Influence of Community Design and Sociodemographic Characteristics on Teleworking

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Abstract: The traffic on the roads in many countries has been increasing in recent decades, and the increases in congestion and carbon emission are contributing significantly to climate change. To minimize these adverse effects, the use of more sustainable travel modes, such as public transit, walking, bicycling, carpool and ridesharing, has been widely promoted. Apart from these travel modes, alternatives, such as teleworking, which reduces commute trips, should also be promoted. The objective of this study is to identify different neighborhood design and social characteristics that are associated with teleworking. In this case study, a multiple regression model is applied to 2011 census data and road infrastructure data of 185 communities from the city of Calgary in Canada. In addition, a random intercept model is estimated to account for unobserved heterogeneity. We find that different street patterns, geographical size, land use, mass rapid transit, and road types have a significant effect on teleworking or working-at-home and should be considered when designing new communities. We also find several significant sociodemographic characteristics, including family size, marital status, children, housing type and language. Policy implications based on this research are then provided.

Keywords: teleworking; working from home; community design; sociodemographic characteristics

1. Introduction

In recent decades, many metropolitan areas in the world have experienced a significant increase in traffic congestion, environmental pollution, accidents, excessive fuel consumption, and excessive capital investments for infrastructures due to an increase in vehicle usage deriving from urban sprawl and car ownership growth. For example, the congestion cost increased from USD 73.1 billion in 2004 to USD 87.2 billion in 2007 in America alone [1]. Moreover, according to Mitropoulos et al. [2], the consumption of fossil fuel in transportation contributed to about 31% of the total carbon dioxide emissions in America and 26% of the total greenhouse gas emissions in 2011. Greenhouse gas emissions for urban travel in Canada in 1997 were estimated at 215 gm per passenger-kilometer for a car or a light truck, 77 gm for urban transit, 26 gm for intercity bus travel and 0 gm for walking or cycling [3]. Of course, since teleworking would not require any transportation, it too would have 0 gm of emission, in addition to no negative transport externalities such as noise pollution, excessive fuel consumption, excessive capital investments for infrastructure, and traffic collisions.

All these negative externalities derived from personal vehicle usage could be minimized by various technological inventions like eco-driving, improvement in automobile engine and fuel use, and artificial

intelligence in vehicle control. However, these measures alone would not be sufficient. Several traffic control policies have also been proposed and widely adopted by many jurisdictions, including travel demand management [4,5], mobility management [6], transportation control measures [7] and travel blending [8]. Along with these interventions, more sustainable travel modes, such as cycling, walking and public transit use at community level, have also been widely promoted. Pasha et al. [9,10] and Rifaat et al. [11] found that several factors related to socioeconomic, demographic, road infrastructure and different street patterns had a significant influence on cycling, walking and public transit ridership.

Besides promoting these sustainable transportation modes, it is also possible to reduce commuting trips in a community by promoting a home-based office or teleworking. According to de Graaff et al. [12], a teleworker is an individual who uses information and communication technology (ICT) to work fully or partly at home (or somewhere other than at the office). Teleworking has been increasing in popularity [13,14] since the mid-1970s, with the rapid development and adoption of ICT. This resulted in an increase in the flexibility of the labor force, and workers are less constrained to working together at the same location. For example, in the USA, telework has been facilitated by tools such as groupware, virtual private networks, conference calling, videoconferencing, virtual call center, and the decreasing cost of good-quality laptop computers. Teleworking is an efficient and useful means for many companies, since it allows workers to communicate from long distances, thereby saving travel time and cost. The easy accessibility of broadband internet connections with high bandwidths at home enables workers to maintain regular communications with their offices. In addition, with the advances in wireless and cloud computing technologies, employees can work on their laptops, mobile phones, personal digital assistant devices and other portable devices at any time and from any place [15,16].

Balancing working life and family life is an important factor in increasing the productivity of employees. Considering the travel time and cost savings, enhanced safety and security, and the luxury of spending more time with family, working at home is a better alternative than working in the office. According to Harpaz [17], telework is also beneficial from an individual's perspective. The absence of direct supervision may increase the level of responsibility of individuals due to an increase in autonomy and self-control. Moreover, many governments in the European Union are actively promoting telework to reduce traffic congestion and to expand employment opportunities for the physically challenged population [17]. On the other hand, early telework initiatives in the USA were rooted in social policy issues, which focused on the beneficial impacts that telework would have on the environment and traffic in urban areas [17].

Despite its many benefits, teleworking has some limitations. For individuals, there are possible downsides such as social and professional isolation, lack of separation between home and work, and work and family conflict [12,18]. From an organizational perspective, the major drawbacks are difficulties in measuring employees' performance, lack of innovative teamwork, safety and liability, sufficiency of technology, security of information, selection of eligible employees, costs involved in the transition to a new work method, training and reduced commitment [12,18]. These influences have limited the uptake of teleworking. In the United States, for example, a 2012 estimate suggests that over fifty million U.S. workers (about 40% of the working population) could work from home at least part of the time [19]. However, only 3.7 million employees worked from home at least half the time in 2017 [20].

Although the uptake of teleworking or the home office has not been as promising in the past, it has immense potential due to the rapid developments in ICT. Moreover, teleworking may be necessary in the event of a major pandemic, such as the current COVID-19 crisis when many governments around the world have issued a "stay at home" order to slow the spread of a deadly virus. Although the long-term impact of such an order has yet to be examined in the literature, it is highly likely that teleworking will be more prevalent even when the pandemic is over. Therefore, there is a critical need to identify the factors contributing to the adoption of teleworking, not only to promote this sustainable mode of commute but also to understand the impact of any travel restrictions on workers and communities. Besides understanding the roles of technologies, teleworking feasibilities

and workers' attitudes, policy makers also need to know how neighborhood design (land use and infrastructure) and sociodemographic characteristics will affect teleworking. However, there are few studies showing relationships between teleworking and community characteristics to provide evidence-based recommendations to promote this sustainable mode of transportation.

Thus, the objective of this study is to identify the significant neighborhood design and sociodemographic characteristics that influence teleworking, using the City of Calgary as a case study. Based on the results from this study, some policy recommendation will also be provided. This study will contribute to the literature on sustainable transportation by examining the factors contributing to teleworking and reducing the need to commute. It will focus on the influences of design, land-use and infrastructure, as well as the sociodemographic characteristics, which have thus far received insufficient attention in the literature on teleworking.

2. Methodology

2.1. Model

The objective of this study is to identify factors contributing to the share of teleworking in commute trips. Since the share of teleworking (%) is a continuous variable, the standard regression model is initially applied

$$Y = X \times \beta + \varepsilon \qquad (1)$$

where Y is the percentage of teleworking in each community area; X is a vector of explanatory variables; β is a vector of parameters to be estimated; ε is the normally distributed error term.

To account for unobserved heterogeneity, a random effects modelling approach was then adopted by incorporating a random intercept term in the model. Several widely used distributions, such as the normal and uniform distributions, were explored in this study. The results from preliminary analyses indicated that the model with the uniform distribution had the highest log-likelihood and lowest Akaike Information Criterion.

Although the factors contributing to the "voluntary" or non-legally mandated adoption of teleworking are numerous and diverse, this study will focus on two categories. The first category consists of physical factors, which include land use, neighborhood design, road infrastructure and traffic. These factors have been widely examined in many travel modes [9,10]. The second category consists of neighborhood sociodemographic characteristics, which have received little attention in the literature to date.

From a conceptual perspective, we can argue that the sociodemographic characteristics of the neighborhood where a person lives may be a reflection of his/her socioeconomic status. It may also reflect his or her attitudes and beliefs on transportation, sustainability and well-being, which will have an influence on attitudes toward work-life balance and teleworking. The sociodemographic characteristics of the neighborhood where a person lives may also have a significant influence on his/her social norms, which, according to the Theory of Planned Behavior, will have a significant influence on his/her intentions and behaviors [21,22].

2.2. Data

For this study, the dependent variable was the percentage of people teleworking in each community area of Calgary, Canada, which was compiled using the Calgary Civic Census in 2011. After excluding the few communities that did not have sufficient data on some key variables, the final sample consisted of 185 observations. Table 1 presents the commute choice of residents in these community areas. This choice is defined in the census as "the main mode of transportation a person uses to travel between his or her home and his or her place of work" and telework is reported in the Civic Census as "Work from Home". As shown in the table, teleworking in Calgary is not a very popular commute mode, with a mean of only 2.96% and a maximum of 10%. Therefore, there is a huge potential for improvement.

Table 1. Commute mode choices (%) in the City of Calgary.

Mode Choice	Mean	Max	Min
Private Vehicle	68.90	94.83	15.15
Public Transport	16.91	49.11	1.72
Walk	5.74	67.31	0
Carpool	3.87	21.11	0
Telework	2.96	10.00	0
Bicycle	1.15	5.78	0
Motorcycle	0.05	0.38	0
Other Modes	0.41	5.12	0

This study focused on two categories of independent variables; namely, sociodemographic variables and accessibility and land-use related variables. Data on these variables were collected from several sources and were guided by previous studies [10–12]. First, the 2011 Population Census provided data on socioeconomic and demographic characteristics of each community areas, including income, employment, education, age, gender, ethnicity, family structure, and housing. Second, the City of Calgary's Land Information and Mapping database provided data on the neighborhood design and road infrastructure, including the length of different types of roads, and the number and areas of intersections. Third, the locations of light rail transit lines and stations were identified from the Calgary Transit Map. Finally, the street pattern in each community area was taken from previous studies [10–12]. The summary statistics for the variables used in the final model are reported in Table 2. Note that one of the categories from each categorical variable is used as a reference in the regression, because the categories always sum to one.

Table 2. Summary statistics.

Variables	Mean	Std. Dev.
Accessibility and Land-Use Variables		
Street pattern *		
Curvilinear	0.242	0.429
Gridiron	0.203	0.403
Irregular	0.383	0.487
Mixed	0.172	0.378
Area (10 km^2) *		
≤10	0.220	0.415
(10–25]	0.392	0.489
(25–75]	0.370	0.484
>75	0.018	0.132
Total population (1000)	4.666	4.434
Industrial area (%)	12.163	27.606
Residential area (%)	48.115	26.603
Rapid transit (m)	2.094	11.283
Intersection area (km^2)	43.385	20.519
Expressway/Highway (km)	0.862	1.576
Service lane area (m^2)	0.493	2.66

Table 2. *Cont*.

Variables	Mean	Std. Dev.
Sociodemographic Variables		
Lone parent families (%)		
Female	76.907	10.743
Male	23.461	10.027
Family size (%)		
2	51.143	12.954
3	21.775	4.987
4	19.621	7.601
5	7.659	3.815
Marital Status of those not living with a spouse (%)		
Single	68.439	9.133
Separated	5.901	4.862
Divorced	15.363	4.432
Widowed	10.593	6.576
Children living at home (%)		
<6	25.945	9.632
6–14	31.412	5.747
15–17	11.846	4.098
18–24	21.077	6.786
≥25	10.115	3.995
Person 65 years and older not living with family (%)		
Living with relatives	19.313	19.991
Living with non-relatives	6.824	6.079
Living alone	74.066	22.981
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	22.000	25.609
Other dwelling	1.544	11.159
Knowledge of official languages (%)		
English Only	89.275	3.985
French Only	0	0
English and French	8.643	3.464
Neither English nor French	2.038	3.761

* Means of categorical variable are the proportion in each category.

3. Results and Discussions

The results from the statistical analysis are shown in Table 3. In general, the simple linear model had a good goodness-of-fit statistic (R^2 = 0.3907; F = 6.6135; p < 0.0001). Note that only variables that were statistically significant at the 90% confidence level were retained in the model. Although the 95% confidence level is the traditional threshold, many researchers [9,10,23–25] and software (e.g., NLogit) have also reported variables that are significant at the 90% and 99% confidence levels.

To account for unobserved heterogeneity, a random effects or random intercept model was also estimated. In general, the model fitted the data quite well (χ^2 = 90.6; p-value < 0.001). As shown in Table 3, the standard deviation was statistically significant (p < 0.001), indicating the random intercept model was preferred. However, all the estimated coefficients were very similar to those of the simple linear model. Most of the standard errors were also quite similar, with the exception of the "Service lane area", which had become statistically not significant.

Table 3. Regression results for telework.

Variables	Simple Linear Model			Random Intercept Model		
	Coeff.	**Std. Err.**	**p-Value**	**Coeff.**	**Std. Err.**	**p-Value**
Street pattern						
Irregular	0.496	0.271	0.069	0.498	0.242	0.039
Area						
(10–25]	−0.465	0.248	0.062	−0.471	0.226	0.037
Total population	−0.088	0.036	0.017	−0.088	0.035	0.012
Industrial area	−0.036	0.016	0.031	−0.035	0.016	0.026
Residential area (%)	0.013	0.008	0.080	0.013	0.007	0.052
Rapid transit (m)	−0.024	0.011	0.034	−0.024	0.012	0.052
Intersection area (km^2)	−0.0197	0.008	0.013	−0.019	0.006	<0.001
Expressway/Highway (km)	−0.202	0.092	0.029	−0.201	0.099	0.043
Service lane area (m^2)	−0.074	0.044	0.097	−0.074	0.059	0.212
Lone parent families (%)						
Female lone-parent (%)	−0.040	0.011	0.001	−0.040	0.007	<0.001
Family size (%)						
3	−0.058	0.026	0.029	−0.058	0.019	0.002
Children living at home (%)						
6–14 years (%)	0.062	0.023	0.008	0.063	0.019	0.001
Marital Status of those not living with a spouse (%)						
Widowed	−0.035	0.019	0.072	−0.035	0.017	0.043
Person 65 years and older not living with family (%)						
Living with relatives	−0.035	0.008	<0.001	−0.035	0.009	<0.001
Occupied private dwellings by structural type (%)						
Apartment	−0.024	0.006	<0.001	−0.024	0.006	<0.001
Knowledge of official languages (%)						
English	−0.085	0.035	0.015	−0.084	0.030	0.005
Constant (Mean)	15.587	3.329	<0.001	15.441	2.730	<0.001
Constant (Standard deviation)				1.355	0.247	<0.001

Compared with other neighborhood street patterns, an irregular pattern was associated with an increase in the share of teleworking in a community. A gridiron pattern was usually present in the urban downtown, inner-city and outer commercial-industrial areas. To avoid traffic congestion, people might like to live near their offices. The traditional gridiron pattern also allowed travelers to use different roads to get to their destinations in a community, which might be a good reason for decreasing teleworking. In Calgary, the newly built communities were mostly curvilinear road, which were usually situated in suburban areas. These communities were well connected to the train system by many feeder bus services, which would encourage commuters to use public transit, consequently decreasing teleworking. In contrast, irregular street patterns were usually found in the suburban areas and older, more expensive neighborhoods. They had less street connectivity and accessibility to public transport. These results implied that neighborhoods with less street connectivity and accessibility to public transport might encourage teleworking as compared to neighborhoods with more street connectivity and accessibility to public transport.

Our results showed that the size of a community played an important role. Smaller to mid-size communities (10–25 × 10 km^2) were associated with lower "work-at-home" or teleworking. Most of these communities were located in the inner suburbs close to the city center. These communities were well provided with public transportation, so people might feel discouraged to work at home. On the other hand, communities with a larger population were associated with lower "work-at-home" or teleworking. Most high-density housing developments in Calgary were located in the city and near transit stations (transit-oriented development). This inference was supported by the findings that higher shares of apartments were associated with lower teleworking, whereas rapid transit was positively related to teleworking.

As expected, the land use patterns of the community areas had a significant impact on teleworking. We found that the share of teleworking was smaller for highly industrial areas. If many of the people living in these areas also worked there, then teleworking would be expected to be smaller because most jobs in manufacturing and industry would require employees to be present in the work place. On the other hand, teleworking was found to be higher in highly residential areas. Many newly developed communities in Calgary had high percentages of residential land use and they were mostly located at the outer suburbs of the city. The connectivity and accessibility to public transport were low, which might discourage commuting and encourage teleworking.

As expected, the road infrastructure of the community areas had a significant influence on teleworking. As the area used for road intersections increased, the share of teleworking decreased. More intersections in a community would mean more connectivity, which would promote the usage of active transport and public transit, as well as personal vehicles, for commute to work, which would discourage teleworking. As the length of an expressway increased in a community, the share of teleworking in a community decreased. Favorable driving conditions on the expressways might be a reason for more residents driving to work instead of working at home. Finally, more land allocated to service lanes in a community was associated with lower teleworking. This might be due to higher levels of connectivity and accessibility by private vehicles.

It should be noted that, although neighborhood design and infrastructure provision may influence the residents' decision to commute to work or telework, it is also plausible that employees who need to travel to work and those who do not self-select into neighborhoods with different features. For example, employees who need to travel may be more likely to live in areas with high road network connectivity and high accessibility to public transportation to reduce their commute costs. Since the city center and industrial areas are centers of employment, these areas also tend to attract residents who need to physically commute to work in these areas.

In this study, we argue that the socio-demographic characteristics of the neighborhood where a person lives may be a reflection of his/her socioeconomic status, as well as attitudes and beliefs on transportation, sustainability and well-being, which will have an influence on the person's attitudes towards work-life balance and teleworking. The socio-demographic characteristics of the neighborhood

where a person lives may also have a significant influence on his/her social norms, which will have a significant influence on his/her behavior [21,22].

As expected, household size was found to be a significant factor associated with teleworking. Households with three persons were negatively associated with teleworking. These households would be more likely to consist of two adults and one child. If only one adult is working, then the other can stay home to look after the children. If both adults are working, they will be more able to afford childcare services. If all three members are adults, there is less need for any to stay at home to work. Muhammad et al. [26] noted that traditional factors like household type, number of children in the household, and the stage of life cycle played a dominant role in residential location preferences and telecommuting.

As shown in Table 3, relative to male lone parents, female lone parents were negatively associated with teleworking. This might imply that female lone parents preferred to work outside rather than at home. Alternatively, it might imply that female lone parents were not employed in jobs that would be amenable to working-at-home. It might also be due to the greater social support and public assistance programs, which enabled them to place their children in childcare centers. As expected, households with children aged 6–14 were positively associated with teleworking. Children at this age would attending elementary schools and might be too old to be placed in childcare centers. Thus, parents might prefer to work at home.

As shown in Table 3, households with widowed persons and older persons living with relatives who were not their families were associated with less teleworking. Perhaps, these people might prefer working outside of their homes to reduce loneliness and to increase their social connectivity through work.

Interestingly, residents who speak English only are negatively associated with teleworking. Households that speak both French and English or neither French nor English are more likely to telework. Although French is an official language in Canada, it is not widely used in Alberta. Immigrants who do not speak English well are more likely to be self-employed or employed in "back office" jobs that are more amenable to working at home.

4. Conclusions

Urban planners and policy makers are looking for ways to make cities more livable and the transportation system more sustainable by reducing the use of private vehicles and promoting the use of public transportation and active modes of transportation. With the recent rapid development of the ICT sector, reducing the need to commute by working-at-home or teleworking represents a better solution. Since teleworking does not require any transportation, it has no negative transport externalities such as air pollution, noise pollution, excessive fuel consumption, excessive capital investments for infrastructure, and traffic collisions [27,28]. To implement and encourage teleworking in existing and newly built communities, transport planners need to know the influence of urban form, road infrastructure and sociodemographic characteristics on teleworking.

Complex relationships exist between transportation modes and choice of residential area [29]. By changing the accessibility of various opportunities and services, transport developments may affect the residential choice of different socioeconomic segments of the population. The choice of residential area depends on socio-economic characteristics (e.g., income, number of members, and the number of owned cars), neighborhood characteristics (e.g., housing price and accessibility to various services and opportunities), and accessibility to pre-specified destinations such as workplaces [30–34]. However, telecommuting and travel time delay are strongly correlated and affected by the residential location of households as well [35,36].

Our study finds that neighborhoods with an irregular street pattern (loops and lollipop design) and high residential land-use are positively associated with teleworking, whereas neighborhoods with a smaller land area and large population, more industrial land-use, greater street connectivity and greater access to public transportation are negatively associated with teleworking. Although higher density

housing, greater road network connectivity and greater accessibility to public transportation will reduce the use of private vehicles, it is also associated with lower teleworking. Therefore, there appears to be a slight trade-off between teleworking with no commute and more sustainable travel modes in terms of urban design and transportation infrastructure. Hence, more research needs to be conducted to better understand these trade-offs and their impacts on sustainability. Meanwhile, policy makers and planners may need to consider the impact of policies promoting transit-oriented-development on teleworking and find ways to minimize this conflict. Alternatively, other policies to encourage teleworking among commuters using less sustainable modes of transportation need to be strengthened and expanded.

Besides road infrastructure and land use, our study indicates that the sociodemographic characteristics of the residents in a community area should be considered when developing policies and programs for promoting teleworking. Sociodemographic characteristics that are negatively associated with teleworking include female lone parents, widowed persons not living with spouse, older people who are living with relatives instead of family, and English-only speakers, whereas households with primary school age children are more likely to engage in teleworking. It should be noted that these sociodemographic characteristics pertain to the neighborhood and not the individual employees who are teleworking or commuting to work.

Admittedly, policies and programs to increase teleworking have to start with the business practices, work and workplaces. Nevertheless, urban planners and policy makers can contribute to the process by developing neighborhoods with the appropriate land-use mix and providing appropriate transportation pricing, and policies and infrastructure that encourage teleworking, especially those that discourages trips in private cars. When developing policies and programs to promote teleworking, they should consider the differential impacts on different community areas with different land-use and transportation infrastructures, as well as different sociodemographic characteristics.

It is important to note that this study identifies the land-use, transport infrastructure and sociodemographic characteristics of communities that are associated with non-mandatory teleworking. Under the mandatory work-at-home order issued by the government, the results of this study can be used to identify which communities will be impacted more than the others due to greater disruptions to work. Arguably, communities with a higher share of non-mandatory teleworking will be less affected by mandatory teleworking, and designing communities with features that are more likely to encourage teleworking will reduce the stress associated with a mandatory "work-at-home" order.

Author Contributions: Conceptualization: S.M.R., R.T., M.A.A.B., A.D.B.; methodology: S.M.R. and M.A.A.B.; software, M.A.A.B.; validation, M.A.A.B., S.M.R., R.T.; formal analysis: M.A.A.B.; investigation: M.A.A.B.; resources: A.D.B.; data curation: A.D.B.; writing—original draft preparation: M.A.A.B., R.T., S.M.R.; writing—review and editing: R.T.; supervision: S.M.R.; project administration: S.M.R. All authors have read and agreed to the published version of the manuscript.

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