The Open Transportation Journal

Content list available at: https://opentransportationjournal.com

CrossMark
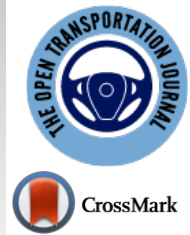
RESEARCH ARTICLE

Effect of Community Road Infrastructure, Socio-Demographic and Street Pattern in Promoting Walking as Sustainable Transportation Mode

Shakil Mohammad Rifaat[1], Mosabbir Pasha[1], Richard Tay[2,*] and Alex De Barros[3]

[1]*Civil and Environmental Engineering, Islamic University of Technology Dhaka, Dhaka, Bangladesh*
[2]*RMIT University, Melbourne, Victoria, Australia*
[3]*Department of Civil Engineering, University of Calgary, Calgary, Alberta, Canada*

Abstract:

Background:

Traffic demand is growing worldwide and the increased carbon emission from transport and travel activities is contributing to greenhouse gas emission and climate change. As the oil and gas capital of Canada, the city of Calgary has a very high carbon footprint per population and the reduction of automobile use is an important policy goal for the city. Walking, a part of active transportation promotes sustainable transportation initiative by reducing greenhouse gas emission. To encourage walking, favorable walking environment should be ensured which largely depends on street pattern and connectivity. However, the effect of street pattern on walking at community level was not explored much in previous studies, particularly at rapidly expanding city such as Calgary's context.

Aims and Objectives:

The study identifies the effects of different neighborhood design and planning factors associated with the share of walking in work trips while controlling for differences in social economic characteristics of the neighborhood.

Methods:

A linear regression model was developed using community-level data from the 2011 census and the road infrastructure data of Calgary.

Results:

Our study finds that different street patterns and types of land use, length of train tracks, number of train stations and number of schools have significant effect on walking.

Conclusion:

Thus, different neighbourhood street patterns and land uses should be considered in the development of new communities for promoting active and sustainable transportation.

Keywords: Active transport, Community development, Neighborhood design, Street pattern, Walking, Road infrastructure.

1. INTRODUCTION

New communities are being built continually to accommodate the growing population, especially in urban centers around the world. Accompanying this urban growth is the growth of vehicular traffic and its associated externalities, such as congestion and pollution. Despite efforts targeted at reducing the

* Address correspondence to this author at the RMIT University, Melbourne, Victoria, Australia; Tel: +61399251438;
Emails: rtay888@gmail.com; richard.tay@rmit.edu.au

environmental impact of cars by means of technological innovations (*e.g.* more efficient engines, hybrid fuel systems, and fuel cell technology), the transportation sector is still a major contributor to environmental pollution and global climate change. Transport accounts for 14% of global greenhouse gas emissions with the vast majority of emissions produced by the road transport sector. Road transport is currently the dominant mode in contributing to carbon dioxide (CO_2) emissions and road passenger modes are expected to account for close to two-thirds of emissions by 2030, with emissions from the road

freight sector growing at an even faster rate [1]. Moreover, this phenomenon is experienced in both developed and developing countries [2 - 5].

Besides minimizing private vehicle usage by adapting certain policies [6] to reduce the greenhouse gas emission, promoting sustainable transportation system is mandatory. Authorities of different countries have initiated, implemented policies and programs to promote sustainable transportation and evaluated whether this initiative helps moving toward or away from establishing sustainable transportation goal [7 - 9]. Reduction of greenhouse gas emissions (GHG) does not depend on one strategy, rather the best policy is to pursue combinations of transportation GHG reduction strategies such as alternative fuel and vehicle options, low carbon and renewable power, travel demand management and land use changes to meet reduction goals [10].

Schiller and Kenworthy [11] mentioned that introducing efficient vehicles such as Autonomous Vehicle (AVs) and Electric Vehicles (EVs) reduces CO_2 emission. Egbue *et al.* [12] stated that mass penetration of electric vehicles into the market will have a number of impacts and benefits, including the ability to substantially reduce greenhouse gas emissions from the transportation sector. Their research results show that several factors which include willingness to pay for new appealing technology, distance driven, perceptions of electric vehicles as good for the environment, and perception of EV speed influencing willingness to purchase an electric vehicle significantly. Miller [13] explored the potential of monorail as a mean of sus-tainable mobility. He made a comparison of operational issues and sustainability impacts of monorail to other major rapid transit modes - bus rapid transit, light rail transit, and rail rapid transit. He concluded that monorail would serve as an effective transit mode based on cost, capacity, geographic context, and sustainability impacts of mass transit modes. Besides promo-ting the advanced and efficient vehicular options, trip sharing policy limits the number of trips as well, thus reducing the negative environmental impacts arising from transportation of goods and people. Sayyadi and Awasthi [14] revealed that trip-sharing policy effectively decreases congestion while car ownership decreases tendency of vehicular trips and increases public transit trips. Equity is an important issue for implemen-ting any sustainable transportation initiative. Teunissen *et al.* [15] showed that TransMilenio BRT offers equal access for all Socio-Economic Strata (SES) when compared with other sustainable transportation initiative.

Land use, road infrastructure, urban form has a strong in-fluence on establishing sustainable transportation system. Delucchi [16] proposed two accessible travel net-works at a citywide scale: one for Fast Heavy motor Vehicles (FHVs) and the other for low-speed, low-mass modes inclu-ding walking and cycling as high kinetic energy of Fast Heavy motor Vehicles (FHVs) make transportation and land use sys-tem unsustainable. Yao and Chen [17] explored the complex relationships between the transportation system and urban growth to find the inter-dependent relationships between the various components. The components in this exploratory study include population, economy, housing, transport, and urban/

developed land. Lv *et al.* [18] indicated that trans-port structure and management measures have important im-pacts on transportation energy consumption. Donais, Abi-Zeid and Lavoie [19] assessed and ranked streets as a function of their potential to become complete street.

To reduce the greenhouse gas emission in the transport sector, cleaner and greener travel modes, such as public trans-port, cycling, and walking, are often promoted as a way to reduce auto dependency and increase the sustainability of the transportation system. Ride sharing, carpool and home office are also other alternatives besides public transport, cycling, and walking to enhance sustainable transportation system and alter-native to transportation. A survey done by University of California Transportation Center in 2012, prospective parti-cipants said that they would share rides primarily to save time and money and secondarily, to reduce the environmental im-pacts of driving. To save time, most would prefer a service that matches riders and drivers automatically, based on stated cri-teria, rather than one that gives the participant a list of contacts and expects them to follow up [20]. According to Graaff and Rietveld [21], a teleworker is an individual who works mainly at home or in other places rather than the actual workplaces. Therefore it can be said that teleworking is a broader form of home office.

Greenhouse gas emissions for urban travel in Canada in 1997 were 215 grams per passenger-kilometer (g/pk) for a car or a light truck, 77 g/pk for urban transit, 26 g/pk for intercity bus travel, and, of course, 0 for walking or cycling [22]. There-fore, a modal shift by decreasing the share of automobile trips and increasing the share of work trips undertaken by walking is one of the most effective means in reducing emissions. Besides reducing private motor vehicle usage, walking also has many health benefits [23, 24].

To encourage a higher demand for walking, a greater understanding of the factors influencing this mode choice is needed. Although several studies have attempted to identify the factors influencing walking, few studies have explored the effects of different urban form and design like neighborhood street patterns. The objective of the study is to examine the effects of urban design and planning factors on walking, inclu-ding the influences of street pattern, land use, road infra-structure, public transport, schools and gas stations, while cont-rolling for socioeconomic and demographic characteristics of the communities.

Calgary is chosen as the study area because this city has been growing rapidly for a decade due to the economic boom in the oil and gas sector. To accommodate the increased popu-lation, the city has expanded laterally and many new commu-nities are being built. Also, due to its heavy carbon footprint, reducing vehicle emission is an important policy goal of the city. Therefore, evidence on the effects of different neigh-borhood design and planning factors on greener travel modes, such as walking, is needed to help policy makers, developers and residents make more informed choices.

2. LITERATURE REVIEW

Waygood and Susilo [25] found that reduced distances, better support for local shops, and reduce traffic speed through

street design and regulation could increase walking in Scot-land. In Australia, Turrell, *et al.* [26] found that higher levels of walking in disadvantaged neigh-borhoods were associated with living in a built environment that was more conducive to walking (*i.e.* greater street connect-ivity and mixed land use). In a separate study, Koh and Wong [27] found that rain shelter supplants distance as the most important factor for selecting walking routes in Singapore. Other important influences in the study included comfort, shops and scenery.

In the United States, Yang *et al.* [28] found that the con-centration of mixed land use (differential density of residences and businesses) is an important determinant of walking. In the state of New Jersey, Sehatzadeh, *et al.* [29] found sufficient evidence that suggested fewer cars were owned in areas with a more walkable built environment. They also found that dog ownership was strongly associated with walking. In California, Park, *et al.* [30] found that sidewalk ameni-ties, traffic impacts, street scale and enclosure, and landscaping had a strong influence on walking as a choice of mode. In Minnesota, Hearst *et al.* [31] found that both individual level and area-level socioeconomic factors were significant in deter-mining walking although individual-level factors had a stron-ger effect.

Finally, in Canada, Clark and Scott [32] used a series of li-near regression models to examine how components of the social environment (companionship, encouragement, role mo-dels, neighborhood social cohesion) influence the time spent for walking while controlling for individual and physical envi-ronments. They found that only role models and neighborhood social cohesion influenced walking time, whereas physical environment such as population density, street connectivity, retail floor area ratio, pedestrian infrastructure, and land-use mix had little effect.

To consider walking as a solution for sustainable mobility, Masoumi [33] mentioned that neighborhood-oriented planning should be promoted over automobile-oriented planning. More specifically, his study discussed that by strengthening neigh-borhoods and Neighborhood Unit Centers (NUCs) can promote sustainable transportation by ensuring walking-friendly envi-ronment. Neighborhood-centric design made urban travel short and localized.

To promote walking-friendly environment in Calgary, at first it is important to identify the effect of socio-demographic, road infrastructure and street pattern on walking, specifically at a community level. Considering community-based data as a unit of analysis will help policy makers to take integrated deci-sion on promoting walking a sustainable transportation mode.

3. METHODOLOGY

3.1. Statistical Model

The objective of the study is to identify the factors associated with the share of work trips undertaken by walking in a community area. The study will focus on urban design and planning factors, while controlling for socioeconomic and demographic factors. As the percentage of walking in a comm-unity area is a continuous variable, the multiple linear regre-ssion approach is appropriate for our study. The structural form of the model is given below [34]:

$$y = X*\beta + \varepsilon \qquad (1)$$

where y is the percentage of work trips by walking in each suburb

X is a vector of explanatory variables

β is a vector of parameters to be estimated

ε is the normally distributed error term

3.2. Data

Several sources of data were used in this study. The primary data source was the 2011 Census which provided demographic information on the community areas in the city of Calgary, as well as data on the relative shares of work trips originating in each community area that were undertaken using different transport modes. The share of walking trips in each community area or suburb was extracted and used as the dependent variable in this study. In addition, to control for the influences of socio-demographic variables on walking mode choice, the relevant data were also extracted from this dataset.

Since this study focused on the effects of urban design and planning factors on commute mode choice, another important database used to gather the required information was the city of Calgary's Land Information and Mapping database. The census data, as well as road infrastructure data, were collected from the University of Calgary library where they maintained the GIS database. It contained information on infrastructure and spatial attributes, such as streets, schools, liquor stations and train stations in each community. The road network section of this database was also used to obtain data on different road infrastructure, such as traffic volume, heavy vehicle traffic, length of different types of roads and number of intersections. In addition, information on the size of the community areas and primary land use (residential, commercial) of each suburb was also extracted for the study.

The street pattern in each community was classified using a scheme adapted from the one developed by Southworth and Ben-Joseph [35] who classified street patterns into five categories: gridiron, fragmented parallel, wrapped parallel, loops and lollipops, and lollipops on a stick. The simplified classification scheme used in this study had only four cate-gories and had been used in several previous studies to examine the influence of neighborhood design on road safety [36 - 38] and transit use [39]. The example of a community in each of the four categories is shown in Fig. (**1**) and the distribution of street pattern in Calgary is shown in Fig. (**2**). Road network in some of the Calgary communities are shown in Fig. (**3**).

The final dataset used in the study contained complete information on 168 community areas. A summary of the data used in the analysis is shown in Table **1**. Since some of the factors are recorded in a categorical manner, several dicho-tomous or binary (0 or 1) variables are used to capture their effects. For example, the type of street pattern in the neigh-borhood is captured by four dichotomous variables: grid-iron, warped parallel, loops and lollipops, and mixed patterns. If a community has grid-iron road pattern then it will be denoted as 1 otherwise 0. This is same for all other categories. Note that

the mean of a dichotomous variable simply represents the pro-portion of the sample belonging to the particular category.

Therefore, the mean of the grid-iron variable is 0.185 which indicates that 18.5% of the sample has a grid-iron street pattern.
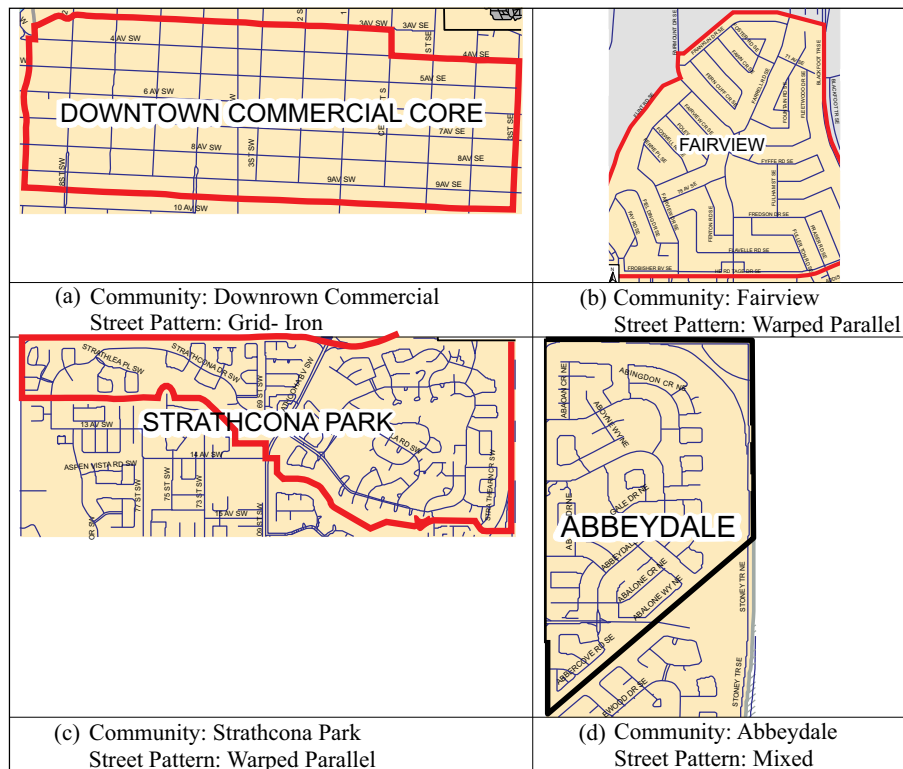
(a) Community: Downrown Commercial Street Pattern: Grid- Iron	(b) Community: Fairview Street Pattern: Warped Parallel
(c) Community: Strathcona Park Street Pattern: Warped Parallel	(d) Community: Abbeydale Street Pattern: Mixed

Fig. (1). Example of road pattern in Calgary.

Table 1. Summary statistics.

Variable	Mean	Std. Dev.	Min	Max
Dependent Variable				
Walking Share of Work Trips (%)	5.729	9.847	0	67.31
Urban Design and Planning Variables				
Street pattern	–	–	–	–
Gridiron	0.185	0.389	0	1
Warped parallel	0.292	0.456	0	1
Loops and Lollipops	0.327	0.471	0	1
Mixed	0.196	0.917	0	1
Number of train stations	0.205	0.891	0	11
Length of train route (m)	2.220	10.723	0	73.4
Number of schools	1.762	1.525	0	8
Parkland (%)	0.361	0.215	0	1.27
Total land area (km^2)	–	–	–	–
< 1.0	0.220	0.416	0	1
1,0 - 2.5	0.399	0.381	0	1
> 2.5	0.381	0.487	0	1
Social, Economic and Demographic Variables				
Home ownership (%)	68.214	21.855	0	99
Immigrant population (%)	22.605	10.028	3.6	81.4
Percent with high school certificate	24.715	4.800	6.1	33.4
Percent with trade certificate	7.870	3.448	0	15.8

(Table 1) contd.....

Variable	Mean	Std. Dev.	Min	Max
Average Household Size	–	–	–	–
≤ 2.0	0.149	0.357	0	1
> 2.0	0.851	0.357	0	1
Divorced and not living with partner (%)	15.356	4.315	3	34

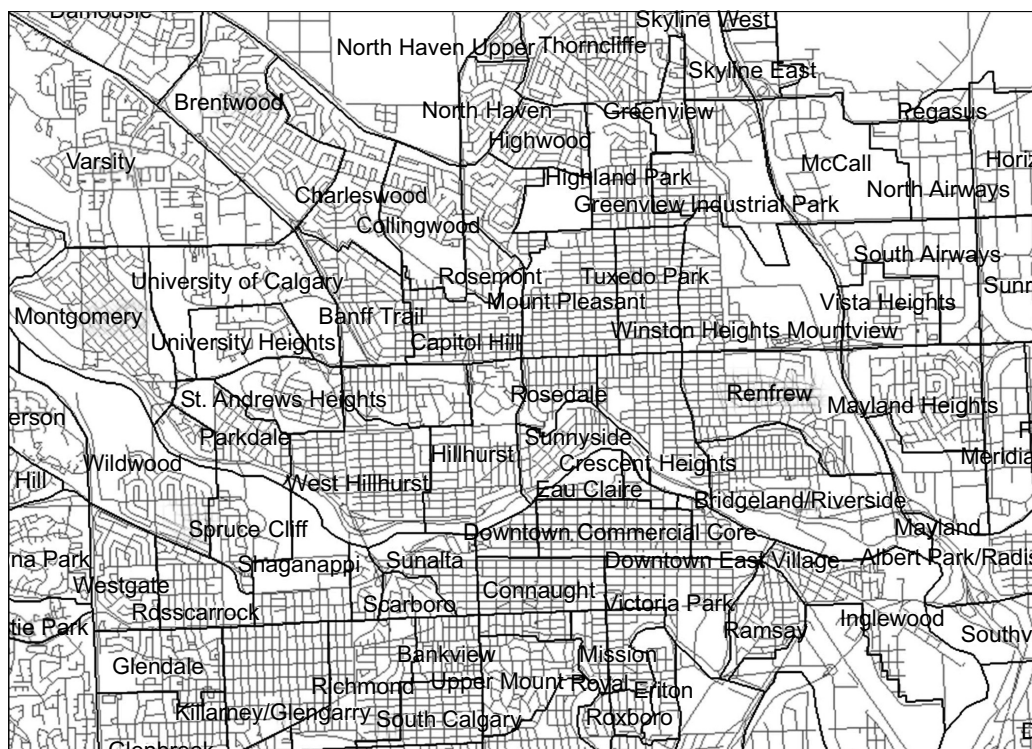**Fig. (2).** Distribution of street pattern in Calgary.

Fig. (3). Road network in some Calgary communities.

Also, several of the contributing factors 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 grid iron is omitted and the estimated coefficients of the other three patterns are interpreted as relative to the grid iron pattern. In case of interpreting the model results, the positive sign of the estimated coefficients β indicate the higher chances of using public transit as the value of the associated variables increases while negative signs suggest the converse. Some of the variables are continuous. For example, mean of the immigrant population in percentage determines the average percentage of immigrant population in every community.

Before arriving the best fit model, several combinations of variables are used and different models have been developed. At this model development process, some variables show statistically insignificant result and omitted from the final model. Note that a substantial number of factors, such as population, unemployment, educational status, ethnicity, religion, languages spoken, *etc*. were found to be statistically insignificant in preliminary analyses and not thus reported in the table. Before starting the analysis, it is necessary to check if the data is adequate with the assumptions of multiple linear regression model. 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 are to be normally distributed. The validity of these assumptions were checked during model development process.

4. RESULTS AND DISCUSSION

The results of the statistical analyses were summarized and shown in Table **2**. In general, the model had a good goodness-of-fit statistic as assessed by moderate R-square and adjusted R-square and small p-value for the F-test. Variables with at least ninety percent confidence level were retained in the model. Some of the transportation, urban design and planning variables that were statistically insignificant included traffic volume, heavy vehicle volume and percentage, number of intersections, intersection density, road length, road density, lengths and shares of different classifications of roads (expressway, arterials, collectors, local roads), lengths and shares of different types of roads (one/two way, divided/undivided, barrier/no barrier), number of bus stops, number of gas stations, number of housing units, housing density, share of different types of housing (apartments, row houses, semi-detached, detached) and population density. It has been observed that walking is not only influenced by neighborhood street pattern but also by other social and economic variables. In Table **3**, the effect of different variables on walking has been shown by sign ("+" or "-"). If a particular variable promotes walking it is also termed as "advantageous" and "disadvantageous" to *vice-versa*.

Table 2. Linear regression results for walking trips.

Number of observation	168		
F-statistic	21.71		
R-squared	0.682		
Adjusted R-squared	0.650		
P-value	< 0.0001		
Variables	**Coefficient**	**Std. Err.**	**P-Value**
(Urban Design and Planning Variables)			
Street pattern			
Warped parallel	-4.172	1.706	0.016
Loops and lollipops	-4.483	1.811	0.014
Mixed	-4.142	1.689	0.015
Number of train stations	1.579	0.524	0.003
Length of train routes (m)	-0.084	0.044	0.059
Number of schools	0.696	0.358	0.053
Parkland (%)	0.102	0.023	< 0.001
Total land area (km^2)			
1.0 - 2.5	-3.463	1.331	0.010
> 2.5	-3.117	1.537	0.044
Social, Economic and Demographic Variables			
Home ownership (%)	-0.117	0.031	< 0.001
Immigrant population (%)	0.239	0.051	< 0.001
Percent with high school certificate	-0.498	0.122	< 0.001
Percent with trade certificate	-0.540	0.202	0.008
Average Household Size			
> 2.0	-3.260	1.701	0.057
Divorced and not living with partner (%)	0.472	0.146	0.001
Constant	21.275	4.411	< 0.001

Table 3. Effect of different variables on walking.

Variable Name	Variable Sign	Policy Decision to Promote Walking
Urban Design and Planning Variables		
Street pattern		
Warped parallel	-	Disadvantageous
Loops and lollipops	-	Disadvantageous
Mixed	-	Disadvantageous
Number of train stations	+	Advantageous
Length of train routes (m)	-	Disadvantageous
Number of schools	+	Advantageous
Parkland (%)	+	Advantageous
Total land area (km^2)		
1.0 - 2.5	-	Disadvantageous
> 2.5	-	Disadvantageous
Social, Economic and Demographic Variables		
Home ownership (%)	-	Disadvantageous
Immigrant population (%)	+	Advantageous
Percent with high school certificate	-	Disadvantageous
Percent with trade certificate	-	Disadvantageous
Average Household Size		
> 2.0	-	Disadvantageous
Divorced and not living with partner (%)	+	Advantageous
Positively Significant +, Negatively Significant -		

Compared to gridiron, all the other three street patterns had statistically significant effects on the share of walking trips in the community. More specifically, mixed pattern (β = -4.142, p = 0.015), warped parallel pattern (β = -4.172, p = 0.016), and loops and lollipops pattern (β = -4.483, p = 0.014) were all associated with lower shares of walking than gridiron street pattern. This result was consistent with the study by Turrell *et al.* [26]. Gridiron street pattern might promote walking from one point to another due to their greater connectivity. It also might offer more route choices to the pedestrian. On the contrary, warped parallel, loops and lollipops, and mixed pattern usually offered limited route choices from origin to destination and would also require longer travel distances along disconnected and winding roads. Grid iron street pattern is easily discernable to reach from origin to destination, on the contrary, unfamiliar trip makers often confused and end up at dead end street of loops and lollipops pattern. The visibility of pedestrian at intersection would be obstructed due to the curvilinear nature of warped parallel whereas this problem is not present at grid pattern street.

Interestingly, an increase in the number of train stations in a community was associated with an increase in the share of walk trips (β = 1.579, p = 0.003), whereas an increase in the length of rapid transit in a community was associated with a decrease in the share of walking in work trips (β = -0.084, p = 0.059). These results implied that having more stations and shorter distances for the rapid transit service would encourage more walking. On the other hand, these results might reflect certain high demand areas, such as the central business district and around large shopping centers and the university, where several stations were located quite close to each other. These areas have higher demands for both public transit and walking trips.

Land area is divided into three categories *i.e.*, <1.0 km^2, 1.0- 2.5 km^2 and > 2.5 km^2 where the 1.0- 2.5 km^2 contains the average land area of each community in Calgary. Three categories have been created to check what type of communities (*i.e.*, smaller or larger) promotes or discourages walking compared with the average one. With respect to the land use variables, communities with larger land areas (β = -3.463, p = 0.010; β = -3.117, p = 0.044) were found to be associated with lower share of walk trips whereas larger shares of park area (β = 0.102, p < 0.001) were found to be associated with a larger share of walk trips. Generally, people would be more inclined to take short trips by walking. In smaller communities, a larger share of the trips would be shorter and more conducive to walking because of the proximity of the local amenities, businesses and employment centers. Also, more people might be encouraged to walk in park areas because of the more pleasant environment.

This study found that the number of schools in a neighborhood might play an important role in increasing walking (β = 0.696, p = 0.053). This result was consistent with Park *et al.* [30] who found that a higher public school density was positively associated with choice of an active travel (walking and cycling) mode. Also, in another study, Rahul and Verma [40] found that students were more likely to choose walking when travelling to or from their schools. Living close to school might also increase the walking habit of the students as well as parents.

In terms of control variables, this study found that higher immigrant populations, and a higher share of divorced and not living partner individuals were associated with greater share of walking, whereas having high school or trade certificate, home ownership and larger (>2) households were associated with lower share of walking. These results were expected and generally consistent with the literature [15, 40, 41].

CONCLUSION

New communities are being built continually to accommodate the growing population in many centers around the world, including the city of Calgary in Canada. Accompanying this urban growth is the growth of vehicular traffic and its associated externalities, such as congestion and pollution. As the oil and gas capital of Canada, the city of Calgary has a very high carbon footprint per population and the reduction of automobile use and promotion of active transport is an important policy goal for the city. To encourage a higher demand for walking, a greater understanding of the factors influencing this mode choice is needed.

This study examines the effect of different infrastructure and planning factors on walking. Our results suggest that several street patterns have significant effects on walking and thus should be considered in the development of new communities. To increase sustainable and active transport modes, the traditional gridiron street pattern is preferred for developing new communities in Calgary. Policy makers and planners may also wish to consider increasing other physical measures, such as increasing the number of rapid transit stations, the number of schools and the share of parkland but decrease the total land area of the community.

Besides urban design and planning factors, this study also finds a number of socioeconomic and demographic characteristics to be associated with walking. Educational campaign and fiscal and social policies to promote walking should be targeted at households or communities with lower home ownership, lower shares of high school and trade graduates, lower share of larger household ($\geq$ 2), higher immigrant population, and higher share of divorced and not living with partner individuals.

LIST OF ABBREVIATIONS

EV	=	Electric Vehicles
AV	=	Autonomous Vehicles
SES	=	Socio Economic Strata
FHMV	=	Fast Heavy motor Vehicles
NUC	=	Neighbourhood Unit Centers

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Data are extracted from publicly available sources. Please

contact the corresponding author if you need assistance in extracting the data.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

REFERENCES

[1]   D. Hensher, "Climate change, enhanced greenhouse gas emissions and passenger transport what can we do to make a difference", *Transp. Res. Part D Transp. Environ.,* vol. 13, pp. 95-11, 2008.
[http://dx.doi.org/10.1016/j.trd.2007.12.003]

[2]   P. Perez-Martínez, "Energy consumption and emissions from the road transport in Spain: A conceptual approach", *Transport,* vol. 27, no. 4, pp. 383-396, 2012.
[http://dx.doi.org/10.3846/16484142.2012.751051]

[3]   S. Bubeck, J. Tomaschek, and U. Fahl, "Potential for mitigating greenhouse gases through expanding public transport services: A case study for Gauteng Province, South Africa", *Transp. Res. Part D Transp. Environ.,* vol. 32, pp. 57-69, 2014.
[http://dx.doi.org/10.1016/j.trd.2014.07.002]

[4]   S. Jia, B. Mao, S. Liu, and Q. Sun, "Calculation and analysis of transportation energy consumption level in China", *J. Transp. Syst. Eng. Inf. Technol.,* vol. 10, no. 1, pp. 22-27, 2010.
[http://dx.doi.org/10.1016/S1570-6672(09)60020-9]

[5]   D. He, H. Liu, K. He, F. Meng, Y. Jiang, M. Wang, and Q. Wang, "Energy use of and CO2 emissions from China's urban passenger transportation sector – carbon mitigation scenarios upon the transportation mode choices", *Transp. Res. Part A Policy Pract.,* vol. 53, pp. 53-67, 2013.
[http://dx.doi.org/10.1016/j.tra.2013.06.004]

[6]   C. Kormos, R. Gifford, and E. Brown, "The influence of descriptive social norm information on sustainable transportation behavior: A field experiment", *Environ. Behav.,* vol. 47, no. 5, pp. 479-501, 2015.
[http://dx.doi.org/10.1177/0013916513520416]

[7]   J. Zhou, *Frontiers of Architectural Research,* vol. 1, no. 2, pp. 150-165, 2012.
[http://dx.doi.org/10.1016/j.foar.2012.02.012]

[8]   A.O. Abulibdeh, E. Zaidan, and A. Abuelgasim, "Urban form and travel behavior as tools to asses sustainable transportation in the greater Toronto area", *J. Urban Plann. Dev.,* vol. 141, no. 3, 2015.
[http://dx.doi.org/10.1061/(ASCE)UP.1943-5444.0000227]

[9]   M. Malayath, and A. Verma, "Activity based travel demand models as a tool for evaluating sustainable transportation policies", *Res. Transp. Econ.,* vol. 38, no. 1, pp. 45-66, 2013.
[http://dx.doi.org/10.1016/j.retrec.2012.05.010]

[10]   Y. Mashayekh, P. Jaramillo, C. Samaras, C.T. Hendrickson, M. Blackhurst, H.L. MacLean, and H.S. Matthews, "Potentials for sustainable transportation in cities to alleviate climate change impacts", *Environ. Sci. Technol.,* vol. 46, no. 5, pp. 2529-2537, 2012.
[http://dx.doi.org/10.1021/es203353q] [PMID: 22192244]

[11]   P.L. Schiller, and J.R. Kenworthy, *An introduction to sustainable transportation: Policy, planning and implementation: Second edition,* pp. 1-420, 2017.

[12]   O. Egbue, S. Long, and V.A. Samaranayake, "Mass deployment of sustainable transportation: Evaluation of factors that influence electric vehicle adoption", *Clean Technol. Environ. Policy,* vol. 19, no. 7, pp. 1927-1939, 2017.
[http://dx.doi.org/10.1007/s10098-017-1375-4]

[13]   P. Miller, *Proceedings, Annual Conference,* 2015pp. 996-1008

[14]   R. Sayyadi, and A. Awasthi, "A system dynamics based simulation model to evaluate regulatory policies for sustainable transportation planning", *Int J Mod Simul,* vol. 37, no. 1, pp. 25-35, 2017.
[http://dx.doi.org/10.1080/02286203.2016.1219806]

[15]   T. Teunissen, O. Sarmiento, M. Zuidgeest, and M. Brussel, "Mapping

equality in access: The case of Bogotá's sustainable transportation initiatives", *Int. J. Sustain. Transport.,* vol. 9, no. 7, pp. 457-467, 2015.
[http://dx.doi.org/10.1080/15568318.2013.808388]

[16]   M. Delucchi, *J. Urban Plann. Dev.,* vol. 140, no. 4, 2014.
[http://dx.doi.org/10.1061/(ASCE)UP.1943-5444.0000172]

[17]   H. Yao, and D. Chen, "A system dynamics model for urban sustainable transportation planning (2016) International Conference on Geoinformatics",

[18]   Y. Lv, S. Wang, Z. Gao, and W. Sun, Identification of Sustainable Transportation Energy Management Strategies Using a Stochastic Fractional Programming Approach under Uncertainties (2015) CICTP 2015 - Efficient, Safe, and Green Multimodal Transportation - Proceedings of the 15th COTA International Conference of Transportation Professionals, pp. 3347-3361

[19]   F.M. Donais, I. Abi-Zeid, and R. Lavoie, "Building a shared model for multi-criteria group decision making: Experience from a case study for sustainable transportation planning in Quebec City", *Lect. Notes Bus. Inf. Process.,* vol. 293, pp. 175-186, 2017.
[http://dx.doi.org/10.1007/978-3-319-63546-0_13]

[20]   E. Deakin, K.T. Frick, and K. Shively, Dynamic ridesharing; University of California, Transportation Center; University of California: http://escholarship.org/uc/item/1c0421x7

[21]   T. De Graaff, and P. Rietveld, "Substitution between working at home and out-of-home: The role of ICT and commuting costs", *Transp. Res. Part A Policy Pract.,* vol. 41, pp. 142-160, 2007.
[http://dx.doi.org/10.1016/j.tra.2006.02.005]

[22]   Transport Canada, *Key Issues in Transportation.,* 2008. Ottawa: Transport Canada. http://www . tc . gc . ca / programs / environment/sd/strategy0103/issues.htm

[23]   E. Waygood, and R. Kitamura, "Children in a rail-based developed area of Japan: Travel patterns, independence, and exercise", *Transp. Res. Rec.,* no. 2125, pp. 36-43, 2009.
[http://dx.doi.org/10.3141/2125-05]

[24]   R. Larouche, T.J. Saunders, G. Faulkner, R. Colley, and M. Tremblay, "Associations between active school transport and physical activity, body composition, and cardiovascular fitness: A systematic review of 68 studies", *J. Phys. Act. Health,* vol. 11, no. 1, pp. 206-227, 2014.
[http://dx.doi.org/10.1123/jpah.2011-0345] [PMID: 23250273]

[25]   E. Waygood, and Y. Susilo, "Walking to school in Scotland: Do perceptions of neighborhood quality matter?", *IATSS Res.,* vol. 38, no. 2, pp. 125-129, 2015.
[http://dx.doi.org/10.1016/j.iatssr.2014.12.002]

[26]   G. Turrell, M. Haynes, L.A. Wilson, and B. Giles-Corti, "Can the built environment reduce health inequalities? A study of neighbourhood socioeconomic disadvantage and walking for transport", *Health Place,* vol. 19, pp. 89-98, 2013.
[http://dx.doi.org/10.1016/j.healthplace.2012.10.008] [PMID: 23207291]

[27]   P. Koh, and Y. Wong, "Influence of infrastructural compatibility factors on walking and cycling route choices", *J. Environ. Psychol.,* vol. 36, pp. 202-213, 2013.
[http://dx.doi.org/10.1016/j.jenvp.2013.08.001]

[28]   Y. Yang, A.H. Auchincloss, D.A. Rodriguez, D.G. Brown, R. Riolo, and A.V. Diez-Roux, "Modeling spatial segregation and travel cost influences on utilitarian walking: Towards policy intervention", *Comput. Environ. Urban Syst.,* vol. 51, pp. 59-69, 2015.
[http://dx.doi.org/10.1016/j.compenvurbsys.2015.01.007] [PMID: 25733776]

[29]   B. Sehatzadeh, R. Noland, and M. Weiner, "Walking frequency, cars, dogs, and the built environment", *Transp. Res. Part A Policy Pract.,* vol. 45, no. 8, pp. 741-754, 2011.
[http://dx.doi.org/10.1016/j.tra.2011.06.001]

[30]   S. Park, K. Choi, and J. Lee, "To walk or not to walk: Testing the effect of path walkability on transit users' access mode choices to the station", *Int. J. Sustain. Transport.,* vol. 9, no. 8, pp. 529-541, 2014.
[http://dx.doi.org/10.1080/15568318.2013.825036]

[31]   M.O. Hearst, J.R. Sirard, A. Forsyth, E.D. Parker, E.G. Klein, C.G. Green, and L.A. Lytle, "The relationship of area-level socio-demographic characteristics, household composition and individual-level socioeconomic status on walking behavior among adults", *Transp. Res. Part A Policy Pract.,* vol. 50, pp. 149-157, 2013.
[http://dx.doi.org/10.1016/j.tra.2013.01.006] [PMID: 23729994]

[32]   A. Clark, and D. Scott, "Does the social environment influence active travel? An investigation of walking in Hamilton, Canada", *J. Transp. Geogr.,* vol. 31, pp. 278-285, 2013.
[http://dx.doi.org/10.1016/j.jtrangeo.2013.06.005]

[33]   H.E. Masoumi, *Theoretical and Empirical Researches in Urban*

Management, vol. 9, no. 1, pp. 44-60, 2014.

[34]   W.H. Greene, *Econometric Analysis,* Fourth Edition 2000. New Jersy: Prentice Hall

[35]   M. Southworth, and E. Ben-Joseph, *Streets and the shaping of towns and cities.,* Island Press: Washington, DC, 2003.

[36]   S. Rifaat, and R. Tay, "Effect of street pattern on injury risks in two-vehicle crashes", *Transp. Res. Rec.,* no. 2102, pp. 61-67, 2009. [http://dx.doi.org/10.3141/2102-08]

[37]   S. Rifaat, R. Tay, A. Perez, and A. De Barros, "Effects of neigh-borhood street patterns on traffic collision frequency", *J. Transp. Saf. Secur.,* vol. 1, no. 4, pp. 241-253, 2009. [http://dx.doi.org/10.1080/19439960903328595]

[38]   S. Rifaat, R. Tay, and A. de Barros, "Effect of street pattern on road safety: Are policy recommendations sensitive to different aggregations

of crashes by severity?", *Transp. Res. Rec.,* no. 2147, pp. 58-65, 2010. [http://dx.doi.org/10.3141/2147-08]

[39]   M. Pasha, S. Rifaat, R. Tay, and A. de Barros, "Effects of street pattern, traffic, road infrastructure, socioeconomic and demographic characteristics on public transit ridership", *KSCE J. Civ. Eng.,* vol. 20, no. 3, pp. 1017-1022, 2016. [http://dx.doi.org/10.1007/s12205-016-0693-6]

[40]   T.M. Rahul, and A. Verma, "Study of impact of various influencing factors on NMT mode choice", *Procedia Soc. Behav. Sci.,* vol. 104, pp. 1112-1119, 2013. [http://dx.doi.org/10.1016/j.sbspro.2013.11.207]

[41]   O. Rubin, C.H. Mulder, and L. Bertolini, "The determinants of mode choice for family visits - evidence from Dutch panel data", *J. Transp. Geogr.,* vol. 38, pp. 137-147, 2008. [http://dx.doi.org/10.1016/j.jtrangeo.2014.06.004]