead to an optimal allocation of resources.

If somehow, the above-mentioned problems were solved, people would still be faced with congestion. When congestion gridlocks a system, certainly the system won't be viewed as a sustainable system. Also, congestion is a problem of density and solution lies in controlling the density. Commercial and public vehicles should be managed properly, but should not be decreased. So, controlling and reducing private vehicles by suitable policy making and implementing them firmly with road pricing could be a good solution for traffic congestion problem.

2.2.3.4 Private Car Ownership and Environmental Issues

Climate change and air quality are two main environmental challenges in urban and rural areas. Among other sectors, road transport is one of the main contributors to the environmental damage. The rate of pollution by private cars are far higher than public transportation. Increased number of private cars is the main reason behind this. Road transportation, in European Union, has been estimated to be responsible for approximately 71.4% of CO_2 emission which corresponds to more than 20% of global emission (European Union, 2012). Of all the modes of transportation, cars account for the largest proportion of emission of polluting substance, such as CO_2, thereby contributing to global warming (OECD, 2002). For example, greenhouse gas emission for urban travel in Canada in 1997 was 215 gm. per passenger-kilometer for a car or light truck, 77 gm for urban transit, 26 gm for intercity bus travel and of course 0 gm for walking and cycling (Transport Canada, 2008). In OECD countries, commuting accounts for an estimated 25% of household travel (OECD, 2002). Private vehicles consume around 2-3 MJ/person-km compared with 1MJ/person-Km. Despite efforts at reducing the environmental impacts of cars by technological innovation, various trends tend to nullify this positive effect such as increased car ownership, increased frequency of car use and increased teleworking. Therefore, to make a transportation system sustainable and to reduce pollution, promoting public transportation, eco-friendly vehicles, cycling, ridesharing, telecommuting in associate with the controlled and reduced use of private vehicles could provide good opportunities. So, the governments both in developed and developing countries should initiate innovative policies to control private vehicles and their travel frequency without disrupting daily life of people.

2.2.3.5 Parking Problems and Private Car Ownership

Due to economic development in recent years caused by industrialization and urbanization, the number of public and private vehicles are increasing rapidly which results in traffic congestion and environmental pollution all over the world. With these problems, providing parking facilities for private vehicles has become acute. Especially in commercial areas, there are usually less parking facilities than the parking demand. So, people have to travel more, burn more fuel to find parking spots causes more pollution and congestion. Even people have to park their vehicles in the refuge lanes of the streets. Increased car ownership and single occupancy vehicle rate make these problems acuter. Increasing parking facilities is not the solution for this. This action will cause wastage of valuable lands for parking facilities along with government and private investments. Shoup (2006) conducted a survey in 11 major cities in the USA and found that on average 30% of the cars in congested downtown traffic were cruising for parking and the average cruising time is 8.1 minutes per car. Even if the cruising time is smaller, the cumulative consequences will be startling since there are always a large number of cars moving in these areas. Shoup (2011) also claimed that the average time to find a parking space in Manhattan is 3.1 minutes in 2008. Cruising for parking, cars generate 325 tons of CO_2 and cause 36600 miles traveling the effective assignment of parking spaces can largely improve the congested traffic based on recent technological advances in information collection and storage. Parking problems can be reduced by providing infrastructures which cause drainage of investment. In commercial areas, people should use carpool, ridesharing, public transportation, cycling, walking. Companies could provide transits to the employees that give them home to workplace round trip. Besides, all of these, local authority can implement higher tolls for single occupancy vehicles, lower parking price for high occupancy vehicles and controlling the growth of private vehicles by any means necessary.

2.2.3.6 Reduction Policies of Car Use

The previous century witnessed an extreme growth in private vehicles which also continues to this century (OECD, 2001). This results in various negative consequences like congestion, pollution, wastage of investments all over the world (Van Wee, 2007). To minimize these consequences, different travel demand management measures have been designed and implemented over the years (Kitamura et al., 1997). Needs, desires, and obligations to participate in and out of home activities can control private vehicle usage (Axhausen and Garling, 1992; Vilhelmson, 1999). Any changes in these factors cause potential consequences. Car use reduction set by households also depends on the family structure, income, age, gender, communication facilities. For this, every household needs to choose among alternatives regarding trip generation, distribution, mode choices and passenger activities. Social policies taken by the government that controls household activities and properties can reduce private vehicle usage in micro level.

Various TDM strategies including carpooling, parking policies, park and ride, promotion of public transportations like BRT, MRT, walking, cycling, teleworking road pricing for vehicle occupancy rate together can reduce car usage in national level. Meyer and Miller (2001) suggested that well-conceived and aggressively promoted travel demand management and Policies can decrease peak period traffic in many cities by 10-15-%. Sundo and Fujii (2005) suggested that different departure time for work set by the authority can reduce traffic jam. In 2008, Bangladesh government used daylight saving policy to reduce traffic congestion by controlling departure time for schools and offices which also promoted ridesharing and car use reduction. In 2003, Seoul Metropolitan Government introduced a TDM measure which is known as no driving Day in a week. In this measure, people of a certain area are not allowed to use private cars once in a week, encouraged to use public transport which shows a great deal of reduction in congestion, pollution, and single occupancy vehicle usage.

Car use increases with longer travel distances and public transport scarcity. Shorter distances results in shorter car trips, more use of buses, metro rails, carpooling, greater use of walking and cycling. Locating business in central areas along with clustering residential, commercial, industrial and agricultural areas may minimize transportation demand and private car dependency (Tonnesen, 2015). He also suggested that land use policies need to be combined with wider national strategies to reduce car use. Tennoy (2012) suggested some measures to reduce private car use such as:

(1) Encouraging urban densification and clustering rather than urban sprawl

(ii) Locating commercial, industrial business and residential area in a car independent fashion

(iii) Imposing toll for road and parking for single occupancy vehicles

(iv) Subsidies for high occupancy vehicles and as well as public transports.

(v) Improving road infrastructure facilities

(vi) Improving public vehicle facilities.

(vii) Encouraging for walking and cycling

In a nutshell, sustainability in the transportation system and well-developed communication are the key factors for a nation's development among others. This sustainability in transport system alone can save money and time which can be used in other sectors for development. Well-arranged public transportation, reduction of private cars, ridesharing and telecommuting together can trigger a country's ultimate development. Proper policy-making and their firm and inflexible implementation can only lead to the ultimate sustainability of a transport system.

CHAPTER THREE: DATA AND METHODOLOGY

This chapter describes the data collection procedure, formulation of data and the methodology used in the effect of neighborhood characteristics for three models of transportation. Linear regression models will be used to identify the different factors affecting and promoting the sustainable transportation modes and alternatives. Three models will be developed for three different transportation modes and alternatives. The formulation of these models will help to understand how these models can be employed to fulfill the main objective of the study; that is, to identify the effects of neighborhood characteristics on carpool, teleworking and private vehicle usage as well as the elasticity of the variables, will be calculated. The sources of the database used in this study are discussed before describing the mathematical formulation of the model, its assumptions and estimation procedures.

3.1 Main Steps in Methodology

In order to achieve the objective of the study, the suitable statistical model needs to be selected. The models will be developed using a percentage of different mode usage data at the community level that correlates the usage of carpool, teleworking and private transit usage with road infrastructure, land use, socioeconomic and demographic factors. Model calibrations will then be done to find the best model among the competing set of models. The result of the final model will then be analyzed to find the critical factors contributing to carpool, working at home or home office and private transit uses. The methodology can be divided into three main steps: `

(a) Collection and processing of road infrastructure, land use, and demographic data to develop the regression model;
(b) Selection of statistical model to express the percentage of carpool, working at home or home office and private transit uses as a function of various neighborhood characteristics data such as road infrastructure, land use, socioeconomic and demographic characteristics of different communities.

(c) Analysis and interpretation of model findings; that is, engineering judgment of factors affecting carpool, working at home or home office and private transit uses in communities at Calgary. Finally, to check the relative significance of independent variables from the final model, the elasticity of the variables will be calculated.

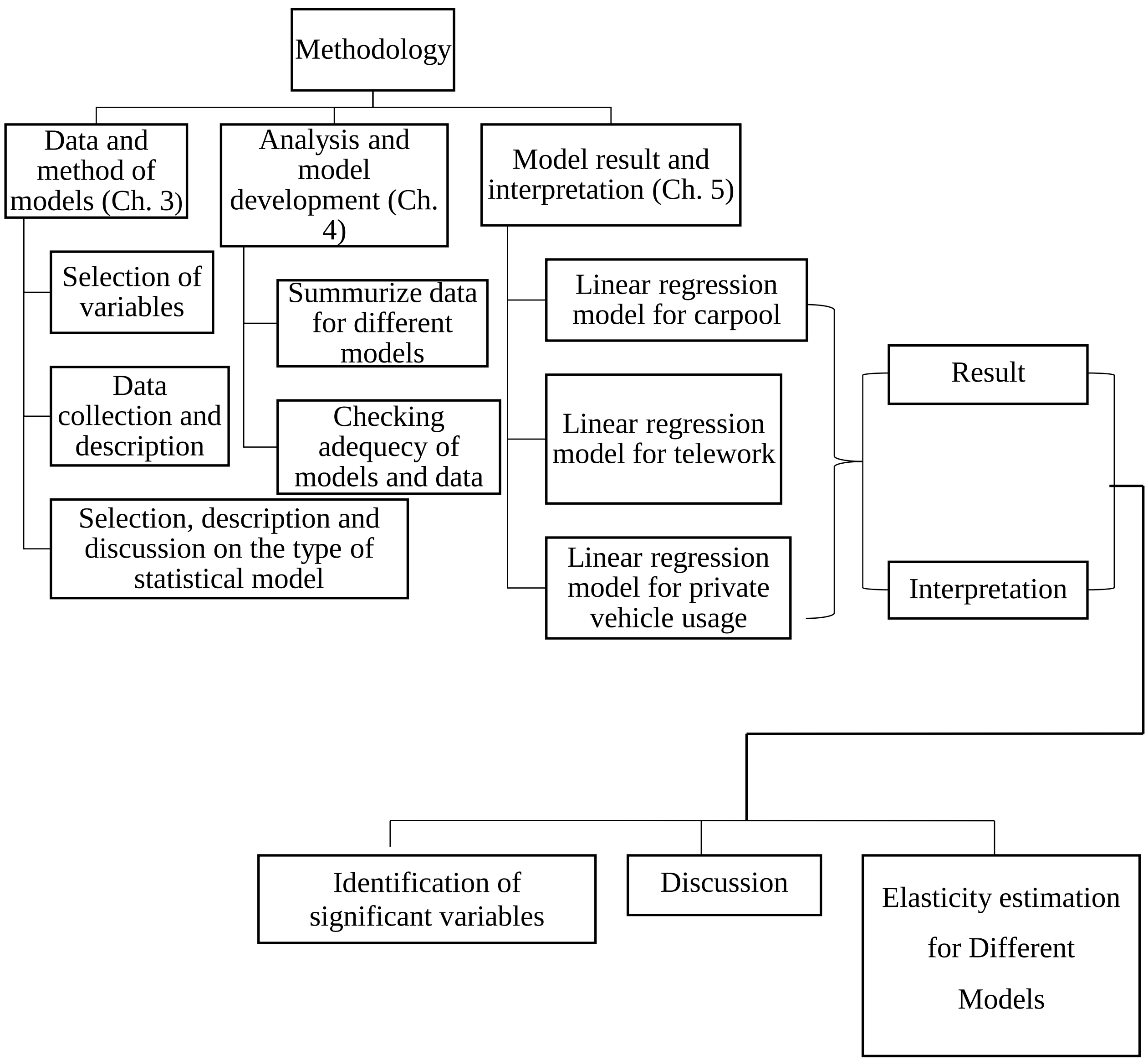


Fig. 3.1: Methodology flow chart

3.2 Description of Data

3.2.1 Mode Share and Increased Auto Dependency in Calgary

Auto ownership has a significant effect on mode choice. If the auto ownership increases sustainable transportation mode such as carpool and mode alternatives like working at home or home office and private transit uses is reduced. Fig. 3.2 shows, in Calgary it was found that the household auto ownership has been increased over the last forty years. In 1971, it was 1.19 vehicles per household where it becomes 1.85 vehicles per household in 2011 and the average household auto ownership has increased from 1.50 vehicles per household in 1981 to 1.85 vehicles per household in 2011. This is a 23% increase in auto ownership despite a decline in the average household size (from 2.77 people per household in 1981 to 2.58 people per household in 2011) (CARTAS, 2013).

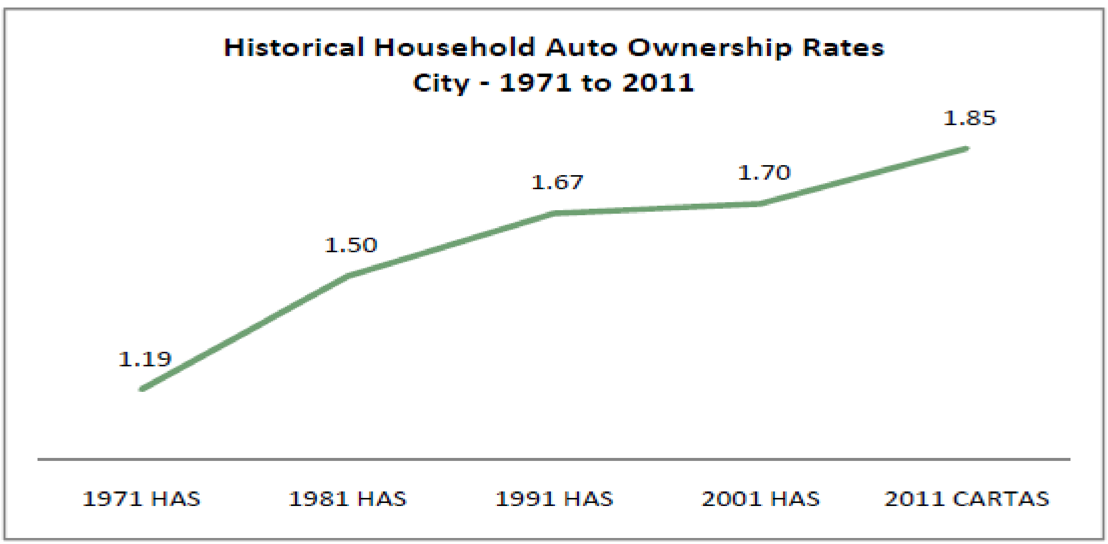


Fig. 3.2: Auto ownership rate (CARTAS, 2013)

In Fig. 3.3 mode share of all person trips in Calgary city has been shown. Most of the trips produced are carried by the auto driver (Driver owns the vehicle). Walk, bike and transit carry the lowest number of trips. As it can be seen from Fig. 3.3 from 2001 to 2011 mode share of the auto passenger has been increased from 20.9% to 22.2% where mode share of the walk has been decreased from 13.2% to 11.7% which is really very alarming statistics for the city of Calgary (CARTAS, 2013).

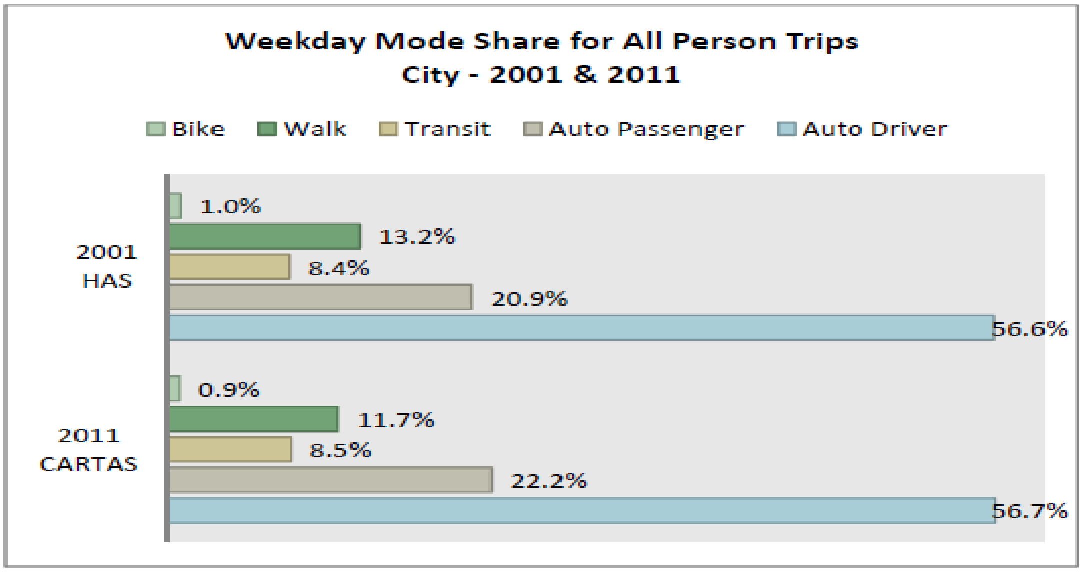


Fig. 3.3: Weekday mode share for all persons' trips (CARTAS, 2013)

Transportation modes and alternatives choices for different communities of the city of Calgary have been provided by the Department of Transport Authority, Calgary, Canada (2011). Appendix A shows percentage usages of different transportation modes and alternatives for different communities in Calgary. Table 3.1 summarizes APPENDIX A.

Table 3.1: Summary of the percentage usage of different transportation modes and alternatives in the City of Calgary

Mode Choices and alternatives	Public Transport	Bicycle	Walk	Carpool	Tele work or Home Offic-e	Private Vehicle Usage as Driving Alone	Motorcycle	Other Modes
Average (%)	16.8734	1.1356	5.656	3.832	2.927	69.116	0.0541	0.405
Maximum (%)	49.1103	5.7823	67.31	21.11	10	94.828	0.3841	5.115
Minimum (%)	1.72414	0	0	0	0	15.152	0	0

According to table 3.1, in Calgary, private vehicles are the highest used mode for commute. In each community, on average private vehicle usage is about 70%. The Maximum usage of private vehicle is about 95% in Eagle Ridge and the minimum usage is 15.15% in Downtown Commercial Area. The second highest usage is public transportations. In each community of Calgary public transportation usage is on average 17%. The maximum usage is in University of Calgary area by 49% and the minimum usage is 1.72% in Eagle Ridge. Carpool usage is on average 3.83%; maximum 21 % in Spruce Cliff, lowest usage 0% in Eagle Ridge, Roxboro, Saddle Ridge Industrial Area and Shepard Industrial Area. Teleworking is on average is 2.93%; maximum 10% in Scarboro, minimum 0% in Saddle Ridge Industrial Area, Skyline East, University of Calgary Area.

3.2.2 Socioeconomic, Demographic and Infrastructure Data

Demographic and socioeconomic characteristics for each community were collected from the 2011 census data published by Statistics Canada. Information about population, income, and employment, family, social isolation, education, diversity, and housing were found for each community of Calgary in census 2011 database.

In census database, population is characterized into various age groups such as 0-4, 5-14, 15-19, 20-24, 25-34, 35-44, 45-54, 55-64, 65-74 and 75+. Information on population diversity is also provided in the census data. For example, number of aboriginal population, immigrant population, visible minority population and languages used are available for each community. The economic condition of each community is captured by the unemployment rate, average income, median income and percentage population of low income in private household.

Family-related information includes marital status (never married, common law, married, separated, widowed and divorced), percentage of children at home by different age group (i.e. under 6 years of age, 6-14 years, 15-17 years, 18-24 years, 25 years and over), and average number of children at home. Educational level is classified as less than high school, high school graduation, trades, and college and university. The number of people in each education level and their percentages are presented. Population, aged 15-24, by school attendance is also provided.

Housing-related information such as occupied private dwelling by structure type (i.e., single detached, semi-detached, row house, apartment- detached duplex), occupied private dwelling by tenure (i.e., owned, rented, average rent per month), number of occupied dwellings by dwelling size, average number of people in each household of a community are available. Area related information such as total commercial area (8%), agricultural area (4%), park area (27%), residential area (49%), industrial area (12%), and community area was also incorporated in the analysis.

Note that not all information that is found in the census will be used in our study. Only demographic, socioeconomic, household data which are relevant to our study will be considered. Previous research works will be used as a guideline in this regard. Information available in the community census will further be used to form different factors affecting sustainable transportation modes. Each factor may be further subdivided into various independent variables.

3.2.3 Classification of Street Patterns in Calgary

In addition to extracting information from population census, data on the road network and other infrastructures, such as school, train stations, etc. are collected from the City of Calgary Department of Transportation. The street pattern in each community is classified using a scheme that is adapted from a similar scheme developed by Southworth and Ben-Joseph (2003). The authors classify street patterns into five categories: gridiron, fragmented parallel, wrapped parallel, loops and lollipops, and lollipops on a stick. Their classification is shown in Fig. 3.4. However, it should be remembered that while

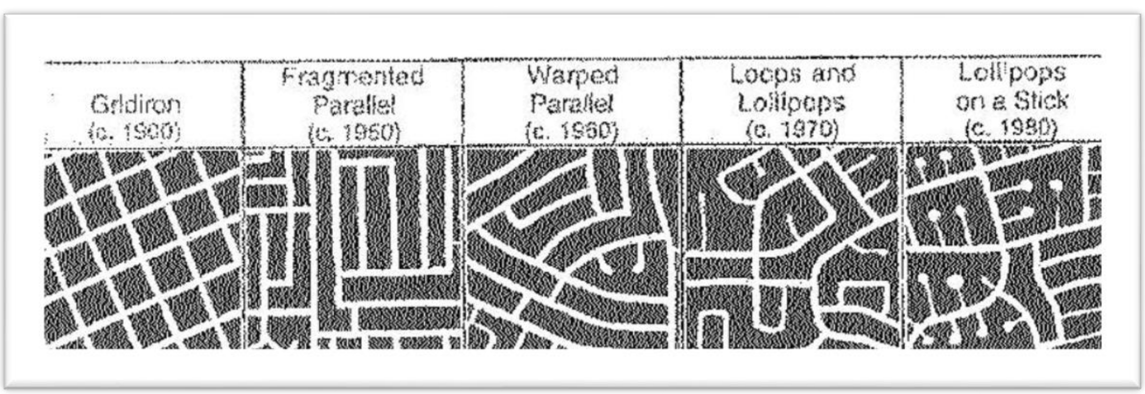


Fig. 3.4: Classification of street patterns (Southworth and Ben-Joseph, 2003)

Differentiating among these patterns, several characteristics are often discussed, including the length of roads, number of intersections, number of access points, number of loops and cul-de-sac, etc. However, two neighborhoods may have many of these features in common but still have a different layout or pattern. For example, a neighborhood with a fragmented parallel pattern may have approximately the same amount of roads, intersection, etc. as another neighborhood with a warped parallel design. Nevertheless, the orientation of the pattern may still play a vital role in determining crash occurrences when all else being equal.

Since most of the social economic and demographic data were collected from the Canadian Population Census, the community areas defined by the census were used as the basic unit of analysis for street patterns. The street maps of different community areas defined by the Census were extracted from the street directory for the City of Calgary. Based on the street maps, the research team first classified the street pattern of each unit using the classification scheme shown in Fig. 3.4. It was found that there were very few units with fragmented parallel pattern and this category was merged with the grid-iron pattern since it contained mainly straight roadways. Also, the two street patterns with the lollipop designs were merged into one to simplify the classification scheme. Finally, a separate category called mixed pattern was created to allow for community areas with the mixed design. An example of a community in each of the four categories is shown in Fig. 3.5.

(a) Community: Downtown commercial
street pattern: Gridiron

(b) Community: Fairview
street pattern: Warped parallel

(c) Community: Strathcona Park
street pattern: Loops and lollipops

(d) Community: Abbeydale
street pattern: Mixed

Fig. 3.5: Examples of road patterns in Calgary (Southworth and Ben-Joseph; 2003)

Of the 185 community areas considered in our study, 32 are classified as grid-iron, 50 are wrapped parallel, 63 are loops and lollipops, and the remaining 40 are mixed pattern (see Fig. 3.6).

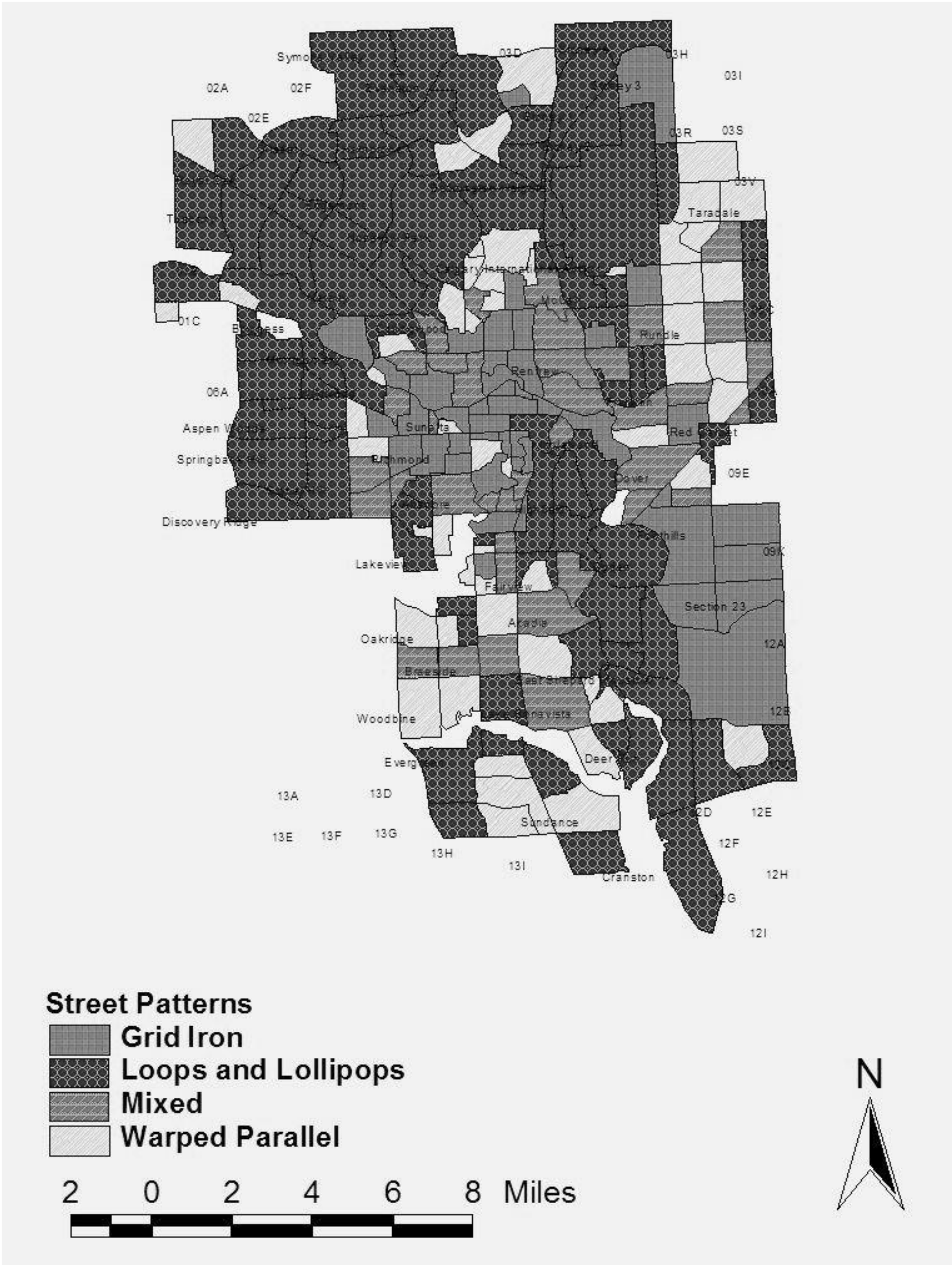


Fig. 3.6: Distributions of street patterns in Calgary

3.3 Linear Regression Model

The principle objective of this study is to build up a relationship between a dependent variable and a set of independent variables. To develop this relationship, statistical analysis is necessary. The statistical analysis model must examine:

a) Whether the observed patterns in the data are consistent with theoretical prediction;
b) The relationship between a quantitative dependent variable and one or more quantitative or qualitative independent variables.

So, the relationship will be in the form of

$$Y = f(X) \tag{3.1}$$

Where the dependent variable Y is a function of a set of independent variables X. In the analysis, the Y represents the percentage of different sustainable modes and X represents the different street pattern, socioeconomic features, road infrastructure etc.

Various types of statistical analysis can be used to build up this relationship such as linear regression, Binomial distribution, Poisson distribution etc. The sample data or the observed values for this study are continuous. So, the predicted dependent variable must be continuous. Again, in the analysis, random coefficients can be used. But, the use of random coefficients in the analysis may show heterodasticity in data. In residual analysis, because of heterodasticity, variance will not remain constant and it may vary at a constant rate which proves that data are inadequate for analysis. To avoid such problems, linear regression analysis can be used. In linear regression analysis, dependent variables are assumed to be continuous and also, the variables are assumed to be homosedastic (means variance remains constant). Again, linear regression analysis is suitable for a wide variety of relationships between variables. Moreover, the assumptions of linear regression analysis are often suitably satisfied in many practical applications. Furthermore, regression model outputs are relatively easy to interpret and communicate to others, numerical estimation of regression models is relatively easy.

3.3.1 Assumptions of the Linear Regression Model

Linear regression is used to model a linear relationship between a continuous dependent variable and one or more independent variables. Most applications of regression seek to identify a set of independent variables that are thought to co-vary with the dependent variable. There are numerous assumptions of the linear regression model, which should be thought of as requirements. When any of the requirements are not met, remedial actions should be taken, and in some cases, alternative modeling approaches should be adopted.

The following assumptions of the linear regression model are explained by following Washington et al. (2010).

3.3.1.1 Continuous Dependent Variable Y

The assumption in regression is that the response is continuous; that is, it can take on any value within a range of values. A continuous variable is measured on the interval or ratio scale. Although it is often done, regression on ordinal scale response variables is incorrect. For example, count variables (nonnegative integers) should be modeled with Poisson and negative binomial regression. Modeling nominal scale dependent variables (discrete variables that are not ordered) requires discrete outcome models.

3.3.1.2 Linear-in-Parameters Relationship Between Y and X

The form of the regression model requires that the relationship between variables is inherently linear- a straight-line relationship between the dependent variable Y and the independent variables. The simple linear regression model is given by:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \varepsilon_i \tag{3.2}$$

In this algebraic expression of the simple linear regression model, the dependent variable Y is a function of a constant term β_0 and a constant β_1 times the value X_1 of independent variable X for observation i, plus a disturbance term ε_i. The subscript i corresponds to the individual or observation, where i = 1, 2, 3…n. In most applications, the response variable Y is a function of many independent variables.

3.3.1.3 Observations Independently and Randomly Sampled

An assumption necessary to make inferences about the population of interest is that the data are randomly sampled from the population. Independence requires that the probability that an observation is selected is unaffected by other observations selected into the sample. In some cases, the random assignment can be used in place of random sampling, and other sampling schemes such as stratified and cluster samples can be accommodated in the regression modeling framework with corrective measures.

3.3.1.4 Uncertain Relationship Between Variables

The difference between the equation of a straight-line and a linear regression model is the addition of a stochastic, disturbance, or disturbance term, ε. This disturbance term consists of several elements of the process being modeled. First, it can contain variables that were omitted from the model — assumed to be the sum of many small, individually unimportant effects, some positive and others negative. Second, it contains measurement errors in the dependent variable or the imprecision in measuring Y again assumed to be random. Finally, it contains random variation inherent in the underlying data-generating process.

3.3.1.5 Disturbance Term Independent of X and Expected Value Zero

The requirements of the disturbance term ε can be written as follows:

$$E[\varepsilon_i] = 0 \quad (3.3)$$

$$VAR[\varepsilon_i] = \sigma^2 \tag{3.4}$$

Equation 3.4 shows that the variance of the disturbance term, σ^2, is independent across observations. This is referred to as the homoscedasticity assumption and implies that the net effect of model uncertainty, including unobserved effects, measurement errors, and true random variation, is not systematic across observations; instead, it is random across observations and across covariates. When disturbances are heteroscedastic (vary systematically across observations), then alternative modeling approaches such as weighted least squares or generalized least squares may be required.

3.3.1.6 Disturbance Terms Not Auto-Correlated

This requirement is written as follows:

$$COV\left[\varepsilon_{i\,,}\varepsilon_j\right] = 0 \; if \; i \neq j \tag{3.5}$$

Equation 3.5 specifies that disturbances are independent of observations. Common violations of this assumption occur when observations are repeated on individuals, so the unobserved heterogeneity portion of the disturbance term ε is the same across repeated observations. Observations across time often possess autocorrelated disturbances as well. When disturbances are correlated across observations, generalized least squares or other correction methods are required.

3.3.1.7 Regressors and Disturbances Uncorrelated

This property is known as exogeneity of the regressors. When the regressors are exogenous, they are not correlated with the disturbance term. Exogeneity implies that the values of the regressors are determined by influences “outside of the model.” So Y does not directly influence the value of an exogenous regressor. In mathematical terms, this requirement translates to

$$COV\left[X_i, \varepsilon_j\right] = 0 \; for \; all \; i \; and \; j \tag{3.6}$$

When an important variable is endogenous (depends on Y), then alternative methods are required, such as instrumental variables, two and three stage least squares, or structural equations models.

3.3.1.8 Disturbances Approximately Normally Distributed

Although not a requirement for the estimation of linear regression models, the disturbance terms are required to be approximately normally distributed in order to make inferences about the parameters from the model. In this regard, the central limit theorem enables exact inference about the properties of statistical parameters.

3.3.2 Regression Fundamentals

Regression seeks to provide information and properties about the parameters in the population model by inspecting properties of the sample-estimated betas, how they behave, and what they can tell about the sample and thus about the population. The linear regression model thought to exist for the entire population of interest is

$$E[Y_i|X_i] = E\left[\beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \cdots + \beta_{p-1} X_{p-1,i}\right] \quad (3.7)$$

The true population model is formulated from theoretical considerations, past research findings, and postulated theories. The expected value of Y_i given covariate vector X_i is a conditional expectation. In some texts, the conditional expectation notation is dropped, but it should be understood that the mean or expected value of Y_i is conditional on the covariate vector for observation i. The population model represents a theoretically postulated model whose parameter values are unknown, constant, and denoted with betas, as shown in Equation 3.7. The parameters are unknown because Equation 3.7 is based on all members of the population of interest. The parameters (betas) are constant terms that reflect the underlying true relationship between the independent variables X1, X2,…,X_{p-1} and dependent variable Y_i, because the population N is presumably finite at any given time. The true population model contains p parameters in the model, and there are n observations.

The unknown disturbance term for the population regression model (Equation 3.7) is given by

$$\varepsilon_i = Y_i - \bar{Y}_i = Y_i - E[\beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \cdots + \beta_{p-1} X_{p-1,i}] \quad (3.8)$$

Regression builds on the notion that information is learned about the unknown and constant parameters (betas) of the population by using information contained in the sample. The sample is used for estimating betas random variables that fluctuate from sample to sample and the properties of these are used to make inferences about the true population betas. There are numerous procedures to estimate the parameters of the true population model based on the sample data, including least squares and maximum likelihood. The following description is explained from Washington et al. (2010).

3.3.2.1 Least Squares Estimation

Least squares estimation is a commonly employed estimation method for regression applications. Often referred to as "ordinary least squares" or OLS, it represents a method for estimating regression model parameters using the sample data.

Consider the algebraic expression of the OLS regression model shown in Equation 3.7. OLS, as one might expect, requires a minimum (least) solution of the squared disturbances. OLS seeks a solution that minimizes the function Q (the subscript for observation number is not shown):

$$Q_{min} = \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2_{min} = \sum_{i=1}^{n} (Y_i - (\beta_0 + \beta_1 X_i))^2_{min} = \sum_{i=1}^{n} (Y_i - \beta_0 - \beta_1 X_1)^2_{min} \quad (3.9)$$

Those values of β_0 and β_1 that minimize the function Q are the least squares estimated parameters. Of course, β_0 and β_1 are parameters of the population and are unknown, so estimators B_0 and B_1 are obtained, which are random variables that vary from sample to sample.

By setting the partial derivatives of Q with respect to β_0 and β_1 equal to zero, the least squares estimated parameters B_0 and B_1 are obtained:

$$\frac{\partial Q}{\partial \beta_0} = -2\sum_{i=1}^{n}(Y_i - \beta_o - \beta_1 X_i) = 0 \qquad (3.10)$$

$$\frac{\partial Q}{\partial \beta_1} = -2\sum_{i=1}^{n} X_i(Y_i - \beta_0 - \beta_1 X_1) = 0 \qquad (3.11)$$

Solving these equations using B_0 and B_1 to denote the estimates of β_0 and β_1, respectively, and rearranging terms yields

$$\sum_{i=1}^{n} Y_i = nB_0 + B_1 \sum_{i=1}^{n} X_i \qquad (3.12)$$

$$\sum_{i=1}^{n} X_i Y_i = B_0 \sum_{i=1}^{n} X_i + B_1 \sum_{i=1}^{n} X_i^2 \qquad (3.13)$$

Solving simultaneously for the betas in Equations 3.12 and 3.13 yields

$$B_1 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^{n}(X - \bar{X})^2} \qquad (3.14)$$

$$\beta_0 = \frac{1}{n}\left(\sum_{i=1}^{n} Y_i - B_1 \sum_{i=1}^{n} X_i\right) = \bar{Y} - \beta_1 \bar{X} \qquad (3.15)$$

3.3.2.2 Maximum Likelihood Estimation

The previous section showed the development of the OLS estimators through the minimization of the function Q. Another popular and sometimes useful statistical estimation method is called maximum likelihood estimation, which results in the maximum likelihood estimates, or MLEs. The joint density of observing the sample data from a statistical distribution with parameter vector θ, such that

$$f(x_1, x_2, \dots, x_n, \theta) = \prod_{i=1}^{n} f(x_i, \theta) = L(\theta|X) \qquad (3.16)$$

For the regression model, the likelihood function for a sample of n independent, identically, and normally distributed disturbances is given by

$$L = (2\pi\sigma^2)^{-\frac{n}{2}} EXP[-\frac{1}{2\sigma^2}\sum_{i=1}^{n}(Y_i - X_i^T\beta)^2] = (2\pi\sigma^2)^{-\frac{n}{2}} EXP[-\frac{1}{2\sigma^2}(Y - X\beta)^T(Y - X\beta)] \quad (3.17)$$

As is usually the case, the logarithm of Equation 3.17, or the log likelihood, is simpler to solve than the likelihood function itself, so taking the log of L yields

$$LN(L) = LL = -\frac{n}{2}LN(2\pi) - \frac{n}{2}LN(\sigma^2) - \frac{1}{2\sigma^2}(Y - X\beta)^T(Y - X\beta) \quad (3.18)$$

Maximizing the log likelihood with respect to β and σ^2 reveals a solution for the estimates of the betas that is equivalent to the OLS estimates, that is $B = (X^TX)^{-1}X^TY$.

3.3.3 Regression Model Goodness-of-Fit Measures

According to Washington et al. (2010), goodness-of-fit (GOF) statistics are useful for comparing the results across multiple studies, for comparing competing models within a single study, and for providing feedback on the extent of knowledge about the uncertainty involved with the phenomenon of interest. Three measures of model GOF are discussed: R-squared, adjusted R-squared, and the generalized F test. To develop the R-squared GOF statistic, some basic notions are required. Sum of squares and mean squares are fundamental in both regression and analysis of variance. The sum of square errors (disturbances) is given by

$$SSE = \sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2 \quad (3.19)$$

The regression sum of squares is given by

$$SSR = \sum_{i=1}^{n}(\hat{Y}_i - \bar{Y})^2 \quad (3.20)$$

And the total sum of squares is given by

$$SST = \sum_{i=1}^{n}(Y_i - \bar{Y})^2 \tag{3.21}$$

The SSE is the variation of the fitted regression line around the observations. The SSR is the variation of the fitted regression line around, and SST is the total variation — the variation of each observation around. It also can be shown algebraically that SST = SSR + SSE. Mean squares are just the sum of squares divided by their degrees of freedom. SST has n-1 degrees of freedom because 1 degree of freedom is lost in the estimation of Y. SSE has n – p degrees of freedom because p parameters are used to estimate the fitted regression line. Finally, SSR has p – 1 degrees of freedom associated with it. As one would expect, the degrees of freedom are additive such that n – 1 = n – p + p – 1. The mean squares, then, are MSE = SSE/(n – p) and MSR = SSR/(p – 1). The coefficient of determination, R-squared, is defined as

$$R^2 = \frac{[SST - SSE]}{SST} = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \tag{3.22}$$

R^2 can be thought of as the proportionate reduction of total variation accounted for by the independent variables (X). It is commonly interpreted as the proportion of total variance explained by X. When SSE = 0, $R^2 = 1$, and all of the variance is explained by the model. When SSR = 0, $R^2 = 0$, and there is no association between X and Y. Because R^2 can only increase when variables are added to the regression model (SST stays the same, and SSR can only increase even when statistically insignificant variables are added), an adjusted measure, $R^2_{adjusted}$, is used to account for the degrees of freedom changes as a result of different numbers of model parameters, and allows for a reduction in $R^2_{adjusted}$ as additional, potentially insignificant variables are added. The adjusted measure is considered to be superior for comparing models with different numbers of parameters. The adjusted coefficient of multiple determinations is

$$R^2 adjusted = 1 - \frac{\frac{SSE}{n-p}}{\frac{SST}{n-1}} = 1 - \left(\frac{n-1}{n-p}\right)\frac{SSE}{SST} \tag{3.23}$$

The following guidelines should be applied:

- The R^2 and $R^2_{adjusted}$ measures provide only relevant comparisons with previous models that have been estimated on the phenomenon under investigation. Thus, an $R^2_{adjusted}$ of 0.40 in one study may be considered "good" only if it represents an improvement over similar studies and the model provides new insights into the underlying data-generating process. Thus, it is possible to obtain an improvement in the R^2 or $R^2_{adjusted}$ value without gaining a greater understanding of the phenomenon being studied. It is only the combination of a comparable $R^2_{adjusted}$ value and a contribution to the fundamental understanding of the phenomenon that justifies the claim of improved modeling results.
- The absolute values of R^2 and $R^2_{adjusted}$ measures are not sufficient measures to judge the quality of a model. Thus, an R^2 of 0.20 from a model of a phenomenon with a high proportion of unexplained variation might represent a breakthrough in the current level of understanding, whereas an R^2 of 0.90 of another phenomenon might reveal no new insights or contributions. Thus, it is often better to explain a little of a lot of total variances rather than a lot of a little total variance.
- Relatively large values of R^2 and $R^2_{adjusted}$ can be caused by data artifacts. A small variation in the independent variables can result in inflated values. This is particularly troublesome if in practice the model is needed for predictions outside the range of the independent variables. Extreme outliers can also inflate R^2 and $R^2_{adjusted}$ values.
- The R^2 and $R^2_{adjusted}$ assume a linear relationship between the response and predictor variables and can give grossly misleading results if the relationship is nonlinear. In some cases, R^2 could be relatively large and suggest a good linear fit when the true relationships are curvilinear. In other cases, R^2 could suggest a very poor fit when in fact the relationships are nonlinear. This emphasizes the need to plot, examine, and become familiar with data prior to statistical modeling.
- The R^2 and $R^2_{adjusted}$ values are bound by 0 and 1 only when an intercept term is included in the regression model. When the intercept is forced through zero, the R^2 and $R^2_{adjusted}$ values can exceed the value 1 and more caution needs to be used when interpreting them.

Another measure for assessing model fit is the generalized F test. This approach is a general and flexible approach for testing the statistical difference between competing models. First, a full or unrestricted model is estimated. This could be a model with ten independent variables. The full model is fit using the method of least squares and SSE is obtained — the sum of square errors for the full model. For convenience, the sum of square errors for the full model is denoted as

$$SSE_F = \sum_{i=1}^{n}\left(Y_i - \hat{Y}_{Fi}\right)^2 \tag{3.24}$$

Where the predicted value of Y is based on the full model.

A reduced model is then estimated, which represents a viable competitor to the full model with fewer variables. For example, this could be a model with nine independent variables, or a model with no independent variables, leaving only the Y-intercept term B_0. The sum of squared errors is estimated for the competing or reduced model, where

$$SSE_R = \sum_{i=1}^{n}\left(Y_i - \hat{Y}_{Ri}\right)^2 \tag{3.25}$$

The logic of the F test is to compare the values of SSE_R and SSE_F. Recall from the discussion of R-squared that SSE can only be reduced by adding variables into the model, thus $SSE_R \geq SSE_F$. If these two sum of square errors are the same, then the full model has done nothing to improve the fit of the model; there is just as much "lack of fit" between observed and predicted observations as with the reduced model, so the reduced model is superior. Conversely, if SSE_F is considerably smaller than SSE_R, then the additional variables add value to the regression by adding sufficient additional explanatory power. In the generalized F test the null and alternative hypotheses are as follows:

$$H_0: all\ \beta_k = 0 \tag{3.26}$$

$$H_a: all \beta_k \neq 0 \tag{3.27}$$

In this test, the null hypothesis is that all of the additional parameters in the full model (compared to the reduced model) β_k are equal to zero.

When the null hypothesis is true (making the F test a conditional probability), the F* statistic is approximately F distributed and is given by

$$F^* = \frac{\frac{SSE_R - SSE_F}{df_r - df_F}}{\frac{SSE_F}{df_F}} \approx F(1-\alpha; df_R - df_R, df_F) \tag{3.28}$$

Where $df_F = n - p_F$ and $df_R = n - p_R$ (n is the number of observations and p is the number of parameters). To calculate this test statistic, the sum of square errors for the two models is first computed, then the F* statistic is compared to the F distribution with appropriate numerator and denominator degrees of freedom. Specifically,

$$If\ F^* \leq F(1-\alpha; df_R - df_R, df_F), then\ conclude\ H_0\ ;$$

$$If F^* \geq F(1-\alpha; df_R - df_R, df_F), then\ concude\ H_a \tag{3.29}$$

The generalized F test is very useful for comparing models of different sizes. When the difference in size between two models is one variable, the F test yields an equivalent result to the t-test for that variable. Thus, the F test is most useful for comparing models that differ by more than one independent variable.

Following Montgomery and Runger (2003) the hypotheses of t-test are

$$H_0: \beta_1 = \beta_{1,0} \tag{3.30}$$

$$H_0: \beta_1 \neq \beta_{1,0} \tag{3.31}$$

Where it has been assumed a two-sided alternative and the t-statistics is

$$T_0 = \frac{\beta^{\wedge}{}_1 - \beta_{1,0}}{\sqrt{\acute{\alpha}^2 / S_{xx}}} \tag{3.32}$$

Follows the t distribution with (n-2) degrees of freedom under $H_0:\beta_1=\beta_{1,0}$. It would reject

$H_0:\beta_1=\beta_{1,0}$ if

$$|t_0| > t_{\alpha/2,n-2} \quad (3.33)$$

Where t_o is computed from Equation 3.33.

The denominator of Equation 3.33 is the standard error of slope. So, the test statistic can be written as

$$T_0 = \frac{\beta^{\wedge}{}_1 - \beta_{1,0}}{Se\beta_1^{\wedge}} \quad (3.34)$$

3.3.4 Elasticity of Variables

In order to check the relative significance of independent variables from the final model, the elasticity of the variables was calculated. Elasticity is defined as the percent change in dependent variable due to one percent change in the independent variable. Cheng (2015) explained, in general, the direct elasticity is defined as

$$E_{xij}^{\lambda i} = \frac{\partial \lambda_i}{\partial x_{ij}} . \frac{x_{ij}}{\lambda_i} \quad (3.35)$$

Where E represents the elasticity, x_{ij} is the value of variable j of community i. Equation 3.35 is transformed into the following equation

$$E_{xij}^{\lambda i} = \beta_j x_{ij} \quad (3.36)$$

Where β_j is the coefficient corresponding to variable j.

The elasticity in Equation 3.36 is only appropriate for continuous variables. It is not valid for non-continuous variables such as indicator variables that take on values of 0 or 1. For an indicator variable, a pseudo-elasticity is computed to estimate an approximate elasticity of the variables. The pseudo-elasticity gives the incremental change in frequency caused by a discrete (0-1) change in the indicator variables. The pseudo-elasticity for indicator variable is computed as:

$$E_{xij}^{\lambda i} = \frac{\exp(\beta_j)-1}{\exp(\beta_j)} \tag{3.37}$$

CHAPTER FOUR: ANALYSIS, MODEL DEVELOPMENT AND RESULT

4.1 Introduction

To fulfill the objective of this study, developing relationships between socioeconomic, road infrastructure, demographics factors, street patterns and different transportation modes and alternatives are necessary. In order to do so, in this chapter, three different regression models have been developed for three different transportation mode and alternatives; they are: model for carpool, model for telework and model for private vehicle usage. Linear regression has been employed in all these models. Data have also been analyzed separately for different models. Also, data and models are checked for anomalies according to the assumptions of linear regression.

4.2 Model Adequacy

Before starting the analysis, it is necessary to check if the data is adequate according to the assumptions of multiple linear regression models. Fitting a regression model requires several assumptions. Estimation of the model parameters requires the assumption that the errors are uncorrelated random variables with mean zero and constant variance. Tests of hypotheses and interval estimation require that the errors be normally distributed. To check the validity of these assumptions and to examine the adequacy of the model several graphs have been produced. From the figure 4.1, 4.2 and 4.3, it is observed that the plotted points have fallen approximately along a straight line which means the hypothesized distribution adequately describes the data. Figure 4.2 and 4.3 indicate that both the smallest and the largest observations are larger than expected in a sample from a normal distribution. Generally, if the sample size is $n<30$, there can be a significant deviation from linearity in normal plots, so in these cases only a very severe departure from linearity should be interpreted as a strong indication of non-normality. As sample size is higher, the linear pattern is stronger and the normal probability plots are more reliable as an indicator of the form of the distribution. So, variables (AADT of heavy vehicles, 65+ people living with relatives and single detached house) have followed the standardized normal probability plot.

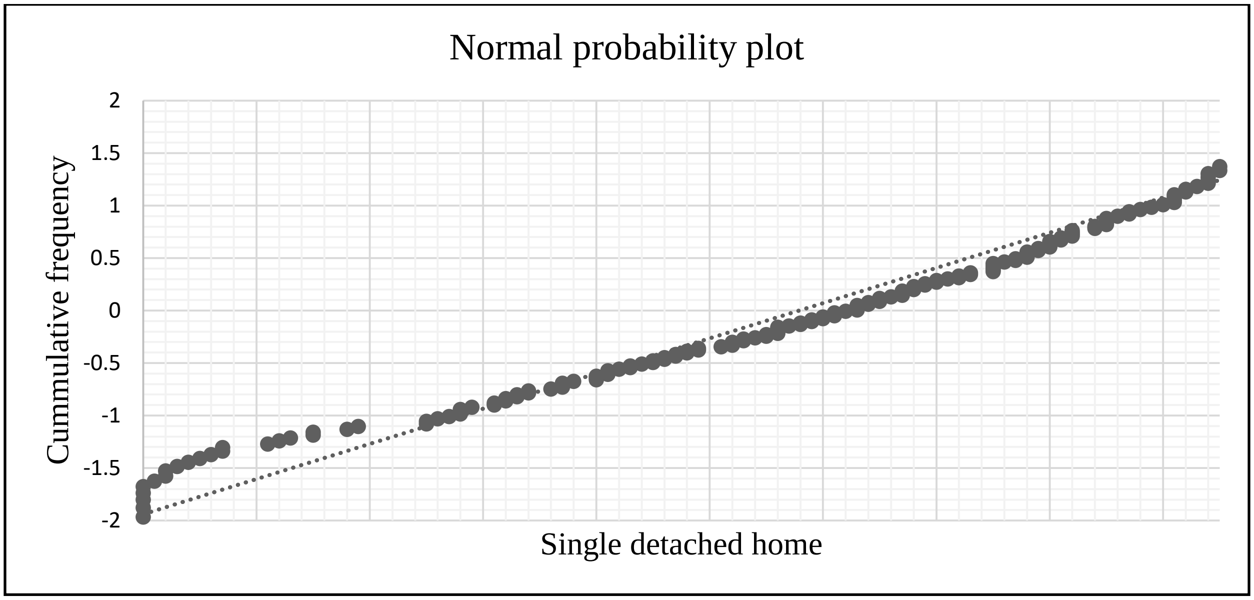


Fig 4.1: Normal probability plot (For carpool)

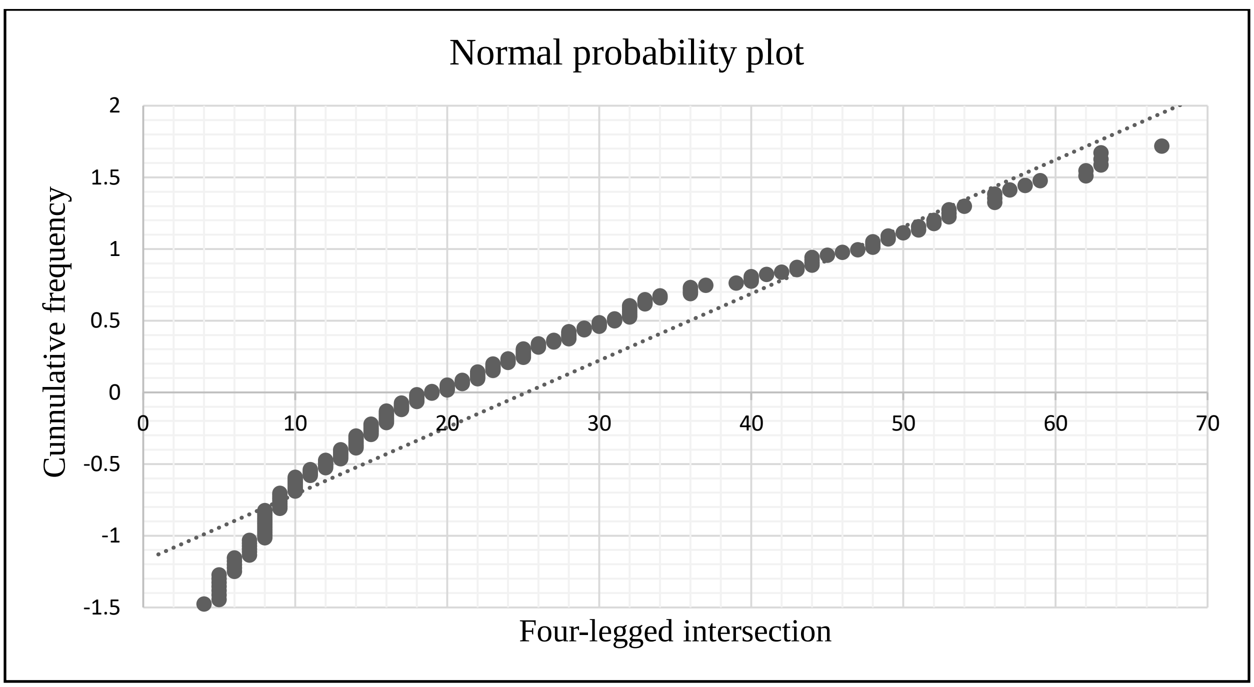


Fig 4.2: Normal probability plot (For telework)

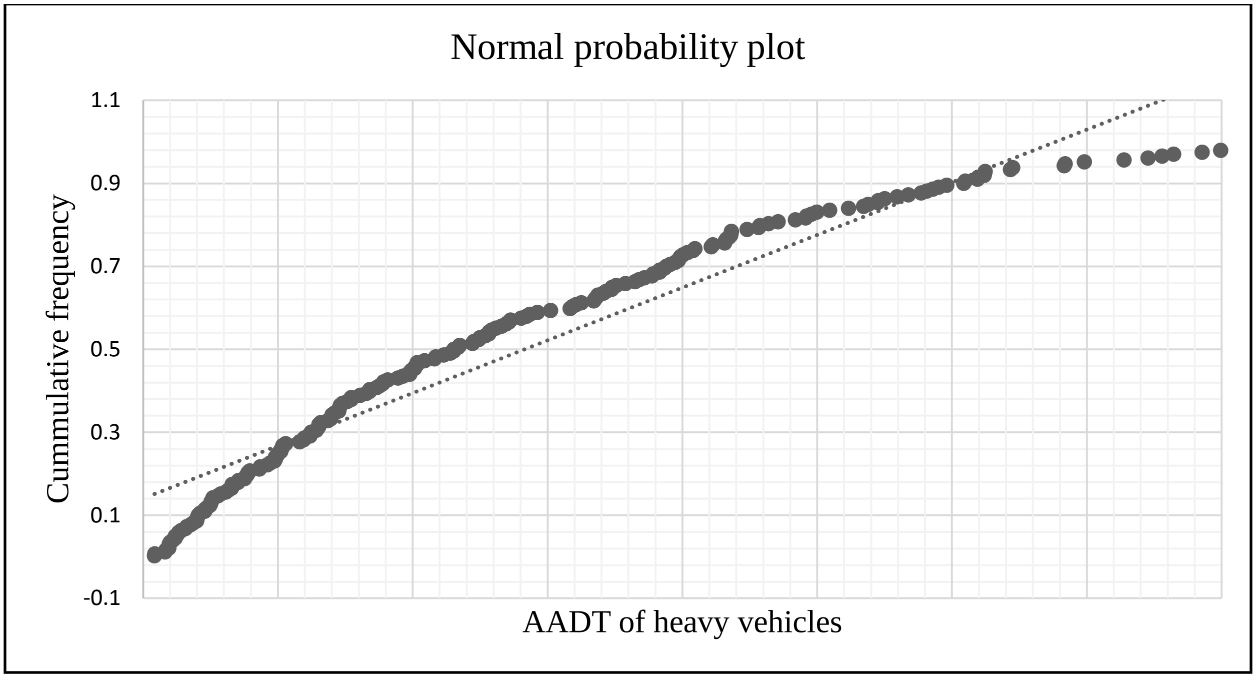


Fig 4.3: Normal probability plot (For private vehicle usage)

The residuals are also plotted against dependent variables in figure 4.4 and 4.5, the residuals against predicted dependent variables in figure 4.6, 4.7, 4.8. If there is no linear relationship between dependent and independent variables, if the variables data are heteroscedastic in disturbance, if the variables are correlated, these plots will show curvilinearity or patterns like cone/ double bow/ funnel. But these plots do not show any patterns like these in disturbances, therefore, data and models are adequate.

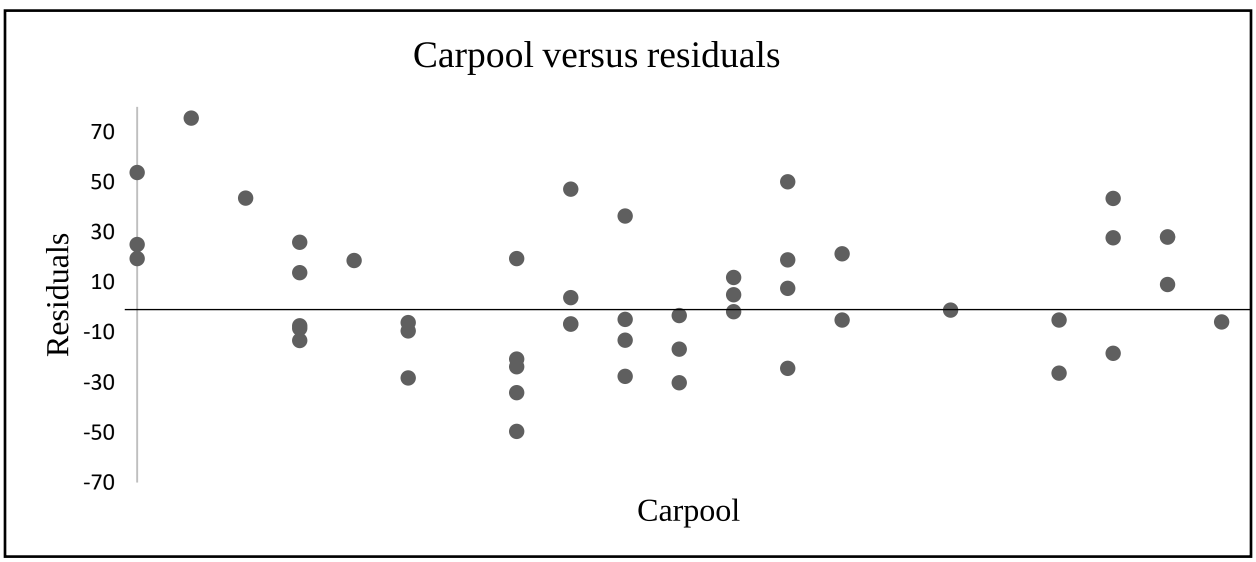


Fig. 4.4: Carpool versus residuals

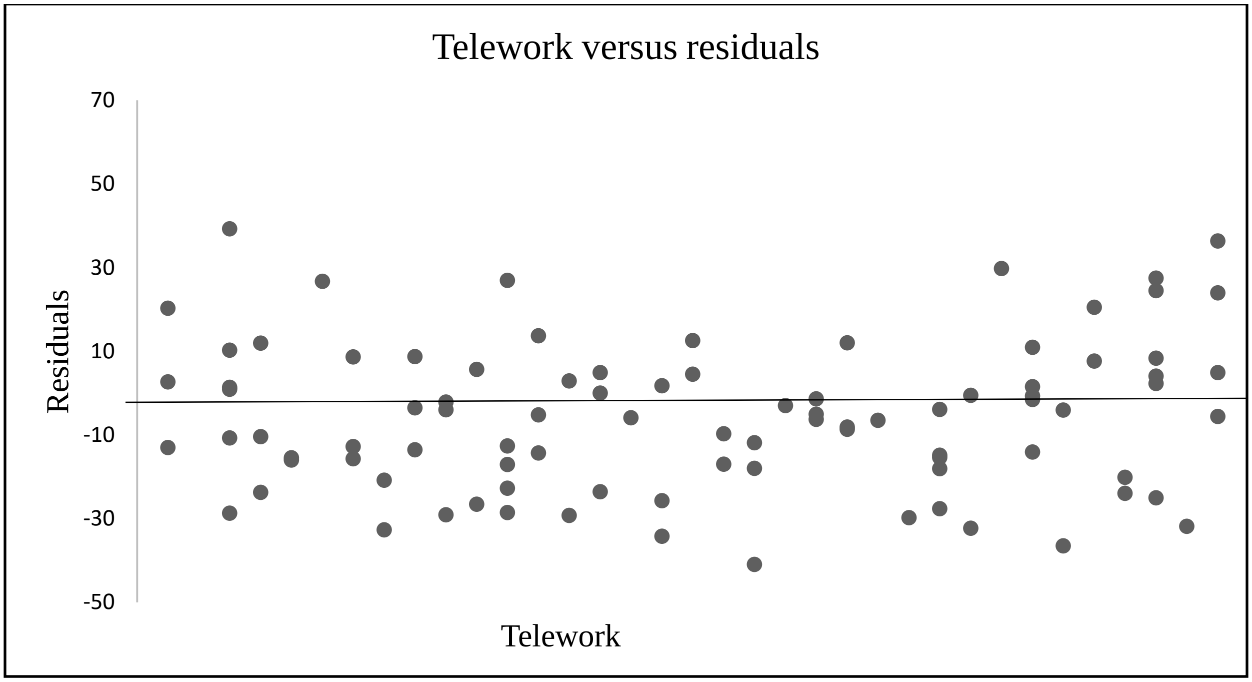


Fig. 4.5: Telework versus residuals

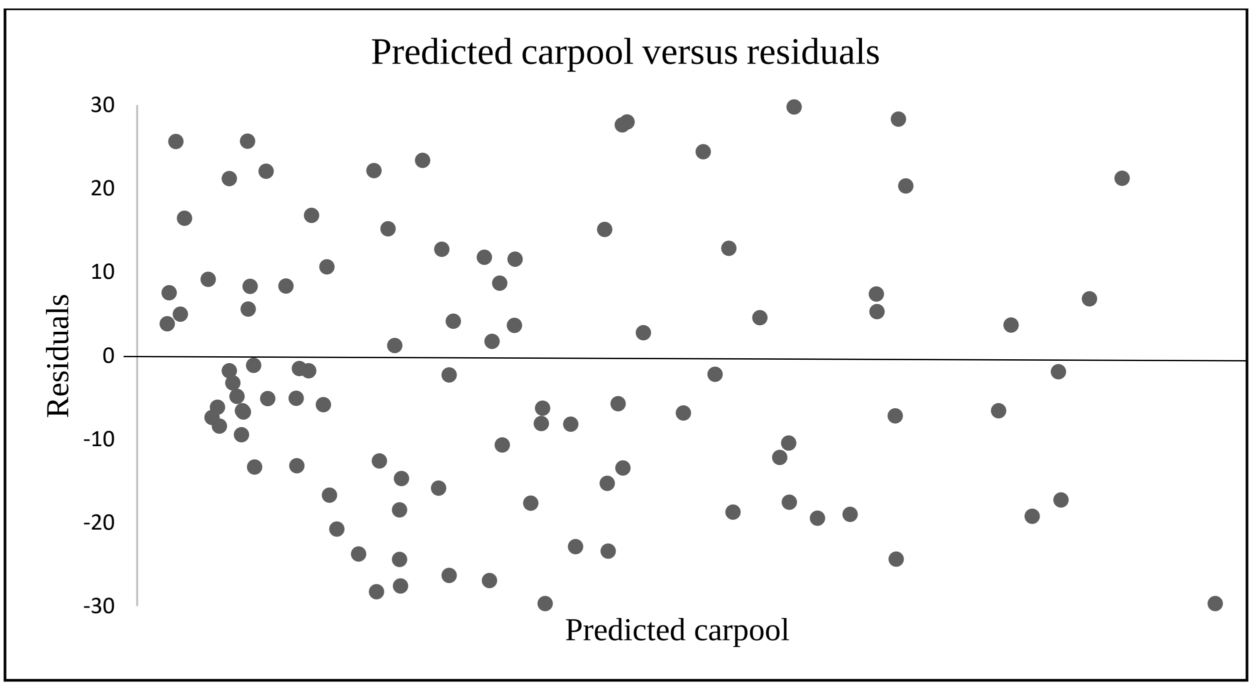


Fig. 4.6: Predicted carpool versus residuals

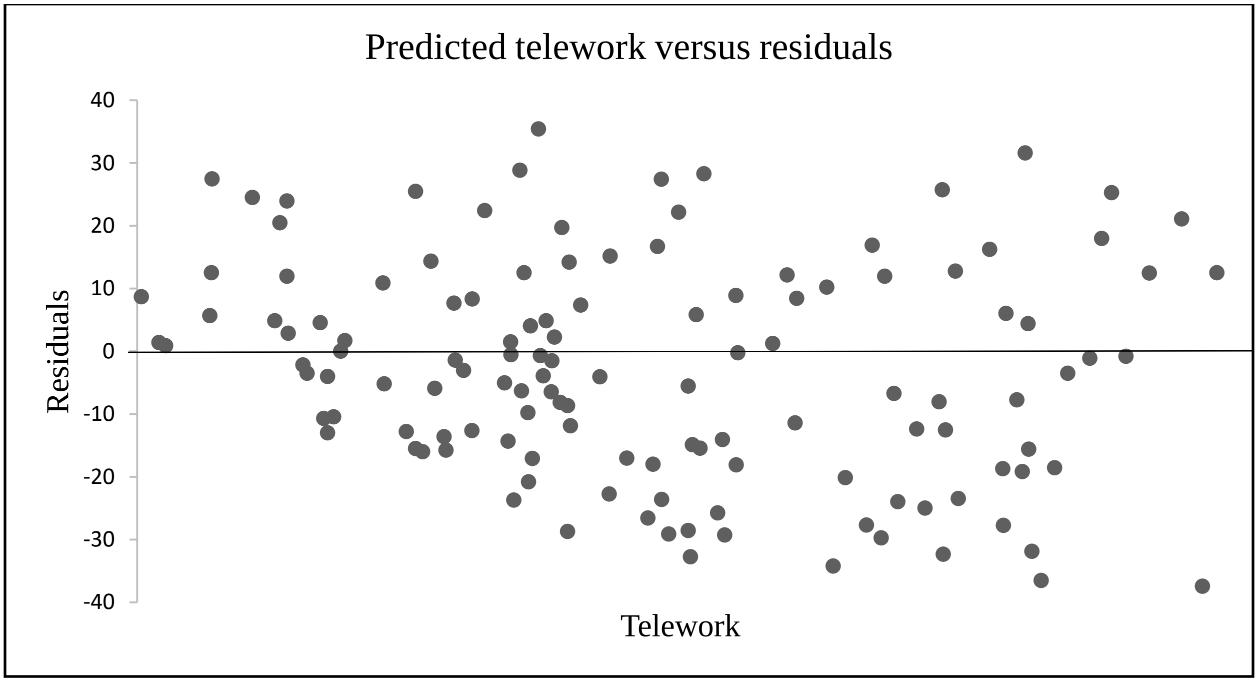


Fig. 4.7: Predicted telework versus residuals

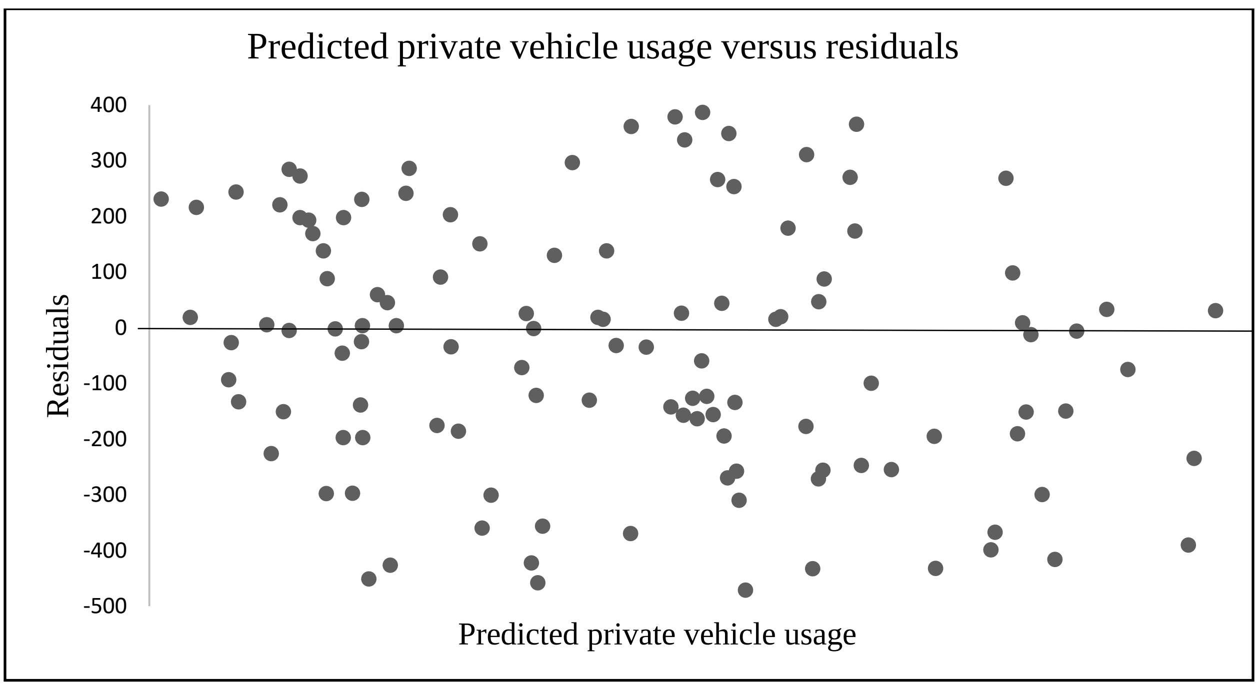


Fig. 4.8: Predicted private vehicle usage versus residuals

Figure 4.9, 4.10 and 4.11 have been produced for independent variables against residuals. There are no patterns like curvilinearity, funnel, cone or double bow. So, independent variables fulfill the assumptions of linear regression.

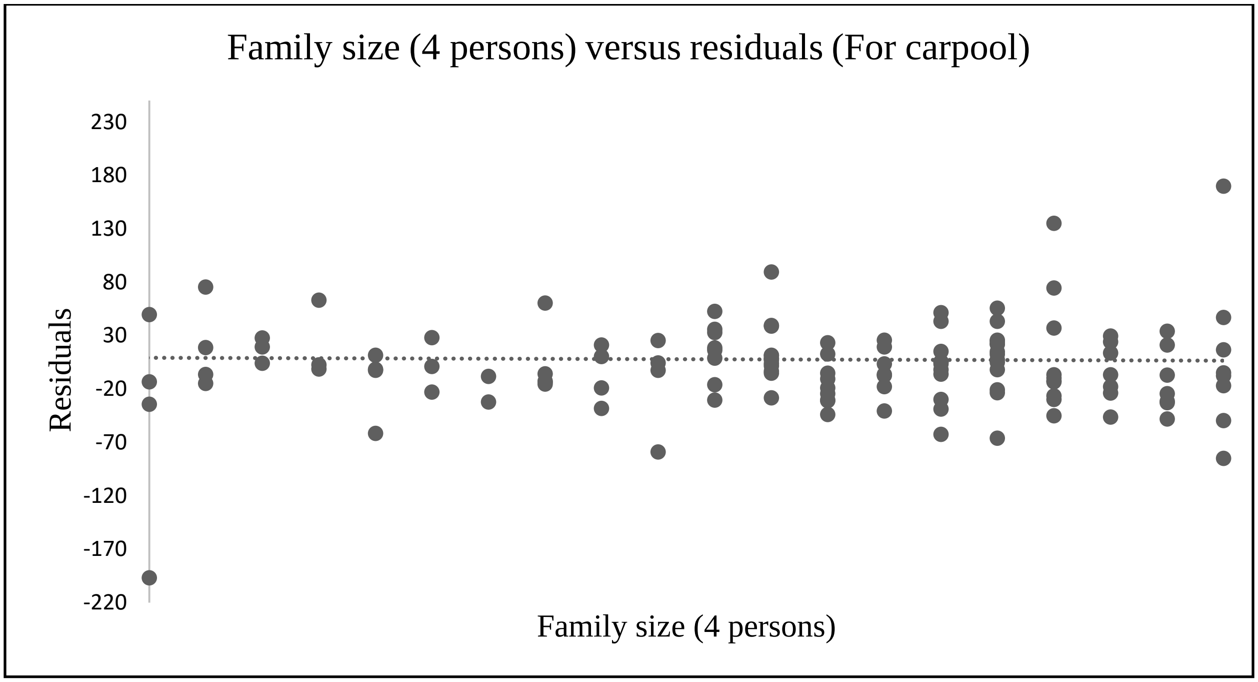


Fig. 4.9: Family size (4 persons) versus residuals (For carpool)

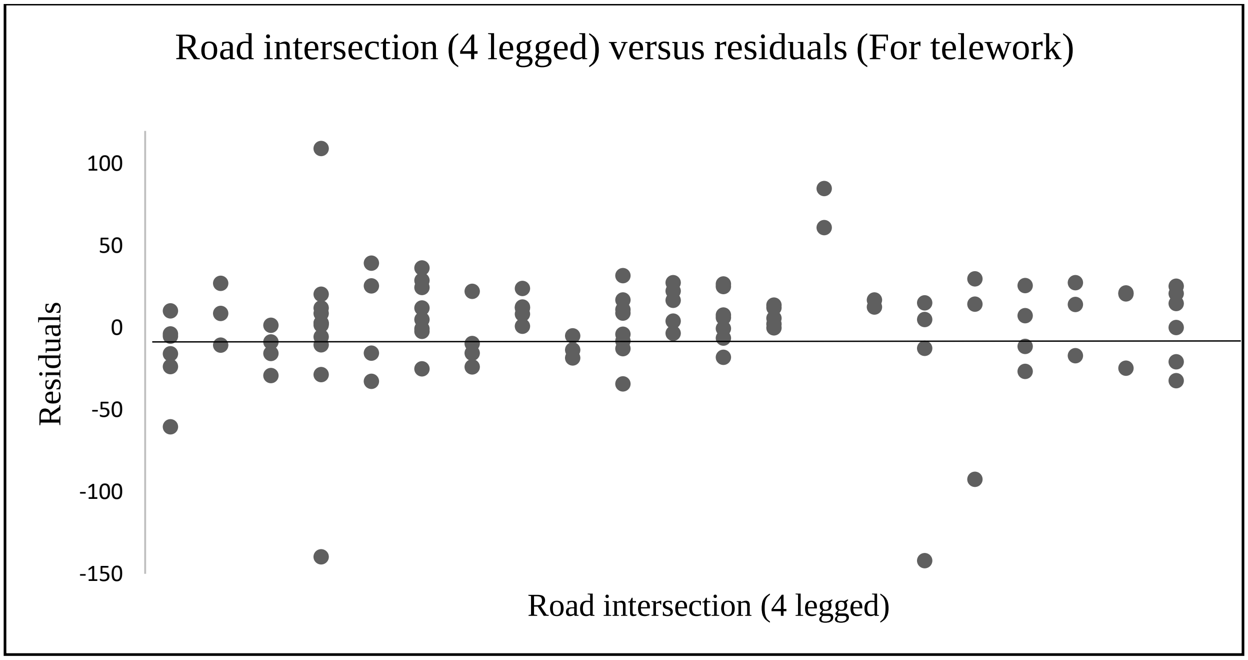


Fig. 4.10: Road intersection (4 legged) versus residuals (For telework)

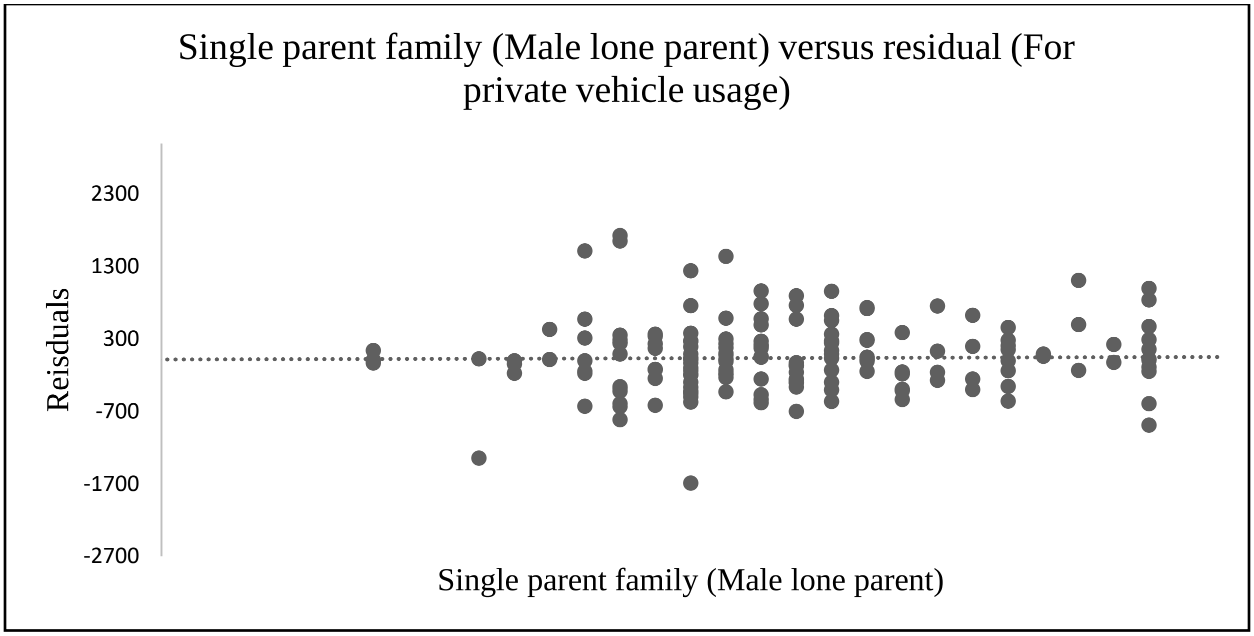


Fig. 4.11: Single parent family (Male lone parent) versus residuals (For private vehicle usage)

4.3 Model Development

Selection of appropriate variables is an important issue for developing the models. These variables can be selected by reviewing similar research or by focusing on local contents having probable effects on transit ridership.

4.3.1 Model for Carpool

Table 4.1: Summary statistics for carpool

Variables	**Mean**	**Standard deviation**
Street pattern		
Curvilinear	0.242	0.429
Gridiron	0.203	0.403
Irregular	0.383	0.487
Mixed	0.172	0.378
Average annual daily traffic volume (Heavy vehicles)	14149.6	10932.45
Total population	5694.14	4257.952
Total park area (m^2)	6018.083	6120.935

Variables	Mean	Standard deviation
Two-legged intersection	6.930	6.148
Area of three-legged and four-legged intersections (km^2)	43.385	20.519
Arterial road (Km)	0.223	0.822
Male (%)	49.885	3.189
Average number of children per census family	1.007	0.276
Number of persons by age		
0-14 years	1018.126	1030.436
15-24 years	758.407	592.925
25-34 years	919.835	754.936
35-64 years	2414.643	1802.357
65 and over 65 years	581.236	443.951
Family size (%)		
Family of 2 persons	51.1429	12.954
Family of 3 persons	21.775	4.987
Family of 4 persons	19.621	7.601
Family of more than 5 persons	7.659	3.815
Median income (×1000 CAD)		
Less than forty	0.114	0.319
Forty to eighty	0.669	0.472
Eighty to one twenty five	0.177	0.383
Greater than one twenty five	0.04	0.196
Census families (%)		
Couple families	85.214	5.995
Lone parent families	15.027	7.860
Aboriginal population (%)	2.443	1.867
Occupied private dwellings by structural type (%)		
Single detached	57.885	29.034
Semi-detached	9.808	9.983
Row house	8.868	11.127
Apartment	22	25.609
Other dwellings	1.544	11.159
Population excluding institutional residents (Language spoken most often at home) (%)		
English	82.720	13.107
French	0.698	0.641
Non-official language	13.016	10.979

Variables	Mean	Standard deviation
Multiple language	3.725	2.605

The variables are sorted according to the variables described in the summary statistics of the carpool. In the model, both continuous and categorical variables were considered. Some of the continuous variables are Average annual daily traffic volume of heavy vehicles, Total Population of a community, Percentage of male in a community etc. Mean of male (%) determines the average number of male in a community. In a categorical manner, several dichotomous or binary (0 or 1) variables were used to capture their effects. Such as, the type of street pattern in the neighborhood is captured by four dichotomous variables: gridiron, curvilinear, irregular and mixed street patterns. If a community has road patterns like gridiron, it will be denoted as 1, if not it will be denoted as 0. The mean of dichotomous variables represents the proportion of the sample belonging to the particular category. Therefore, the mean of the gridiron variable is 0.203 which indicates that 20.3% of the sample has gridiron street patterns. Also, several of the contributing variables are recorded in terms of percentage shares of the different categories. Since categorical data always sum to one or 100%, one or more of the categories have to be omitted from the model and used as a reference or base case by which the estimates of other categorical variables are compared. For example, to estimate the effects of street pattern on mode choice, the categorical variable for gridiron, curvilinear and mixed street patterns are omitted and the estimated coefficients of the irregular patterns are interpreted as relative to the three other patterns. The slope of the dependent variables (y) and explanatory variables (x) meet at a point on the dependent variables. This is called as regression coefficient β. Positive value of β means dependent variables increase with the increase of explanatory variables. Here, various road patterns are considered as repressors' or explanatory variables. In case of interpreting the model results, the positive sign of the estimated coefficients β indicates the higher chances of using carpool as the value of the associated variables increases while negative signs suggest the converse. So, the main equation of multiple linear regression model is

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \varepsilon_i \quad (4.1a)$$

Here, Y_i = Percentage of different sustainable modes (carpool)

β_0 = Constraint Term

Suppose, X_1= street pattern (irregular shaped), X_2 =AADT Volume of heavy vehicles etc.

β_1 = Co-efficient Value for street pattern

In the model, standard deviation represents measures how much the variables data are spread out from the variable mean. For example, the standard deviation of AADT of heavy vehicles is 10932.45 which denotes data are spread out away from the average value of AADT.

The results from the statistical analysis are shown in Table 4.2. In general, the model had a good goodness-of-fit statistic as assessed by the relatively high R-square and adjusted R-square as well as a low p-value of F-test. In the model, the R-square value is 0.7074. R-square is a static that will give information to measure how well the regression line approximates the real data point. R-square values are usually ranged from 0 to 1.0% indicates that the model explains none of the variability of the response data around the mean. On the other hand, 100% indicates that the model explains all the variability of the response data around its mean. In this model, 70.74% data are around the mean. Again, adjusted R-square indicates how well the terms are fit in a curve or line but adjusts for those numbers of terms in a model. If more and more useless variables are added to a model, the adjusted R-square value will decrease. If not, it will increase. Adjusted R-square will always be less than or equal to R-square. In this model, the adjusted R-square value is 0.6709. Note that only variables with at least ninety percent confidence level have been retained in the model.

In addition to the model estimates, the elasticity of carpool with respect to each contributing variables was also computed to provide a common basis for comparison across different variables. The computed elasticities are reported in Table 4.3. Note that elasticities of statistically significant variables were computed and presented in Table 4.3.

Table 4.2: Linear regression model for carpool

Number of observation = 145 F(16, 128) = 19.34 Prob > F = 0.0000 R-squared = 0.7074 Adj R-squared = 0.6709 P-value < 0.1			
Variables	**Coefficient**	**Standard error**	**P-value**
Street pattern: Irregular	-20.591	11.938	0.087
Average annual daily traffic volume (Heavy vehicles)	-0.001	0.001	0.040
Total population	-0.014	0.007	0.050
Total park area (m^2)	0.003	0.001	0.003
Two-legged intersection (“L” shaped)	2.087	0.889	0.020
Area of three-legged and four-legged Intersections (km^2)	0.568	0.327	0.085
Arterial road (km)	-16.317	7.136	0.024
Male (%)	-5.210	1.879	0.006
Average number of children per census family	-164.795	45.608	0.000
Number of persons by age: 35-64 years	0.067	0.018	0.000
Family size: Family of 4 persons (%)	3.928	1.703	0.023
Median income (×1000 CAD): Less than forty	36.458	17.624	0.041
Census families: Lone parent families (%)	1.365	0.652	0.038
Aboriginal population (%)	7.161	3.097	0.022
Occupied private dwellings by structural type: Single-detached (%)	0.682	0.288	0.019
Population excluding institutional residents (Language spoken most often at home): English (%)	-2.325	0.510	0.000
Constant	420.160	124.961	0.001

Table 4.3: Elasticity estimates for carpool

Variables	**Elasticity**
Street pattern: Irregular/ Loops and lollipops	-7.892
Average annual daily traffic volume (Heavy vehicles)	-21.101
Total population	-82.012
Total park area (m^2)	17.961
Two-legged intersection (“L” shaped)	14.465
Area of three-legged and four-legged intersections (km^2)	24.658
Arterial road (km)	-3.632
Male (%)	-259.901
Average number of children per census family	-165.972
Number of persons by age: 35-64 years	0.065
Family size: Family of 4 persons (%)	0.980
Median income (Thousand CAD): Less than forty	1.00
Census families: Lone parent families (%)	0.745
Aboriginal population (%)	17.496
Occupied private dwellings by structural type: Single-detached (%)	0.494
Population excluding institutional residents (Language spoken most often at home): English (%)	-9.224

The main aim of the study was to find out the effect of different road infrastructures and socioeconomic features on carpool. Curvilinear pattern, gridiron pattern and mixed pattern do not have any effects on carpool. On the contrary, Irregular street pattern (β= -20.591, p= 0.087) shows a significant effect at the 90% confidence interval and this road pattern decreases carpool.

Today, many cities, regardless of size, suffer from severe congestion mostly owing to overdependence on a private vehicle. Recent figures show that occupancy rate (the number of passengers in a vehicle), probably one of the main indicators of this overdependence, is 1.59 in the United States (Davis et al., 2013) and around 1.60 in Europe (European Environment Agency, 2010). Considering the four- to six-person capacity of a standard passenger car, these figures represent 60–75% unused capacity. Carpool or the communal use of private vehicles by several individuals is a strategy that might yield ran efficient use of this capacity. The distinctness of ridesharing as a policy lies in its approach, which is not to try to keep individuals from their private vehicles but to increase the occupancy rate (Tezcan, 2015). The infrastructure costs required in irregular street design are significantly lower than the traditional interconnected grid pattern, which can require up to fifty percent more road construction. Again, irregular street patterns are usually present in suburban areas and old community areas (Southworth and Owens, 1993). Since this road pattern carries no through traffic, it is a hustling condition for carpool users to pick up the other passengers which consume more time than usual, especially during the peak periods. Again, due to improper connectivity in the community area having irregularly shaped street patterns, communities are well connected to metro by many feeder services which may encourage the commuter to use public transit. These results implied that neighborhood with less street connectivity discourages carpool usage as compared to the neighborhood with more street connectivity. Therefore, comparing to the other street patterns irregular shaped streets in a community area decreases carpool.

Increased Average Annual Daily Traffic Volume of heavy vehicles (β= -0.001, p= 0.040) reduces carpool usage. Presence of higher number of heavy vehicles is seen especially in industrial and agricultural areas more than in commercial and residential areas. Usually in those areas availability of public transportation is higher. Also, housing location is scattered and may cause difficulties to manage carpool. So, considering cost and fuel consumption and to avoid congestion people prefer more to use public transportation than carpool or driving alone. Table 4.3 shows that the pseudo-elasticity of AADT for heavy vehicles is -21.101 which implies that 1% increase in AADT for heavy vehicles will cause 21.101% decrease of carpool.

Our model shows that the size of population plays an important role. It is seen that (Table 4.2) increased population (β= -0.014, p= 0.050) decreases the usage of carpool. In small communities, public transport usage is less because people might move easily from here and there by walking or cycling or they can use carpool for long distant travelling. But in the communities with large population people mostly use public transports regarding discomfort and inadequacy considering less traffic congestion, cost and time consumption and less environmental pollution which decreases car shearing. In a sense, mediocre communities are much preferable for carpool. Again, total park area in a community (β= 0.003, p= 0.003) increases carpool. To increase socialization and relationship with each other and for recreation, people come to parks with their families and friends. To avoid traffic congestion and considering comfort, carpool or ridesharing is much preferable.

Also, type of intersections plays a significant role in carpool in a community area. According to our model, two-legged intersection (β= 2.087, p= 0.020) increases carpool. These two-legged intersections are mainly “L” shaped road especially in fragmented parallel street patterns and usually placed at the corner of a community’s road network. As this types of streets are mostly placed at the corner and most of the vehicles are likely to move through much straighter ways or through expressways, this type of intersections usually become less congested. So, carpooler may prefer this type of intersections to avoid congestion. Again, in this type of intersections, public transit movement is less than usual due to frequent sharp turning. So, carpool users may prefer these roads to get to the main traffic stream within a lesser period of time. Similarly, intersection density influences carpool. Our model shows that density of two-legged and four-legged Intersections (β= 0.568, p= 0.085) increases carpool. In commercial areas, intersection density is relatively higher. Again due to less parking area and higher parking cost in these areas, carpool can be a much preferable solution.

Length of Arterial road (β= -16.317, p= 0.024) decreases carpool. Usually arterial roads are short distant, high capacity urban roads. Increased length of this type of road causes vehicle users more time to get to the main traffic stream in expressways especially in peak periods. Again, Arterial roads are basically focused on through traffic which decreases the possibility of matched number of destinations in a short period also decreases carpool. According to table 4.3, the pseudo-elasticity for arterial road length is -3.632 which implies that 1% increase in arterial road length decreases carpool by 3.632%.

Model shows that the percentage of male in a community (β= -5.210, p= 0.006) decreases carpool. Comparing to the female persons, men are less socialized, perhaps prefer less to interact or share with each other which decreases carpool. A study conducted by Duecker et al. (1977) included a survey focusing on gender, acquaintance of carpooling members and dimension of the groups. Results show that the gender of the potential carpoolers was of little consequence when the other part was an acquaintance but became of great consequence when the other party was a non-acquaintance. Both females and males preferred to pool with females if the other parties were non-acquaintances.

Accordingly, average number of children in census family (β= -164.795, p= 0.000) decreases the chances of using carpool. To ensure the comfort and safety for the children, parents prefer to use their own car instead of carpool or public transportation. Again, when the number of children is above average, private cars are used mostly for family purpose and can manage many family trips which is not so possible in carpool when destinations are on different directions that decreases the tendency of carpool.

Persons of 35 to 64 years old (β= 0.067, p= 0.000) are mainly the middle-aged working group of a community. According to Chung (2015), much older people shows little carpool tendency for regular route destinations. Comparing with the much younger or much older people, people of this age range shows more logical and mature behaviour and more concerned about their monetary and surrounding environmental conditions which increases carpooling tendency.

Again, Family size influences carpool. A family of 4 persons (β= 3.928, p= 0.023) enhances carpool tendency comparing to public transportation and also comparing to the more or less member containing families. Relatively lower income discourages private car usage comparing to the higher income. When median income is less than 40000 CAD (β= 36.458, p= 0.041), people go for carpool considering comfort comparing to public vehicles and less cost consumption comparing to the private vehicle usage. It's difficult for a lone parent to take care of his/her child especially in developed countries like Canada where day to day living costs are higher. So, lone parent families (β= 1.365, p= 0.038) prefer more to use carpool perhaps maybe because of their week economic condition.

Usually minor population feels comfortable to stay of their own. Similarly, Aboriginal Population (β= 7.161, p= 0.022) enhances use of carpool than others. Because of their weak economic conditions it may seems so. Again, when surrounded by minority, English language speakers at home (β= -2.325, p= 0.000) prefer privacy more than others even sacrificing environmental and economic issues which decreases carpooling tendency. People those who live in single detached (β= 0.682, p= 0.019) household are not so weak considering their economic conditions. Probably, being minority or having less average family income, to become more civilized, to reduce adverse effects of environmental impacts of car use, to reduce day to day living costs and to be incapable to maintain a large house, people living in a single detached house may prefer carpool. For increased socialization and considering cost and environmental issues they may prefer carpool. Table 4.3 shows that the pseudo-elasticity for single detached house is 0.494 which means if single detached home increases by 1% in a community area comparing to the others, carpool is increased by 49.4%.

4.3.2 Model for Telework

Table 4.4: Summary statistics for telework

Variables	**Mean**	**Standard deviation**
Street pattern		
Curvilinear	0.242	0.429
Gridiron	0.203	0.403
Irregular	0.383	0.487
Mixed	0.172	0.378
Average annual daily traffic volume (Heavy vehicles)	14149.6	10932.45
Area		
Zero to ten (×10 km^2)	0.220	0.415
Ten to twenty-five (×10 km^2)	0.392	0.489
Twenty-five to seventy-five (×10 km^2)	0.370	0.484
Greater than seventy-five (×10 km^2)	0.018	0.132
Commercial area (%)	7.279	12.311
Four-legged intersection	25.234	20.154
Area of three-legged intersection (m^2)	0.0000302	0.0000155
Rapid transit (Km)	0.0020938	0.0112827
Collector road (m)	2492.007	2960.495
Employment (%)	95.063	2.657
Median household income (×1000 CAD)		
Less than forty	0.114	0.319
Forty to eighty	0.669	0.472
Eighty to one twenty-five	0.177	0.383
Greater than one twenty-five	0.040	0.197
Educational qualification (%)		

Variables	Mean	Standard deviation
No certificate	17.325	8.559
High school certificate	24.715	4.799
Diploma or trade school certificate	7.870	3.448
College non university certificate	17.164	4.145
University certification (Below graduation)	4.957	1.729
University certification (Post-graduation)	27.968	14.316
Couple families (Census families) (%)		
Without children at home	49	13.730
With children at home	50.813	13.414
Not living with a spouse or common law (Marital status) (%)		
Single	68.439	9.133
Separated	5.901	4.862
Divorced	15.363	4.432
Widowed	10.593	6.576
Not living in a census family (Person 65 years and older in private household by living arrangement) (%)		
Living with relatives	19.313	19.991
Living w/non-relatives	6.824	6.079
Living alone	74.066	22.981
Population excluding institutional residents (Knowledge of official languages) (%)		
English	89.275	3.985
French	0	0
English and French	8.643	3.464
Neither English nor French	2.038	3.761
Population excluding institutional residents (Language spoken most often at home) (%)		
English	82.720	13.107
French	0.698	0.641
Non-official language	13.016	10.979
Multiple language	3.725	2.605

The variables are created according to the variables described in summary statistics of teleworking. Also, several of the contributing variables are recorded in terms of percentage shares of the different categories. Since categorical data always sum to one or 100%, one of the categories has to be omitted from the model and used as a reference or base case by which the estimates of other categorical variables are compared. For example, to estimate the effects of street pattern on mode choice, the categorical variable for the irregular street pattern is omitted and the estimated coefficients of the other three patterns are interpreted as relative to the irregular street pattern. In case of interpreting the model results, the positive sign of the estimated coefficients **β** indicates the higher chances of using home office or teleworking as the value of the associated variables increases while negative signs suggest the converse. So, the main equation of multiple linear regression model is

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \varepsilon_i \qquad (4.1b)$$

Here, Y_i= Percentage of different sustainable modes (teleworking)

β_0 = Constraint Term

Suppose, X_1= Street pattern (curvilinear shaped), X_2 = street pattern (Grid iron shaped) etc.

β_1 = Co-efficient Value for the street pattern (curvilinear shaped)

The results from the statistical analysis are shown in Table 4.5. In general, the model had a good goodness-of-fit statistic as assessed by the relatively high R-square and adjusted R-square as well as a low p-value of F-test. In the model, the R-square value is 0.6256 which implies that 62.56% data are around the mean. Adjusted R-square will always be less than or equal to R-square. In this model, the adjusted R-square value is 0.5794. Note that only variables with at least a ninety percent confidence level have been retained in the model.

In addition to the model estimates, the elasticity of home office with respect to each contributing variables was also computed to provide a common basis for comparison across different variables. The computed elasticities are reported in Table 4.6. Note that elasticities of statistically significant variables were computed and presented in Table 4.6.

Table 4.5: Linear regression model for telework

Number of observation = 165 F(18, 146) = 13.55 Prob> F = 0.0000 R-squared = 0.6256 Adj R-squared = 0.5794 P-value < 0.1			
Variables	**Coefficient**	**Standard error**	**P-value**
Street pattern: Curvilinear	-17.427	6.094	0.005
Street pattern: Gridiron	-23.979	8.338	0.005
Street pattern: Mixed	-16.355	6.715	0.016
Average annual daily traffic volume (Heavy vehicles)	0.001	0.0003	0.000
Area: Ten to twenty-five (×10 km^2)	-9.818	4.669	0.037
Commercial area (%)	-0.561	0.255	0.030
Four-legged intersections	0.354	0.147	0.017
Area of three-legged intersection (m^2)	-545764.5	190214.5	0.005
Rapid transit (Km)	-348.033	206.319	0.094
Collector road (m)	0.002	0.001	0.031
Employment (%)	3.175	1.003	0.002
Median household income (×1000 CAD): Greater than one twenty-five	-34.012	11.976	0.005
Educational qualification: University certificate (Below graduation) (%)	2.971	1.303	0.024
Couple families (Census families): With children at home (%)	0.664	0.268	0.014
Not living with spouse or common law (Marital status): Widowed (%)	-1.627	0.402	0.000
Not living in a census family (Person 65 years and older in private household by living arrangement): Living with relatives (%)	-0.522	0.160	0.001
Population excluding institutional residents (Knowledge of official languages): English (%)	-1.493	0.645	0.022
Population excluding institutional residents (Language spoken most often at home): French (%)	8.533	4.571	0.064
Constant	-139.712	111.138	0.211

Table 4.6: Elasticity estimates for telework

Variables	Elasticity
Street pattern: Curvilinear	-4.222
Street pattern: Gridiron	-4.859
Street pattern: Mixed	-2.810
Average annual daily traffic volume (Heavy vehicles)	17.294
Area: Ten to twenty-five (×10 km^2)	-18366.4
Commercial area (%)	-4.083
Four-legged intersections	8.941
Area of three-legged intersection (m^2)	-16.482
Rapid transit (Km)	-0.729
Collector road (m)	5.119
Employment (%)	0.958
Median household income (×1000 CAD): Greater than one twenty-five	-5.9×10^{14}
Educational qualification: university certificate (Below graduation) (%)	0.949
Couple families (Census families): With children at home (%)	0.486
Not living with spouse or common law (Marital status): Widowed (%)	-4.088
Not living in a census family (Person 65 years and older in private household by living arrangement): Living with relatives (%)	-0.686
Population excluding institutional residents (Knowledge of official languages): English (%)	-3.449
Population excluding institutional residents (Language spoken most often at home): French (%)	0.999

Compared with an irregular pattern, mixed, gridiron and curvilinear pattern have a significant effect on the home office. Curvilinear (β= -17.427, p= 0.005), mixed pattern (β= -16.355, p= 0.016) and gridiron pattern (β= -23.979, p= 0.005) shows significant effect at the 90% confidence interval and all of them decrease the home office. Among these patterns, gridiron pattern is more significant than the others. Gridiron pattern usually present in urban downtown or relatively old community area. To avoid traffic congestions people may like to live near their offices. Traditional gridiron pattern also allows travelers to use different roads to get to their destinations in a community which may be a good reason for decrease home office rate. In Calgary, the newly built communities are mostly curvilinear road which is usually close to/ around suburban area. These communities are well connected to metro by many feeder services which may encourage the commuter to use public transit which may also decrease home office. On the contrary, irregular street patterns usually are in the unplanned sub-urban areas and old community areas and generally, they have less street connectivity and accessibility. These results implied that neighborhood with more street connectivity discourages home office as compared to the neighborhood with less street connectivity. Perhaps, more connectivity means more accessibility of public transport.

Increased average annual daily traffic volume of heavy vehicles (β= 0.001, p= 0.000) enhances the chances of home office. Often people feel safe and relaxed staying at home and doing their official works avoiding all the probable traffic congestion when traffic volume is higher than usual. When heavy vehicles increases in a road network, they cause slow movements for light vehicles which may cause traffic congestions frequently especially in narrow streets and also may increase accident possibilities. Rifaat et al. (2007) showed that compared to an accident involving only cars, the relative fatality risk of a truck-related accident and a bus-related accident is significantly higher. Ouyang et al. (2002) found that heavy vehicles involved in accidents increased the likelihood of severe injury for the collision partner. Perhaps, commuters do not feel safe while there are so many heavy vehicles around them in a community area. According to table 4.6, if AADT volume of heavy vehicles increases by 1% in a community, home office is increased by 17.294%.

Our model results show that size of a community plays an important role. If the community area (10 to 25 $\times 10$ km^2) (β= -9.818, p= 0.037) is relatively smaller, home office decreases. In small communities people can move easily from one place to another by walking or cycling or can use private vehicles. As they need to travel less distances, people in the small community may not prefer home office. Community map of Calgary shows that most of small communities are near to the city center whereas relatively big communities are away from the city center. These communities are well provided with public transportation, people may feel discouraged to work at home rather than working out of home. Comparing to these, relatively medium sized areas have less accessibility which may encourage working at home. Usually commercial areas are well provided with public transportation and parking facilities for private vehicles.

Our model shows that presence of commercial area (β= -0.561, p= 0.030) in a community decreases working at home. Usually commercial areas are well provided with public transportation (especially public bus service and metro rails) and parking facilities for private cars. Friman et al. (2001) emphasized that fare, availability, service quality and public satisfaction towards public transportation services control public transport usage in a certain area. So, a well provided public transport service may control home-based working in an area. Also people can carpool which is beneficial considering less traffic congestion and less time and cost consumption.

In the model, four-legged intersection (β= 0.354, p= 0.017) increases the chances of working at home or telework. Traffic congestion is relatively higher in this type of intersections due to interruption of through traffic movements; especially during peak periods congestion is sever. So people may prefer doing their official business in their home to suffer less hustle. Similarly, intersection density influences home office. Three-legged intersections are less congested than four-legged intersections. Again, signalized three-legged intersections have comparatively higher green time which causes increased traffic flow. So, increased density of three-legged intersection (β= -545764.5, p= 0.005) in a community area decreases home office tendency.

Rapid transit is a type of high capacity public transport generally found in urban areas which operate on an exclusive right of way, which cannot be accessed by pedestrians or other vehicles of any sort. It transports a large number of people both at short and long distances at high frequency. Comparing to the other modes of transportation, rapid transit has a good safety record. So, rapid transit (β= -348.033, p= 0.094) in a community area offers more comfort and safety which decreases the chances for people to work at home. According to table 4.6, when rapid transit length varies over 1%, the home office is decreased by 72.9%. Again, a collector road (β= 0.002, p= 0.031) is a low to moderate capacity road which serves to move traffic from local streets to an arterial road. Collector roads discourage high-speed vehicles comparing to the highways and also causes more time consumption by traffic congestion which is not favorable for smooth driving enhances the chances for people to work at home.

The model shows that Employment increases working at home. Cervero (1990) studied the effect of worksite characteristics on commuter mode choice. He found that employees are most likely to ride share if they commute long distances, work for a large company at a single-tenant site, and work in nonprofessional and non-management positions. But if employment ratio is higher it is difficult for people to find a proper ride to go to the workplaces. De Graaff et al. (2007) showed that firms themselves may experience a positive productivity effect because costs are saved since fewer workplaces are needed when employees work at home. Furthermore, Opportunities to work at home may also be considered as fringe benefits. Namely, employers may offer (new) employees a trade-off between higher wages or possibilities to work at home. Again, in a community when employment ratio (β= 3.175, p= 0.002) is higher, it causes more trip generation that may cause more traffic congestion during peak periods. So some people may prefer to work at home. Again, income more than one twenty-five thousand CAD (β= -34.012, p= 0.005) negatively affects working at home. People of this income range are mostly high officials and executive level officer who need to coordinate office in person which discourages working at home comparing to the less income range people.

According to our study, educational status affects working at home. People not completed graduation degree (β= 2.971, p= 0.024) are more liable to work at home. Limited economic means may be the reason for this finding. Usually, less educated people get jobs that don't pay much compared to higher educated people. These people may prefer working at home as freelancers for an extra source of income outside their daily works. Again these group of people may be irregular commuters and still students which may cause increased home office.

In question of taking care of children at home (β= 0.664, p= 0.014), parents or couple families with children may prefer home office to do their outside jobs compared to those who don't have any children at home. According to table 4.6, if the number of couple family having children at home is increased by 1% compared to couple family having no children at home in a community, the home office is increased by 48.55%. Again, according to our model, increased lone persons such as widows (β= -1.627, p= 0.000) reduces working at home. Perhaps, widowed persons may prefer working outside of their home due to reducing loneliness by socializing comparing to others.

Developed countries like Canada provide better social security for aged people. Senior citizens can afford with what they get as their pension. Again, they may have part-time jobs as an extra source of income and enjoy the company of other people during free time. So, increased senior citizens of 65 and 65+ years old who live with their relatives (β= -0.522, p= 0.001) decreases the chances of working at home. According to our model, increased English speaking people (β= -1.493, p= 0.022) negatively affects working at home. Perhaps, people like to socialize with others apart from family members, especially at workplaces. These people may prefer work in offices in formal ways than others. Again, race and ethnicity may have some issues with the geography of workplaces and living areas. Ellis et al. (2004) emphasized that regular citizens judge the others especially immigrants and other minorities or race not by what they do or where they work but where they live in. Our model shows that increased population who speaks French at home (β= 8.533, p= 0.064) increases home office. Perhaps, as majority of the people in Canada speaks English, French-speaking people don't feel comfortable working with them outside. Again, due to racial issues, native English people may not like to mix up with the people of other races. So they rather stay home and do telework. Again, in Calgary almost all the people speak English and so on racial difference may be a good reason for working at home for others.

4.3.3 Model for Private Vehicle Usage

Private vehicle usage was assumed to be influenced by various factors related to the characteristics of the road infrastructure, community environment, land use, street pattern etc. Pre-selection of the variables was accomplished mainly by following previous research work where these variables had been explored. However, some local variables, thought to have an influence on the drove alone/ private transit usage, were also examined. It should be noted that some important variables such as vehicle license, road toll, fuel price, parking price, weather etc. on private vehicle usage were not examined here because of unavailability.

Table 4.7: Summary statistics for private vehicle usage

Variables	**Mean**	**Standard deviation**
Street pattern		
Curvilinear	0.242	0.429
Gridiron	0.203	0.403
Irregular	0.383	0.487
Mixed	0.172	0.378

Variables	**Mean**	**Standard deviation**
Average annual daily traffic volume (Heavy vehicles)	14149.6	10932.45
Area		
Zero to ten (×10 km^2)	0.220	0.415
Ten to twenty-five (×10 km^2)	0.392	0.489
Twenty-five to seventy-five (×10 km^2)	0.370	0.484
Greater than seventy-five (×10 km^2)	0.018	0.132
Four-legged intersection	25.234	20.154
Private household (%)	15.359	10.920
Number of schools	1.436	1.505
Educational qualification: (%)	24.715	4.799
Non certificate	17.325	8.559
High school certificate	24.715	4.799
Diploma or trade school certificate	7.870	3.448
College non university certificate	17.164	4.145
University certification (Below graduation)	4.957	1.729
University certification (Post-graduation)	27.968	14.316
Train stations	0.159	0.799
Gas stations	0.555	0.862
Male (%)	49.885	3.189
Number of persons by age		
0 to 14 years	1018.126	1030.436
15 to 25 years	758.407	592.925
25 to 35 years	919.835	754.936
35 to 64 years	2414.643	1802.357
65 and 65+ years	581.236	443.951
Lone parent families (%)		
Female lone parent	76.907	10.743
Male lone parent	23.461	10.027
Family size (%)		
Family of 2 persons	51.143	12.954
Family of 3 persons	21.775	4.987
Family of 4 persons	19.621	7.601
Family of 5+ persons	7.659	3.815
Married/ Common law (Marital status) (%)		
Married	83.291	9.774
Common law	16.841	10.277
Children living at home (%)		

Variables	Mean	Standard deviation
Under 6 years of age	25.945	9.632
6 – 14 years	31.412	5.747
15 – 17 years	11.846	4.098
18 – 24 years	21.077	6.7860
25 years and over	10.115	3.995
Occupied private dwellings by structural type (%)		
Single-detached house	57.885	29.034
Semi-detached house or duplex	9.808	9.983
Row house	8.868	11.127
Apartment	22	25.609
Other dwelling	1.544	11.159
Knowledge of official languages (%)		
English	89.275	3.985
French	0	0
English and French	8.643	3.464
Neither English nor French	2.0385	3.761

Also, several of the contributing variables are recorded in terms of percentage shares of the different categories. Since categorical data always sum to one or 100%, one of the categories has to be omitted from the model and used as a reference or base case by which the estimates of other categorical variables are compared. For example, to estimate the effects of street pattern on mode choice, the categorical variable for the gridiron, irregular and mixed street patterns were omitted and the estimated coefficients of the other pattern are interpreted as relative to the curvilinear street pattern. In case of interpreting the model results, the positive sign of the estimated coefficients β indicates the higher chances of using private transit as the value of the associated variables increases while negative signs suggest the converse. So, the main equation of multiple linear regression model is

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \varepsilon_i \qquad (4.1c)$$

Here, Y_i= Percentage of different sustainable modes (private transit usage)

β_0 = Constraint Term

Suppose, X_1= Street pattern (curvilinear shaped), X_2 = AADT of heavy vehicles etc.

β_1 = Co-efficient Value for the street pattern (curvilinear shaped)

The statistical analysis provides the variables that affect private vehicle usage positively or negatively shown in Table 4.8. Total 17 variables were found statistically significant and the rest of the variables were omitted. Some of the variables are like population, educational qualifications, family income, number of children, housing type etc. In general, the model had a good goodness-of-fit statistic as assessed by the relatively high R-square and adjusted R-square as well as a low p-value of F-test. In the model, the R-square value is 0.7666 which implies that 76.66% data are around the mean. Adjusted R-square will always be less than or equal to R-square. In this model, the adjusted R-square value is 0.7396. Note that only variables with at least a ninety percent confidence level have been retained in the model. The main objective of the study was how the road infrastructure, street pattern and socioeconomic features affect the private transit usage in a community.

In addition to the model estimates, elasticity was computed to provide a common basis for comparison across different variables. The computed elasticities are reported in Table 4.9. Note that elasticities are calculated only for the variables that are statistically significant.

Table 4.8: Linear regression model for private vehicle usage

Number of observation = 165 F(17, 147) = 28.41 Prob > F = 0.0000 R-squared = 0.7666 Adj R-squared = 0.7396 P-value < 0.1			
Variables	**Coefficient**	**Standard error**	**P-value**
Street Pattern: Curvilinear	-203.692	92.138	0.029
Average annual daily traffic volume (Heavy vehicles)	0.022	0.007	0.001
Area: Ten to twenty-five (×10 km^2)	-254.227	81.143	0.002
Four-legged intersections	10.730	2.624	0.000
Private household (%)	-22.964	5.604	0.000
Number of schools	-68.428	31.789	0.033
Educational qualification: High school certificate (%)	25.753	11.480	0.026

Variables	Coefficient	Standard error	P-value
Train stations	-117.841	44.038	0.008
Gas stations	-136.310	48.176	0.005
Male (%)	37.063	15.465	0.018
Number of persons by age: 65 and 65+ years	0.680	0. 153	0.000
Lone parent families: Male lone parent (%)	-10.580	4.179	0.012
Family size: Family 2 persons (%)	-17.062	5.936	0.005
Married/ Common law (Marital status): Married (%)	-14.628	6.564	0.027
Children living at home: 25 years and over (%)	-63.386	15.485	0.000
Occupied private dwellings by structural type: Apartment (%)	7.815	2.568	0.003
Knowledge of official languages: English and French (%)	-76.002	15.874	0.000
Constants	1918.451	1181.415	0.107

Table 4.9: Elasticity estimates for private vehicle usage

Variables	Elasticity
Street Pattern: Curvilinear/ Wrapped parallel	-49.29
Average annual daily traffic volume (Heavy vehicles)	305.91
Area: Ten to twenty-five (×10 km^2)	-3×10^{110}
Four-legged intersections	270.758
Private household (%)	-352.704
Number of schools	-98.263
Educational qualification: High school certificate (%)	1.00
Train stations	-18.74
Gas stations	-75.65
Male (%)	1848.89
Number of persons by age: 65 and 65+ years	0.494
Lone parent families: Male lone parent (%)	-39339.1
Family size: Family 2 persons (%)	-2.6×10^{7}
Married/ Common law (Marital status): Married (%)	-2253510
Children living at home: 25 years and over (%)	-3.4×10^{27}
Occupied private dwellings by structural type: Apartment (%)	0.999596
Knowledge of official languages: English and French (%)	-1×10^{33}

This Model shows that, curvilinear street pattern (β= -203.692, p= 0.029) has negative effect on private vehicle usage. Comparing with the traditional grid pattern, in curvilinear pattern the blocks are reconfigured into long, narrow rectangles and L shapes. The streets, rather than being carried through, tend to corners. This limits the degree of interconnection, the choices of routes through a neighborhood, and the number of access points in and out. Also, the curving streets make user orientation more confusing in these neighborhoods. As a result, private transit usage is less here than other street pattern. Usually, industrial and agricultural areas are more crowded with heavy vehicles than residential and commercial areas. Also there may be less provisions for using public transportations. Again, people may not prefer walking or cycling due to safety purposes. As a result, increased AADT volume of heavy vehicles (β= 0.022, p= 0.001) increases private transit usage. According to table 4.9, the elasticity for Average Annual Daily Traffic (AADT) is 305.91 which implies that one percent increase in AADT will cause 305.91% increase in private vehicle usage.

Increased community area decreases private transit usage. From an economic point of view, in smaller communities walking and cycling is preferable than using a personal car to travel a shorter distance. Again, though bigger communities are well provided with public transportation facilities, it is not so viable for public transit users to go their destination without changing their mode of travelling. But in mediocre communities, reliability and frequency of public transit is within tolerance limit. Lucas (2009) stated that according to UK National Travel Survey data of 2005-2006, the size of a city has had growing importance in explaining patterns of car ownership, with bigger rural areas showing the highest car ownership. Our model shows that mediocre community area (10 to 25 10 km^2) (β= -254.227, p= 0.002) decreases private transit usage than bigger community areas. Presence of four-legged intersections in a community give commuters more chances to choice different routes as well as points of access than others. Accordingly, increased number of four-legged intersection (β= 10.730, p= 0.000) in a community area increases private vehicle usage.

Ferdous et al. (2010) stated that household activity-travel patterns are closely related to household consumption patterns and monetary expenditure. When households engage in more consumption of goods and services outside at home (such as eating out, going to movies and shopping), this leads to more activities and travel consistency. They also have showed short-term and long-term impacts on household consumption patterns in response to increase in fuel price.

Thakuriah and Liao (2005, 2006) examined household transportation expenditures using 1999 and 2000 consumer expenditure survey data in U.S. and noted that households with one or more vehicles spend, on average, 18 cents of every dollar on vehicles. Again, in Canada areas with higher percentage of private households are well facilitated with bus and metro transit services. As a result commuters use public transit facilities than using a personal car considering economical expenditure. So, when private households (β= -22.964, p= 0.000) increase, it decreases private vehicle usage.

In a community area increased number of school (β= -68.428, p= 0.033) causes higher trip generation from different area to the schools which results huge traffic congestion at a certain time that may discourage parents to use private vehicles and may encourage carpool, walking, public transportations or other modes. Again, reduced vehicle speed in school zone may also decreases private vehicle usage in a community area. Model shows that people having high school certificate (β= 25.753, p= 0.026) increases private vehicles usage. It may be because of these people have the ability to buy and bear costs of a private car comparing with others. Moreover, these people may have less concern for environmental issues than others. Gao et. al. (2009) stated that education level, job skills, race, social networks contribute to private car ownership. As expected, communities with more train stations (β= -117.841, p= 0.008) would experience a significant decrease in private vehicle usage. Train lines are accompanied with very good bus connectivity, therefore, encourages the usage of public transit. The more train stations mean more usage of public transit because of more access to the different communities. According to table 4.9, 1% increase of train station in a community will cause 18.74% decrease in private vehicle usage. Chakour and Eluru (2013) found that increased transit stations increases the public transit ridership. As a result, private transit usage is decreased. Again, model shows that increased number of gas stations (β= -136.310, p= 0.005) decreases private vehicle usage. Frequency of gas stations is relatively higher in commercial area and areas with higher business activities which are provided with good public transit facilities or have less parking facilities which may decrease private vehicle.

If the percentage of male (β= 37.063, p= 0.018) increases in a community, private vehicle usage is increased. Comparing with female, male can tolerate boredom and loneliness (Farber et al., 2014). Again male don't like share rides with strangers or acquaintances comparing to female. So they may like to travel alone. Hensher, (1985) and Mannering (1983) showed that workers, young people and males are more likely to drive alone. Collia et al. (2003) explained that for older adults (65 and 65+ years of age) Travel by personal vehicle remains the dominant mode of transportation across age group for daily and long-distance travel. 75% of the total older adults in America use mostly private vehicles. It may be to avoid hustle in public transportation and for higher comfort during travelling. So, in a community when the number of older adults of 65 and 65+ years of age (β= 0.680, p= 0.000) increases, private vehicle usage is also increased.

Male lone parents (β= -10.580, p= 0.012) don't prefer using private vehicles perhaps because of their week economic condition. It is logical that more family members mean more trips with diversified destinations which cannot be managed by only one or two personalized vehicles. Considering fuel and vehicle maintenance cost, 2/3/4 family members can use a private vehicle to go to their destinations. But for a 2 person family, the frequency of traveling will decrease and the cost will increase. So increased 2 person families (β= -17.062, p= 0.005) in a community discourage private vehicle usage. Similarly, for married people (β= -14.628, p= 0.027), possible travel destination might be different if both of them are service holders. So, more than a car will be expensive to maintain which discourages private vehicle usage. Again, Children of 25 and 25+ years of age living at home (β= -63.386, p= 0.000) with their parents are discouraged to use private vehicles may be because of their weak economic conditions and cannot bear expenses of a private vehicle.

Type of residence also plays an important role in mode choice. Generally, people with high-income level live in expensive apartments (β= 7.815, p= 0.003). They are working class people who have jobs and bare expenses of a car. According to table 4.9, 1% increase of apartments in a community compared to single detached home or semi-detached home or others types of houses will cause 99.95% increase of private transport usage. Again, English and French language speakers (β= -76.002, p= 0.000) are more adaptable, tolerant, broader minded and show no racial privileges. These people may use public transit quite often than others which decrease private vehicle usage.

4.4 Summary Findings

This chapter of the study helps to understand the relations between neighborhood street pattern, socioeconomic and demographic features, road infrastructure with carpool, home office, and private transit usage. It has been explored how these three mode choice are affected by not only neighborhood street pattern but also by other social and economic variables. In Table 4.10, a comparison of the effect of different variables on the three sustainable modes has been shown.

Table 4.10: Effect of different variables on carpool, telework, and private vehicle usage

Variables	**Significance on different modes**		
	Carpool	Telework	Private vehicle usage
Street pattern: Gridiron		-	
Street pattern: Curvilinear		-	-
Street pattern: Irregular	-		
Street pattern: Mixed		-	
Average annual daily traffic volume (Heavy vehicles)	-	+	+
Total population	-		
Area: Ten to twenty-five (×10 km^2)		-	-
Commercial area (%)		-	
Total park area (m^2)	+		
Two-legged intersection (“L” shaped)	+		
Four-legged intersections		+	+
Area of three-legged intersection (m^2)		-	
Area of two-legged and four-legged area (km^2)	+		
Private household (%)			-
Rapid transit (Km)		-	
Arterial road (km)	-		
Collector road (m)		+	
Employment (%)		+	
Number of schools			-
Train stations			-
Gas stations			-

Variables	**Significance on different modes**		
	Carpool	Telework	Private vehicle usage
Median household income (×1000 CAD): Greater than one twenty-five		-	
Median income (×1000 CAD): Less than forty	+		
Educational qualification: University certificate (Below graduation) (%)		+	
Educational qualification: High school certificate (%)			+
Aboriginal population (%)	+		
Male (%)	-		+
Average number of children per census family	-		
Number of persons by age: 35-64 years	+		
Number of persons by age: 65 and 65+ years			+
Family size: Family of 4 persons (%)	+		
Family size: Family 2 persons (%)			-
Census families: Lone parent families (%)	+		
Lone parent families: Male lone parent (%)			-
Couple families (Census families): With children at home (%)		+	
Children living at home: 25 years and over (%)			-
Married/ Common law (Marital status): Married (%)			-
Not living with spouse or common law (Marital status): Widowed (%)		-	
Not living in a census family (Person 65 years and older in private household by living arrangement): Living with relatives (%)		-	
Occupied private dwellings by structural type: Single-detached (%)	+		
Occupied private dwellings by structural type: Apartment (%)			+

Variables	Significance on different modes		
	Carpool	Telework	Private vehicle usage
Population excluding institutional residents (Knowledge of official languages): English (%)		-	
Knowledge of official languages: English and French (%)			-
Population excluding institutional residents (Language spoken most often at home): English (%)	-		
Population excluding institutional residents (Language spoken most often at home): French (%)		+	
Positively significant +, Negatively significant -, Insignificant (No sign)			

4.4.1 Generic and Specific Variables

Table 4.11: Generic and specific variables

Transportation modes and alternatives → / **Types of variables ↓**	**Carpool**	**Private vehicle usage**	**Telework**
Generic variables	AADT volume (Heavy vehicles)		
	-	Street pattern: Curvilinear, Community area: 10-25 (×10 km^2), Type of intersection: 4 legged.	
	Percentage of male		-
Specific variables	Street pattern: Irregular, Total population, Total park area (m^2), Two-legged intersection (“L” shaped),	Private household (%), Number of schools, Train stations, Gas stations, Educational qualification: high school certificate (%), Number of	Street pattern: Gridiron, mixed; Commercial area (%), Area of three-legged intersection (m^2), Rapid transit (Km), Collector road (m), Employment (%),

Specific variables	Area of two-legged and four-legged area (km^2), Arterial road (km), Median income (×1000 CAD): Less than forty, Aboriginal population (%), Average number of children per census family, Number of persons by age: 35-64 years, Family size: Family of 4 persons (%), Census families: Lone parent families (%), Occupied private dwellings by structural type: Single-detached (%), Population excluding institutional residents (Language spoken most often at home): English (%)	persons by age: 65 and 65+ years, Family size: Family 2 persons (%), Lone parent families: Male lone parent (%), Children living at home: 25 years and over (%), Married/ Common law (Marital status): Married (%), Occupied private dwellings by structural type: Apartment (%), Knowledge of official languages: English and French (%)	Median household income (×1000 CAD): Greater than one twenty-five, Educational qualification: university certificate (Below graduation) (%), Couple families (Census families): With children at home (%), Not living with spouse or common law (Marital status): Widowed (%), Not living in a census family (Person 65 years and older in private household by living arrangement): Living with relatives (%), Population excluding institutional residents (Knowledge of official languages): English (%), Population excluding institutional residents (Language spoken most often at home): French (%)

Average Annual Daily Traffic for heavy vehicles is the most important among all the variables that have been considered in the study. It influences all the transportation modes and alternatives altogether. There are also 3 other variables [Street Pattern: Curvilinear, Community Area: 10-25 ($\times 10$ km^2), Type of Intersection: 4 legged] that influence exclusively the alternatives to the transportation modes. Moreover, Percentage of Male in a community is another variable that relates a transportation mode and an alternative. To improve or maximize sustainability in an existing transport system, these generic variables are to be considered at first. Rest of the specific variables are to be considered for promoting different modes and the alternatives exclusively.

4.4.2 Final Equations

Three forecasting equations for three different transportation mode choices/alternatives are:

a) $$Y = 420.160 - 20.591 X_1 - 0.01 X_2 - 0.014 X_3 + 0.003 X_4 + 2.087 X_5 + 0.568 X_6 - 16.317 X_7 - 5.210 X_8 - 164.795 X_9 + 0.067 X_{10} + 3.928 X_{11} + 36.458 X_{12} + 1.365 X_{13} + 7.161 X_{14} + 0.682 X_{15} - 2.325 X_{16} \quad (4.2)$$

Where,

Y= Percentage of carpool,

X_1 = Street pattern: Irregular shaped,

X_2 = Average annual daily traffic volume (Heavy vehicles),

X_3 = Total population,

X_4 = Total park area [m^2],

X_5 = Two-legged intersection/L-shaped intersection,

X_6 = Area of three-legged and four-legged intersection [km^2],

X_7 = Arterial road [km],

X_8 = Male [%],

X_9 = Average number of children per census family,

X_{10} = Number of persons by age: 35-64 years,

X_{11} = Family size: Family of 4 persons [%],

X_{12} = Median income [×1000 CAD]: Less than forty,

X_{13} = Census family: Lone parent families [%],

X_{14} = Aboriginal population [%],

X_{15} = Occupied private dwellings by structural type: Single-detached [%],

X_{16} = Population excluding institutional residents [Language spoken most often at home]: English [%].

b) $Y = -139.712 - 17.427\ X_1 - 23.979\ X_2 - 16.355\ X_3 + 0.001\ X_4 - 9.818\ X_5 - 0.561\ X_6 + 0.354\ X_7 - 545764.5\ X_8 - 348.033\ X_9 + 0.002\ X_{10} + 3.175\ X_{11} - 34.012\ X_{12} + 2.971\ X_{13} + 0.664\ X_{14} - 1.627\ X_{15} - 0.522\ X_{16} - 1.493\ X_{17} + 8.533\ X_{18}$ (4.3)

Where,

Y= Percentage of telework,

X_1 = Street pattern: Curvilinear,

X_2 = Street pattern: Gridiron,

X_3 = Street pattern: Mixed,

X_4 = Average annual daily traffic volume (Heavy vehicles]),

X_5 = Area: Ten to twenty-five [$\times 10\ km^2$],

X_6 = Commercial area [%],

X_7 = Four-legged intersection,

X_8 = Area of three-legged intersection [m^2],

X_9 = Rapid transit [km],

X_{10} = Collector road [m],

X_{11} = Employment [%],

X_{12} = Median household income [×1000 CAD]: Greater than one-twenty five,

X_{13} = Educational qualification: University certificate [Below graduation] [%],

X_{14} = Couple families [Census families]: With children at home [%],

X_{15} = Not living with spouse or common law [Marital status]: Widowed [%],

X_{16} = Not living in a census family [Person 65 years and older in private household by living arrangement]: Living with relatives [%],

X_{17} = Population excluding institutional residents [Knowledge of official languages]: English [%],

X_{18} = Population excluding institutional residents [Language spoken most often at home: French [%]

c) $Y = 1918.451 - 203.692 X_1 + 0.022 X_2 - 254.227 X_3 + 10.730 X_4 - 22.964 X_5 - 68.428 X_6 + 25.753 X_7 - 117.841 X_8 - 136.310 X_9 + 37.063 X_{10} + 0.680 X_{11} - 10.580 X_{12} - 17.062 X_{13} - 14.628 X_{14} - 63.386 X_{15} + 7.815 X_{16} - 76.002 X_{17}$ (4.4)

Where,

Y= Percentage of private vehicle usage,

X_1 = Street pattern: Curvilinear,

X_2 = Average annual daily traffic volume (Heavy vehicles),

X_3 = Area: Ten to twenty-five [×10 km^2],

X_4 = Four-legged intersection,

X_5 = Private household [%],

X_6 = Number of schools,

X_7 = Educational qualification: High school certificate [%],

X_8 = Train stations,

X_9 = Gas stations,

X_{10} = Male [%],

X_{11} = Number of persons by age: 65 and 65+ years,

X_{12} = Lone parent families: Male lone parent [%],

X_{13} = Family size: Family 2 persons [%],

X_{14} = Married/ Common law [Marital status]: Married [%],

X_{15} = Children living at home: 25 years and over [%],

X_{16} = Occupied private dwellings by structural type: Apartment [%]),

X_{17} = Knowledge of official languages: English and French [%])

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

This chapter gives an overview of the important findings of this study. How different socioeconomic, land use, road infrastructure and street patterns influences transportation modes and alternatives are summarized here altogether. Also, how this factors are helpful for policy implications are mentioned here. These are followed by some suggestions, recommendations and precautionary measures that are to be considered to improve transportation modes and alternatives to maximize sustainability in the system. Moreover, some limitations as well as scope for the future research have been discussed in this chapter.

5.1 Major Findings

In this study, several road infrastructure, land use, street patterns, socioeconomic and demographic factors are taken into account to develop relationships with transportation modes and alternatives. Among the variables, AADT (Average Annual Daily Traffic) Volume for heavy vehicles is the only variable that influences all the modes and alternatives altogether. There are three other variables that influence telework and private vehicle usage together. They are: street pattern (Curvilinear), Community area (10 to 25 × 10 km^2 / mediocre area) and Type of intersection (4-legged). Again percentage of male in a community influences carpool and private vehicle usage. Therefore, street pattern (Curvilinear), community area (10 to 25 × 10 km^2 / mediocre area), type of intersection (4-legged) and percentage of male in a community, there variables relates transportation modes and alternatives altogether. The rest of the variables are specifically influence the modes and alternatives. In conclusion it can be said that to improve sustainability in the transportation system, land use, features of road infrastructure and street patterns play vital roles. Moreover, to maximize sustainability in the system, socioeconomic factors are needed to be modified and improved continuously with time being.

Street pattern

The most important parameter for the policymakers is to determine appropriate street patterns for a community and make policies to control the factors that affect mode choices to promote sustainability. Every type of street pattern displays some advantages than others. That's why the result from the study gives a hint for the policy makers to recommend the appropriate street patterns in a particular community.

- Gridiron, curvilinear and mixed street patterns decrease telework.
- Irregular street patterns decrease carpool.
- Curvilinear street patterns decreases private vehicle usage.

Land use

Different types of communities (Agricultural/ Commercial/ Industrial/ Residential), community area, presence of rapid transit, area used for intersections, presence of schools, gas stations and train stations influences mode choices.

- The increased commercial area in a community discourages telework.
- Increased area of parks encourages carpool.
- Mediocre community area has no significance on carpool but it decreases telework and private vehicle usage.
- Area of three-legged intersections decreases telework.
- Increased rapid transit in a community discourages working at home due to the availability of public transits like BRT, MRT etc.
- Number of schools, gas stations and train stations has no significant role on carpool or teleworking but decreases private vehicle usage.

Road Infrastructures

Various road infrastructure factors such as the type of streets (Expressway/ Arterial/ Collector/ Local etc.), type and frequency of intersections (L-shaped/ 3-Legged/ 4-Legged), AADT volume, type of traffic (heavy or light) influence the use of private vehicle and other mode choices.
From the study, it has been found that average annual daily traffic volume, especially for heavy vehicles, plays a bigger role in choosing transportation modes.

- Increased number of heavy vehicles' AADT volume decreases carpool but encourages telework and private vehicle usage.

Type of intersections plays a significant role in transportation mode choice.

- Two-legged/ L-shaped intersections increase carpool.
- Four-legged intersections decrease both telework and private vehicle usage.

Type of roads present in a community plays a significant role in transportation mode choice.

- Arterial roads increase carpool.
- Collector roads increase telework.

Socio-economic and Demographic

Various socio-economic and demographic conditions like population in a community, age, gender, family size and orientation, household type, income, living places and conditions, the presence of senior citizens, number of children, marital and educational status, ethnicity and race etc. also influence on mode choices and control private vehicle usage.

- The total population of a community decreases carpool but has no significance on private vehicle usage and teleworking.
- Percentage of private household decreases private vehicle usage.

Employment and income are major determinants in choosing different modes of choice for traveling work trips.

- Percentage of employment increases telework as more than one jobs can be done simultaneously.
- Higher household income group (greater than one twenty-five thousand CAD) decreases telework as a sustainable mode of transportation in general.
- Comparatively less earning population (less than forty thousand CAD) increases carpool.

Beside income, educational qualification also plays a significant role. Usually, higher educated people are more concerned about environmental and traffic congestion issues than others.

- People having high school certificate are more likely to use private vehicles.
- Undergraduate students of universities are more prone to telework.

Mode choice and type of dwelling also have a significant relationship.

- Person living in an apartment does not show much concern using sustainable transportation modes and more prone to use private vehicles.
- People living in single-detached houses are more likely to use carpool.

Family sizes and family orientations such as the percentage of male, average number of children per family, marital status, type of census families, and type of lone parent families significantly affect the choice of transportation modes.

- If male is increased in a community, they are prone to use private vehicles alone and decreases carpool.
- The family of two persons decreases private vehicle usage whereas a four-person family increases carpool.
- An average number of children per census family decrease carpool.
- Couple families with children at home prefer telework.

- Families of lone parents are more likely to use carpool.
- Male lone parents are discouraged to use private vehicles
- Married couples decrease private vehicle usage whereas widowed people are discouraged to do teleworking.

Age is another important concern for policymakers in promoting sustainable transportation modes

- Working class people (35 to 64 years old) are more prone to carpool than others.
- Older people (65 and 65+ years old) are more likely to drive alone.
- Older people (65 and 65+ years old) living with their relatives are discouraged to work at home.
- Older children (25 and 25+ years old) living at home are less prone to drive alone may be because of their weak economic conditions.

Some of the distinct parameters such as aboriginal population, knowledge of official languages and languages are spoken at home play a significant role in selecting transportation mode choices. Therefore, it can be said that human race and their knowledge of language can change sustainable transportation mode choices.

- Aboriginal population increases carpool.
- Population (excluding institutional residents) speaking English in offices decrease teleworking but those who use both English and French decrease private vehicle usage.
- Population (excluding institutional residents) speaking English at home decrease carpool whereas people who use French increase telework.

Moreover, if a person likes to travel alone will always prefer private vehicles rather than a sustainable mode. Thus, one who drives alone will be reluctant in using sustainable modes while making a work trip.

5.2 Policy Implication

The findings of this study can be useful for the policy makers, the city planners and the engineers while building new communities or expanding old communities. While building new communities, they should emphasize on land use, street patterns and road infrastructure factors. Among these factors the most important of all is heavy vehicles' AADT volume which should be kept minimum considering through traffic in a community. Mediocre sized community area should be considered while building new communities. Also, curvilinear street patterns can be useful to control through traffic especially in residential and commercial areas. Moreover, types and density of intersections in a community should be controlled. These factors hopefully will be helpful to maximize sustainability in the transportation system. Apart from these, policy makers should emphasize on several socioeconomic and demographic factors like family orientations, household income, housing type, ethnicity, employment ratio, age etc. while making or correcting policies to promote or to maintain sustainability in the transportation system.

5.3 Suggestions and Recommendations

This study could be a good example for transportation engineers, planners and policymakers as the models help them to take necessary initiatives that can control the factors which control the different mode choices to achieve or improve the sustainability of a transport system. To do so, they must take steps to control and limit private vehicle usage.

Intersection density should be controlled within community areas especially for commercial areas. The less number of intersections, the less there congestion to be. Choosing mediocre sized community area is hopefully the best while expanding a community or building a new community. Utility services, schools, gas stations should be placed within the community area in controlled manner so that there is less trip attraction or generation especially the private vehicles.

Similar types of housing should be built together based on peoples' income range especially while building a new community. This will also be helpful for the authority to provide necessary transport system and other utility and facility services. Communities can be build based on ethnicity (English/ French/ Immigrants), Minority (French/ Aborigine/Others). Senior citizens (65+ year old) can be resided within a specific community area so that authority can provide necessary services within the community limit and citizens could do less travelling.

Along with these, parking facilities and fare with road toll for high occupancy vehicles should be minimized. To improve teleworking, the policymakers must be concerned about the advancement of the telecommunication sector. The more ease and cheap are telecommunication, the more attraction for teleworking will be generated. Also, the government should make policies to improve overall education, industrial and agriculture sector to boost up sustainability process. Above all, it is necessary to control population growth and the unemployment rate to boost up the economy of the country. Besides, all the information regarding all the sectors should be updated so that policies can be changed and improved based on public demand.

In order to promote sustainable transportation system, carpool services should be improved especially for female passengers. More transit stations should be provided in lower income zone and downtown area, as well as gridiron street pattern, should be preferred in those areas. The parking area should be increased near the public transit stations. Also, multi-stored structures should be constructed for parking in commercial areas. Nuclear families with or without children should be encouraged to use carpool for their daily activities.

In both residential and commercial areas, movement of the heavy vehicle should be restricted. Annual average daily traffic should be reduced by implementing different policies such as increased road toll, high parking price for single occupancy vehicles, restriction of heavy vehicles in community roads, constructing high occupancy vehicle lane etc.

A public awareness campaign should be organized by the government and different road authorities. The government should invest in telecommunication sector to modernize communication and should take necessary steps to ensure the maximum population of the country can be benefited from it.

However, limited access design is more appropriate for the modern community. Limited access pattern is very appropriate to increase carpool and decrease private vehicle usage. The best solution would be the implementation of both gridiron and limited access pattern in community level. Gridiron pattern should be implemented in small communities where most of the trips are produced for a short distance. In larger communities, limited access pattern should be more justified.

If the limited access pattern is implemented in the community several measures have to be taken such as dedicated lane for carpool, high and low occupancy vehicles, less connectivity and through traffic in neighborhood, improved sidewalk, public transit stations should be provided to the community, controlling vehicle speed, restriction for heavy vehicle movement, positioning schools and other services within the community limit etc.

The results of this study will also provide policymakers as well as transportation engineers and planners with important information for selecting the most appropriate street pattern or urban form for the development of new communities. However, engineers, planners and policymakers need to decide which modes are appropriate to promote, to improve and to select for an old or new community so that the highest level of sustainability can be ensured. This study will help them to select, to change or to develop existing designs and policies to promote certain modes in a community. The information is particularly useful for rapidly expanding cities like Calgary, which has experienced great growth over the past decade because of flourishing oil and gas industries.

Moreover, the findings could be utilized in developing cities like Dhaka. There are lots of new communities are rising at the outskirt of Dhaka city. If policymakers want to improve sustainability in those communities' neighborhood design characteristics must have to be considered. The results of this study can play a vital role this aspect.

5.4 Limitations and Future Research

The research has been conducted considering several limitations. In this study, some variables that might have a significant effect on mode choice are omitted due to lack of data which is an inherent problem in much applied research. Several road infrastructures features i.e. number of lanes, speed limit, road width, median width, shoulder width sidewalk have not been incorporated in the study.

Apart from the above-mentioned variables driving license, the frequency of transit, trip purpose, trip generation rate, transit network, fuel price, parking price, cost was not incorporated in the study.

How motorcycles, taxis and other paratransit affect the sustainable transportation modes should be introduced in future studies. Moreover, there may be some correlations among the modes and alternatives while developing relationship with various street patterns, socioeconomic, land use, demographics and road infrastructures altogether. These can be explored and elaborated by artificial intelligence. In addition, a questionnaire survey can be conducted among the residents of different neighborhoods about their preferred street pattern from sustainable traffic mode perspective. As the resident of the communities is the stakeholders, their views are really important in choosing street patterns, type of public transport service, infrastructures, economic and social facilities. Residents' priorities between sustainable mode choice and other advantages and disadvantages associated with various street patterns can also be revealed by this survey.

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APPENDIX

Table A.1: Percentage usage of transportation modes and alternatives in City of Calgary (Source: Department of Transport Authority, Calgary, Canada; 2011)

Name of the Neighbor-hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Abbeydale	13.971	0.0629	0.188	5.03461	0.69226	79.546	0.1258	0.3776
Acadia	21.087	0.6285	6.222	4.96543	2.45129	63.984	**0**	0.6599
Albert Park	25.171	0.8009	4.633	6.29291	1.48741	61.556	0.0572	**0**
Altadore	16.082	2.3881	3.174	4.29262	4.83676	68.833	0.0604	0.3325
Applewood Park	15.506	0.0547	0.931	5.64384	0.49315	77.260	0.0547	0.0547
Arbour Lake	21.501	0.3858	2.104	1.61347	2.4202	71.518	0.0701	0.3858
Aspen Woods	8.7570	0.4943	0.635	6.70904	1.83616	80.720	**0**	0.8474
Banff Trail	34.544	2.0177	16.06	1.53349	1.21065	44.390	**0**	0.2421
Bank view	24.554	1.7005	6.885	3.02779	1.65906	61.509	0.0829	0.5806
Bayview	4.5161	3.2258	1.290	7.74194	9.67742	73.548	**0**	**0**
Beddington Heights	19.505	0.3452	1.265	3.62486	2.7618	72.180	0.0863	0.2301
Bel-Aire	8.2568	**0**	0.917	7.33945	4.58716	78.899	**0**	**0**
Bonavista Downs	8	**0**	**0**	2.66667	1.66667	87.666	**0**	**0**
Bowness	17.057	1.6648	2.756	4.66703	2.34716	70.660	0.1364	0.7096
Braeside	12.289	0.4589	0.866	2.85569	1.63182	81.693	0.0509	0.1529
Brentwood	22.668	1.8425	8.486	3.07091	3.90843	59.799	**0**	0.2233
Bridgeland/ Rive	25.656	2.1881	12.85	2.73523	2.57112	53.172	0.1094	0.7111
Bridlewood	20.871	0.1089	0.735	4.25068	2.64305	71.035	0.0545	0.2997
Brittania	7.2115	0.9615	0.480	8.65385	3.84615	78.846	**0**	**0**
Cambrian Heights	12.948	2.8081	1.872	0.78003	1.71607	78.471	**0**	1.4040
Canyon	20.404	0.3109	1.282	3.80878	2.64283	71.511	0.0388	**0**
Capitol Hill	24.527	2.8030	7.077	3.78416	2.87316	58.794	0.0700	0.0700

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Castleridge	17.581	**0**	2.091	5.29412	2.15686	72.483	**0**	0.3921
Cedarbrae	14.536	0.2926	1.658	2.4878	2.92683	77.219	0.0487	0.8292
CFB Lincoln	13.418	1.1182	1.916	1.27796	2.07668	79.872	**0**	0.3194
Chaparral	11.834	0.0739	0.221	2.77367	3.40237	81.25	0.0369	0.4068
Charles Wood	19.409	2.0431	6.242	4.6538	4.99432	62.315	**0**	0.3405
Chinatown	25.895	0.5509	53.44	2.75482	0.82645	15.427	**0**	1.1019
Chinook Park	17.557	1.7811	3.816	5.59796	5.85242	64.631	0.2544	0.5089
Christie Park	15.399	2.3391	0.584	9.94152	2.33918	69.200	0.1949	**0**
Citadel	18.743	0.5919	0.361	2.36764	3.15686	74.350	0.0657	0.3617
Cliff Bungalow	16.821	2.4361	34.45	0.81206	3.01624	42.459	**0**	**0**
Coach Hill	19.002	1.5051	0.658	2.44591	2.8222	73.283	**0**	0.2822
Colling wood	18.580	2.7190	3.172	3.02115	4.98489	67.371	0.1510	**0**
Copperfiel d	8.2101	0.2873	0.451	6.28079	2.01149	82.553	0.0410	0.1642
Coral Springs	18.308	0.0735	0.220	5.58824	1.02941	74.558	**0**	0.2205
Cougar Ridge	12.737	1.2440	0.355	6.1019	4.62085	74.703	**0**	0.2369
Country Hills	12.780	**0**	1.727	3.54059	1.64076	79.101	0.0863	1.1226
Country Hills V	15.620	0.2670	2.536	2.93725	0.80107	77.303	0.1335	0.4005
Coventry Hills	12.991	0.1448	0.372	5.1717	1.84113	79.127	0.0413	0.3103
Cranston	10.609	0.2806	0.420	3.59248	2.44176	82.234	0.0280	0.3929
Crescent Height	16.573	1.8622	25.51	1.82495	2.71881	51.247	0.0372	0.2234
Crest Mont	8.7058	0.9411	0.470	6.82353	5.41176	75.529	0.2352	1.8823
Dalhousie	28.145	0.7840	1.489	1.64641	1.56801	65.738	0.0392	0.588

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
DeerRidge	12.659	0.0849	2.293	3.39847	5.26763	75.870	**0**	0.4248
Deer Run	11.774	0.2900	1.334	5.85847	4.06032	76.102	0.058	0.5220
Diamond Cove	8.2191	1.3698	0.913	8.21918	6.84932	73.516	**0**	0.9132
Discovery Ridge	5.1985	0.4332	0.288	2.67148	2.52708	88.736	**0**	0.1444
Douglas Glen	11.558	0.4670	0.992	3.47344	3.561	79.276	0.0583	0.6129
Dover	14.478	0.6580	1.824	6.58092	1.01705	75.142	0.0299	0.2692
Downtown	41.925	0.6338	38.24	2.89768	0.72442	**15.152**	**0**	0.4225
Downtown East V	15.158	2.4449	38.14	3.17848	0.978	40.097	**0**	**0**
Downtown Western	34.317	0.369	30.62	0.83026	2.67528	30.073	0.0922	1.0147
Eagle Ridge	**1.7241**	**0**	1.724	**0**	1.72414	**94.827**	**0**	**0**
Eau Claire	4.5706	0.2770	**67.31**	1.66205	1.66205	24.376	**0**	0.1385
Edgemont	16.902	0.7318	0.519	14.542	3.91879	62.889	**0**	0.4957
Elbow Park	6.6666	2.0689	6.206	2.52874	7.47126	74.712	0.1149	0.2298
Elboya	15.859	1.1686	4.674	3.17195	4.50751	69.282	0.1669	1.1686
Erin Woods	13.418	0.4407	0.930	5.92556	1.32223	77.815	**0**	0.1469
Erlton	14.950	1.8272	21.59	0.83056	1.66113	58.804	0.1661	0.1661
Evanston	7.1507	0.2750	0.385	4.78548	2.58526	84.543	**0**	0.2750
Evergreen	16.706	0.2207	0.424	5.60272	2.64856	73.989	0.0339	0.3735
Fairview	14.631	0.4845	2.131	5.71705	1.64729	74.515	**0**	0.8720
Falconridge	13.907	0.0706	0.882	2.36498	0.60007	81.927	0.0353	0.2117
Forest Heights	23.062	0.246	2.890	6.64207	1.35301	65.375	0.0615	0.369
Forest Lawn	25.049	0.6930	4.554	4.50495	1.28713	63.663	0.0495	0.1980
Forest	17.142	**0**	5.714	2.85714	2.85714	71.428	**0**	**0**
Glenbrook	17.824	0.8737	4.368	2.79598	1.57274	72.433	0.0873	0.0436
Glenbrook	17.824	0.8737	4.368	2.79598	1.57274	72.433	0.0873	0.0436

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Glendale	13.202	1.0457	1.437	4.44444	2.61438	77.124	**0**	0.1307
Greenview	21.926	0.1267	4.055	1.39417	0.8872	70.849	0.1267	0.6337
Greenwood /Green	10.736	0.9202	0.613	6.44172	1.22699	79.447	**0**	0.6135
Hamptons	14.453	0.1877	0.422	7.88362	3.3787	73.205	**0**	0.4692
Harvest Hills	13.294	0.4537	1.270	1.81488	2.2686	80.671	0.1814	0.0453
Hawk wood	20.528	0.5443	0.855	7.27061	4.78227	65.746	**0**	0.2721
Haysboro	26.593	0.7821	3.989	2.07274	2.77669	63.629	0.0391	0.1173
Hidden Valley	11.343	0.3781	0.319	5.55556	3.66492	78.504	**0**	0.2326
Highland Park	23.247	0.9908	1.676	3.96341	1.52439	68.140	0.0762	0.3811
Highwood	15.427	3.2258	1.963	1.68303	2.6648	74.894	**0**	0.1402
Hillhurst	19.346	3.4673	25.52	1.35678	4.37186	45.376	0.1507	0.4020
Hounsfield Heights	26.222	4.2963	10.22	1.03704	5.33333	52.296	**0**	0.5925
Huntington Hill	18.125	0.5207	1.661	5.28143	2.23159	71.609	0.0743	0.4959
Inglewood	14.772	2.1390	9.090	8.35561	3.81016	61.430	0.2005	0.2005
Kelvin Grove	12.903	1.0186	4.074	1.52801	1.18846	79.286	**0**	**0**
Killarney/ Gleng	20.957	1.4942	1.915 71	2.98851	2.49042	69.578	0.0383	0.5364
Kingsland	21.728	0.8521	6.999	3.71272	2.00852	64.211	0.0608	0.4260
Lake Bonavista	13.595	0.5479	1.404	2.36301	4.65753	77.020	**0**	0.4109
Lakeview	11.622	1.5964	2.234	8.42912	4.27842	71.647	**0**	0.1915
Lincoln Park	17.246	0.4347	9.855	2.75362	1.88406	67.681	0.1449	**0**
Lower Mount Roy	20.709	2.6950	28.43	1.84397	2.48227	43.262	0.1418	0.4255
Macewan Glen	14.126	0.3479	0.556	3.34029	2.29645	79.192	**0**	0.1391

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Manchester	38.961	0.4329	9.956	0.4329	0.4329	48.917	**0**	0.8658
Maple Ridge	10.223	0.3717	0.371	3.90335	4.83271	79.739	**0**	0.5576
Marlborou g	19.071	0.3641	1.729	3.45926	1.68411	73.054	**0**	0.6372
Marlborou gh Park	13.995	0.2484	1.780	3.93375	0.91097	78.633	**0**	0.4968
Martindale	19.963	0.1510	0.845	16.9133	0.60405	61.250	0.0604	0.2114
Mayfair	5.7377	1.6393	0.819	7.37705	9.83607	74.590	**0**	**0**
Mayland Heights	15.096	0.4052	2.482	4.00203	2.43161	75.430	**0**	0.1519
McKenzie Lake	8.8899	0.4129	0.534	2.74472	4.56643	82.633	**0**	0.2186
McKenzie Towne	10.880	0.0557	1.652	3.30486	2.37653	81.117	0.0185	0.5941
Meadowlar k Park	16.279	1.1627	3.488	7.55814	5.23256	66.279	**0**	**0**
Midnapore	15.333	0.2874	2.539	2.39578	2.15621	76.713	**0**	0.5749
Millrise	23.481	0.2893	1.350	3.51977	3.18226	67.406	**0**	0.7714
Mission	17.902	1.2427	29.35	0.69903	2.21359	48.194	0.0388	0.3495
Monterey	12.610	0.1542	0.539	6.24759	1.58118	78.711	**0**	0.1542
Montgomer	17.135	2.1312	4.177	1.79028	1.79028	67.774	0.0852	**5.1150**
Mount Pleasant	17.181	4.6612	9.268	2.00542	2.49322	62.655	0.3794	1.3550
New Brighton	9.3674	0.0405	1.054	8.23195	2.63585	77.696	0.0405	0.9326
North Glenmore	12	1.8571	1.428	1.57143	2.42857	80.571	**0**	0.1428
North Haven	18.456	1.5128	1.512	0.75643	2.72315	74.886	**0**	0.1512
North Haven Upper	16.574	3.8674	1.657	1.65746	1.65746	74.585	**0**	**0**
Oakridge	13.441	1.4074	1.900	1.8297	5.9817	74.806	0.0703	0.5629
Ogden	17.147	0.4811	2.096	2.74914	1.20275	75.670	0.1718	0.4811

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Palliser	15.665	0.8867	3.054	3.05419	3.44828	73.891	**0**	**0**
Panorama	13.796	0.0346	0.415	5.29687	1.36749	78.570	0.0865	0.4327
Parkdale	13.896	5.0143	14.61	3.86819	4.01146	57.736	0.2865	0.5730
Parkhill	18.918	0.9009	5.855	1.8018	5.25526	66.967	0.1501	0.1501
Parkland	10.247	0.5489	0.823	1.55535	5.03202	81.518	**0**	0.2744
Patterson	16.148	0.7432	1.351	1.62162	3.37838	76.283	0.0675	0.4054
Penbrooke Meado	19.630	0.3961	1.672	3.52113	0.44014	73.679	0.0440	0.6162
Pineridge	16.938	0.3706	1.519	4.00297	1.11193	75.574	0.0741	0.4077
Point Mckay	13.945	**5.7823**	9.353	4.59184	8.16327	58.163	**0**	**0**
Pump Hill	9.1168	0.5698	1.139	0.8547	2.5641	85.470	**0**	0.2849
Queens Park Village	30.555	0.6944	0.694	2.77778	2.08333	61.805	**0**	1.3888
Queensland	12.905	0.3242	1.945	3.5668	2.01038	77.950	0.0648	1.2321
Ramsay	17.524	3.5539	14.09	4.53431	2.69608	57.475	0.1225	**0**
Ranchlands	21.654	0.6234	1.704	3.99002	4.07315	67.082	**0**	0.8728
Red Carpet	12.776	0.4731	1.104	2.36593	0.47319	82.807	**0**	**0**
Renfrew	15.630	2.4959	8.797	1.59574	2.82324	68.126	0.1227	0.4091
Richmond	20.687	2.125	3	3.75	3.1875	67.062	0.0625	0.125
Rideau Park	8.3798	2.7933	11.17	1.11732	8.93855	67.597	**0**	**0**
Riverbend	11.096	0.4968	1.358	1.29182	2.55051	83.007	0.0331	0.1656
Rocky Ridge	15.163	0.1794	0.628	7.6716	4.53118	70.883	0.0897	0.8524
Rosedale	7.8389	1.6949	27.96	1.69492	4.87288	55.508	0.2118	0.2118
Rosemont	21.628	2.0356	1.526	0.76336	3.05344	70.992	**0**	**0**
Rosscarroc k	23.276	0.8952	5.729	3.8496	0.89526	64.906	0.1790	0.2685
Roxboro	7.0707	3.0303	27.27	**0**	4.0404	58.585	**0**	**0**
Royal Oak	17.424	0.4106	0.762	4.66412	3.10942	73.306	**0**	0.3226
Rundle	24.169	0.3050	3.186	2.77966	1.08475	68.169	0.0339	0.2711
Rutland Park	18.038	0.9493	5.379	3.63924	3.63924	68.196	**0**	0.1582

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Saddle Ridge	20.600	**0**	0.096	4.03616	0.25831	74.878	**0**	0.1291
Saddle Ridge In	20	**0**	**0**	**0**	**0**	80	**0**	**0**
Sandstone Valle	20.772	0.4096	0.760	4.44705	1.6969	71.737	0.1170	0.0585
Scarboro	8.2304	2.0576	14.40	1.23457	5.76132	67.901	**0**	0.4115
Scarboro/ Sunalt	10.833	1.6666	1.666	2.5	**10**	73.333	**0**	**0**
Scenic Acres	20.598	0.8239	1.387	2.68864	3.46921	70.771	0.0433	0.2168
Shaganappi	24.390	0.9380	4.127	3.18949	4.69043	62.288	0.1876	0.1876
Shawnee Slopes	19.704	0.4926	0.492	1.72414	7.14286	68.719	**0**	1.7241
Shawnessy	23.313	0.1482	1.704	4.11416	2.66864	67.828	**0**	0.2223
Shepard Industry	6.8181	**0**	4.545	**0**	3.40909	85.227	**0**	**0**
Signal Hill	15.974	0.9830	1.146	4.66958	3.16767	73.730	0.0273	0.3003
Silver Springs	15.805	2.0310	0.997	2.58493	4.57903	73.227	0.0738	0.7016
Skyline East	13.207	0.1886	0.943	0.37736	**0**	85.283	**0**	**0**
Somerset	28.605	0.1975	1.698	8.96879	1.93599	58.158	0.0395	0.3951
South Calgary	18.148	1.5729	3.932	5.80762	4.23472	65.698	0.0605	0.5444
Southview	21.146	0.7905	0.988	1.97628	0.59289	74.505	**0**	**0**
Southwood	24.184	0.3625	2.537	3.31434	2.74469	66.338	0.1035	0.4142
Spring bank Hill	10.549	0.3233	1.091	5.41633	5.37591	76.839	0.0404	0.3637
Spruce Cliff	21.032	1.6704	2.809	**21.1086**	2.50569	50.721	**0**	0.1518
St. Andrews Heights	18.832	3.4482	18.56	1.85676	3.97878	53.315	**0**	**0**
Strathcona	15.692	2.1538	0.717	5.38462	4.35897	71.589	**0**	0.1025

Name of the Neighbor-Hoods	Public Trans-port (%)	Bicycle (%)	Walk (%)	Carpool (%)	Telework or Home Office (%)	Private Vehicle Usage as Driving Alone (%)	Motor cycle (%)	Other Modes (%)
Sunalta	21.567	1.5188	16.64	2.91616	1.09356	55.893	0.1215	0.2430
Sundance	14.163	0.3086	1.851	4.7668	4.7668	73.799	0.0685	0.2743
Sunnyside	30.525	3.1091	25.32	2.31769	3.44828	33.860	0.0565	1.3567
Taradale	15.248	0.1009	0.403	4.31709	0.73214	78.944	**0**	0.2524
Temple	15.791	**0**	0.686	4.11946	1.27017	77.651	0.1716	0.3089
Thorncliffe	19.824	0.6571	2.482	5.40343	2.22709	68.966	0.0365	0.4016
Tuscany	16.801	0.718	0.574	4.73883	4.63113	71.890	0.0359	0.6103
Tuxedo Park	23.725	1.5288	5.832	2.83126	2.54813	62.910	0.0566	0.5662
University Heights	21.637	1.9883	22.22	1.28655	1.52047	50.526	0.2339	0.5848
University of Calgary	**49.110**	2.1352	24.91	2.4911	**0**	21.352	**0**	**0**
Upper Mount Roy	8.7067	1.9206	13.70	1.28041	3.96927	69.526	**0.3841**	0.5121
Valley Ridge	10.591	1.5130	0.825	7.63411	3.37001	74.965	0.0687	1.0316
Varsity	22.484	2.5679	6.688	2.09018	2.06032	63.84	0.0597	0.2090
Vista Heights	15.048	0.4854	1.618	1.61812	1.13269	79.935	0.1618	**0**
West Hillhurst	18.451	5.0632	11.53	3.74878	2.92113	57.156	0.0973	1.0224
West Springs	11.822	1.5555	0.666	5.64444	4.53333	75.422	0.0444	0.3111
Westgate	18.232	1.7679	1.657	5.52486	3.64641	68.839	**0**	0.3314
Whitehorn	21.488	0.2002	2.235	3.77044	1.53487	70.136	0.0667	0.5672
Wildwood	18.306	4.5082	2.049	1.22951	2.18579	71.448	0.1366	0.1366
Willow Park	15.531	0.6365	4.583	4.01018	3.62826	70.719	0.0636	0.8275
Windsor Park	22.903	0.6362	8.733	2.1978	2.94968	62.001	0.1156	0.4627
Winston Heights	14.483	3.0105	3.742	2.11554	2.35964	73.555	0.1627	0.5695
Woodbine	14.405	0.4365	1.018	3.71044	3.41943	76.682	**0**	0.3273
Woodlands	13.765	0.3749	0.964	6.48099	5.1955	72.362	**0**	0.8569