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EXPLORING THE IMPACT OF SMARTER GROWTH PRINCIPLES ON MODE CHOICE BEHAVIOUR

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Abstract: Urban planning has been historically driven by the pursuit of public health. In fact, “sanitary engineers were the first urban planners in America” when the main concerns about public health were infectious diseases and poor sanitation. The twenty-first century marks a new era of public health challenges including increases in physical inactivity rates, road collisions, and Greenhouse Gas (GHG) emissions. These new challenges need to be addressed by shifting the paradigm towards neighbourhood design that reduces automobile dependency and encourages people to use more sustainable modes of transportation. Given the limited impact of current neighbourhood street pattern designs in promoting more sustainable and safe communities, the SMARTer Growth neighbourhood design principles were developed by Canada Mortgage and Housing Corporation with the objective of balancing the needs of safety and health for residents, with those of the automobile and AT, all in pursuit of enhanced community sustainability. However, no study has been able to draw on any systematic research into evaluating the impact of the full-fledged SMARTer Growth design (i.e., considering all elements, including land use, improved safety, higher levels of social interaction, etc.) on mode choice behaviour for active transportation users. The research to date has tended to focus on the street connectivity aspect of the SMARTer Growth design and ignored its other features. This paper expands on previous research related to the influence of SMARTer Growth neighbourhood design principles on active transportation use for work and non-work trips by hypothetical retrofitting of an existing neighbourhood using SMARTer Growth design principles. The results of the mode choice modelling show promise, as applying SMARTer Growth principles in this case study was successful in reducing auto use and increasing the use of transit and AT modes for work trips.

1 INTRODUCTION

The twenty-first century marked a new era of public health challenges for North American citizens including increases in physical inactivity rates, road collisions, and Greenhouse Gas (GHG) emissions. First, the increasing level of physical inactivity has become a major challenge for public health. According to the World Health Organization (WHO), physical inactivity is estimated to kill 3.2 million people annually (*World Health Organization 2009*). Unfortunately, only 17.5 percent of Canadian adults (18-79 years) meet the Canadian physical activity guidelines by accumulating at least 150 minutes of moderate-to-vigorous physical activity each week (Centre for Surveillance and Applied Research, Public Health Agency of Canada 2018). Physical inactivity is associated with increased risk for obesity and many chronic diseases such as type 2 diabetes, stroke, and ischaemic heart disease (Pratt et al. 2014, Sallis et al. 2004, VanBlarcom and Janmaat 2013, Wang et al. 2005). It is therefore not surprising that physical inactivity imposes a significant economic burden on our nation. For instance, the burden of physical inactivity in

Canada was estimated to be \$6.8 billion in direct (i.e., hospitalization, physician, medication) and indirect (i.e., economic output lost due to illness, disability, or premature mortality) costs in 2009 (Janssen 2012). Similarly, Krueger et al. estimated the annual economic burden of physical inactivity to be as high as 10.8 billion in direct and indirect costs in 2012 (Krueger et al. 2015).

Second, road collisions are one of the leading causes of death and injury worldwide, responsible for approximately 1.24 million fatalities annually (World Health Organization 2013). In Canada, almost 2000 people are killed and 165,000 are injured in road collisions annually (CCMTA 2016). The Canadian economic impact of road collisions is estimated to be 37 billion annually or 2.2 percent of Canada's Gross Domestic Product (GDP) (CCMTA 2016). WHO research shows that 95 percent of road collisions are a result of driver errors, which has led to calls for reduced use of private automobiles and increased active transportation. Hence, Canada introduced in 2016 its Road Safety Strategy (RSS) 2025 with the vision of "Towards Zero" collisions to make Canadian roads and highways the safest in the world.

Finally, the Canadian Government has committed, under the Paris Agreement, to reduce GHG emissions by 30 percent below 2005 levels by 2030 (Environment and Climate Change Canada 2016). However, current indicators suggest that Canada will not be able to meet this target, as GHG emissions in 2030 are estimated to be only 21 percent below 2005 level (Environment and Climate Change Canada 2018a). Transportation is the second largest contributor to GHG emissions in Canada, accounting for 28 percent of the total emissions nationwide (Environment and Climate Change Canada 2018b). At the provincial level, 40 percent of British Columbia's GHG emissions are from the transportation sector (Ministry of Environment 2016). Such high levels of transportation-related emissions highlight the critical role the transportation sector can play in achieving the 2030 target.

Consequently, there has been a growing interest in addressing these challenges by promoting more sustainable neighbourhood designs that reduce automobile dependency and encourage people to use more sustainable modes of transportation. Neighbourhood design influences individuals' travel pattern in three ways: 1) it shapes potential travel routes and their characteristics, 2) determines public transit accessibility, and 3) defines available activities (e.g., shopping, work, leisure) (Jin, Xiongbing 2010). The two most employed neighbourhood designs in North America today are 1) the traditional grid pattern and 2) the culs-de-sac or loops and lollypop pattern. The culs-de-sac pattern was employed to address problems associated with the grid street pattern by precluding neighbourhood traffic shortcutting. However, the culs-de-sac pattern has its own disadvantages including being disorienting to navigate within a neighbourhood and increasing distances between origins and destinations (Sun and Lovegrove 2013).

Given the limited impact of neighbourhood designs in promoting more livable and sustainable communities and Active Transportation (AT), the Canada Mortgage and Housing Corporation (CMHC) developed the SMARTer growth neighbourhood design principles (also known as the fused grid). Figure 1 depicts the differences between the traditional grid, culs-de-sac, and SMARTer Growth network patterns.

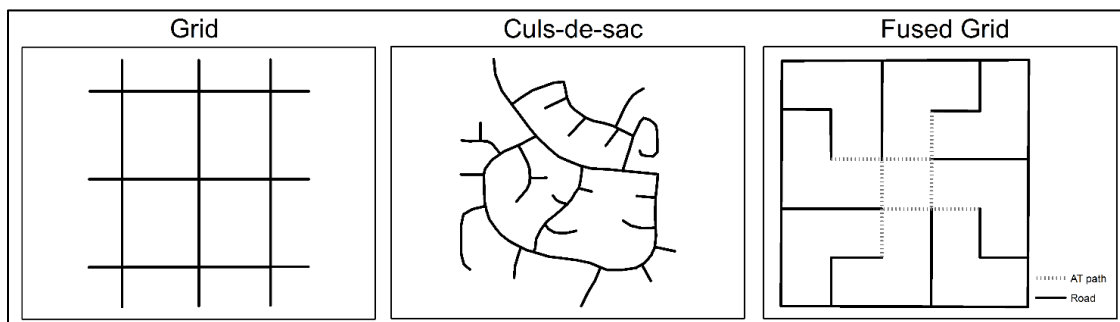


Figure 1: Street network patterns

The SMARTer Growth Neighbourhood Design model was developed by the Canada Mortgage and Housing Corporation (CMHC) to create more livable and sustainable communities. It fuses easy orientation and connectivity from the grid pattern with safety and efficiency from the cul-de-sac pattern

(Grammenos et al. 2008, Sun and Lovegrove 2013). A SMARTer Growth module (see Figure 2) consists of four quadrants. Each quadrant is a 400-square meter neighbourhood, with small block sizes of 80 meters on average, which only provides local accessibility. In each quadrant, through traffic mobility is precluded by central green spaces (i.e., ubiquitous small corner parks and a larger central community green). These green spaces, which account for approximately 8 percent of the land, also supplement the local road network in each quadrant. They provide a continuous active transportation grid network of on-road and off-road routes that allow convenient walking and cycling across the neighbourhood in less than five minutes (Grammenos and Lovegrove 2015). Through traffic mobility is provided at the periphery of the quadrants using the following spacing: 1) minor collectors at 400 m, 2) major collectors at 800 m, and 3) arterials at 1600 m; spacing configuration can vary depending on existing ground conditions and the planned land use activities. All intersections in the SMARTer Growth module are controlled by roundabouts, except for those connecting local roads to perimeter roads, which are controlled via three-way intersections. In summary, SMARTer Growth is composed of three grids: 1) a continuous vehicular grid that is composed of major arterial/collector roads for district and regional connectivity, 2) a discontinuous vehicular road grid for local traffic that prevents shortcutting, and 3) a continuous active transportation grid network of on-road and off-road routes. In terms of land use, the SMARTer Growth's road network layout supports having higher densities and mixed land use within the central blocks located between the perimeter arterial/collector one-way couplet roads. The core of the quadrant is mainly residential areas with medium-to-low density.

There is a relatively small body of literature relating to the impact of SMARTer Growth neighbourhood design on travel behaviour. The low number of studies can be attributed to the fact that the SMARTer Growth principles are relatively new, compared to other neighbourhood designs, and have only been implemented partially in Calgary (Saddlestone development). The research to date has studied the SMARTer Growth as a street network layout and neglected its other components. This paper builds upon previous research on the influence of SMARTer Growth design on mode choice behaviour by considering the land use component of the SMARTer Growth.



Figure 2: SMARTer Growth neighbourhood module

2 Literature Review

SMARTer Growth principles have been investigated in several studies that report on its key features. For instance, Sun and Lovegrove (2013) compared the traffic safety level of five neighbourhood designs (i.e., grid, culs-de-sac, SMARTer Growth, Dutch sustainable road safety patterns, and 3-way offset) using macro-level collision prediction models. The researchers created a total of 45 different neighbourhood

test modules to account for different neighbourhood and block sizes. The study found that the SMARTer Growth neighbourhood design can significantly reduce road collisions by 30-60 percent compared to traditional neighbourhood designs (i.e., grid and cul-de-sac).

In addition, CMHC conducted a comparative evaluation of the traffic performance of the Conventional Suburban, Neo-traditional, and SMARTer Growth neighbourhood designs (IBI Group 2007). The neighbourhood of Barrhaven in Ottawa, ON was selected for this research because it represents a typical suburb in Ottawa with higher than average population density. The street network of the neighbourhood is classified as conventional suburban layout. CMHC developed two design alternatives that represent the Neo-traditional and SMARTer Growth designs. Five land use scenarios were developed to apply for each design of the study area. Traffic volume and modal share for transit and auto modes were first estimated using the city of Ottawa travel demand model developed on EMME/2. Then, Corsim, a microscopic modelling software, was used to estimate delay, level of service and other parameters on each road segment and intersection. The SMARTer Growth neighbourhood design was found to be the most efficient street network in terms of managing traffic flow in/out of the neighbourhood. In addition, it was found that SMARTer Growth can maintain low traffic on local roads compared to other neighbourhood designs, especially with high-density scenarios.

Moreover, Jin and White (2012) utilized agent-based modelling to explore the effect of neighbourhood design on local trip patterns such as mode choice, pollution exposure, and social interaction opportunities; the agent-based modelling aspect of this research will be discussed in section 3.3.1. Similar to Sun and Lovegrove (2013), Jin and White developed seven hypothetical neighbourhood designs that represent different layouts. Mode choice models were estimated using MNL formulation based on the random utility maximization framework. In contrast to the study conducted by CHMC, the mode choice models developed in this study account for changes in AT trips as well; however, it neglects land use factors. Several parameters were considered in this model that are related to socio-economic factors (e.g., vehicles per person in a household) and route characteristics (e.g., walking distance within the neighbourhood). The results showed that the SMARTer Growth was among the best neighbourhood designs for pedestrians in terms of providing high social interaction possibilities, shorter walking distances, and less traffic pollution exposure. These benefits were achieved mainly due to the availability of the pedestrian-only routes in the SMARTer Growth design, and they could vary according to the implementation of the design (e.g. pedestrian network layout).

Similar to Jin and White, Masoud et al. (2017) utilized MNL mode choice models to explore the influence of fused grid neighbourhood design principles on mode choice behaviour in a medium size community for work and non-work trips. This was done by hypothetically retrofitting an existing neighbourhood in the city of Kelowna, BC using the SMARTer Growth design principles. Two design alternatives were developed to show the variability possible in designs that follow FG principles. Although there was a small variation in the results, both alternative designs were successful in significantly reducing auto use and increasing the use of transit and AT modes for work trips, with a very limited impact on non-work trips.

Together, these studies clearly indicate that the SMARTer Growth neighbourhood design can improve neighbourhoods sustainability in several aspects including safer communities, more efficient traffic flow, higher social interaction possibilities, less traffic pollution exposure, reducing auto use, and increasing the use of transit and AT modes. However, no study has been able to draw on any systematic research into evaluating the impact of the full-fledged SMARTer Growth design (i.e., considering all elements, including land use, improved safety, higher levels of social interaction, etc...) on mode choice behaviour for active transportation users. The research to date has tended to focus on the street connectivity aspect of the SMARTer Growth design and ignored its other features. SMARTer Growth is a system design that involves many components other than road network design such as higher density and mix land use at perimeter collector and arterial roads. Including these factors in the analyses will provide a more comprehensive assessment of the SMARTer Growth design.

3 Methodology

This study uses a macroscopic level approach to investigate the impact of SMARTer Growth neighbourhood design on mode choice behaviour. The methodology involves:

1. Identifying a study area
2. Developing a SMARTer Growth design alternative for the study area
3. Use MNL mode choice models to quantify the influence of applying the SMARTer Growth design principles on mode choice behaviour for work trips.

3.1 Study Area

Capri Landmark neighbourhood is one of the major employment hubs in Kelowna, British Columbia. It is located between Spall road on the east, Gordon drive on the west, Highway 97 on the north, and Springfield road on the south. The neighbourhood area is approximately 94 hectares with a total population of approximately 2400 residents and 5200 jobs.

3.2 Design Alternatives

The selected study area was then hypothetically retrofitted using SMARTer Growth design principles as shown in Figure 3. The transportation network retrofit includes a series of local road closures to prevent shortcutting through local roads. The areas that resulted from road closures were preserved to provide green spaces and active transportation corridors in order to maintain high connectivity for pedestrian and cyclists. Although SMARTer Growth road network can maintain a good traffic performance in high-density scenarios compared to other road network layouts, it was assumed that population and employment densities would remain the same in the study area to maintain a conservative analysis. However, the distribution of population and employment within the neighbourhood was changed according to SMARTer Growth Principles such high density and mixed land use are located on the perimeter arterial and major collector corridors as shown in Figure 4.

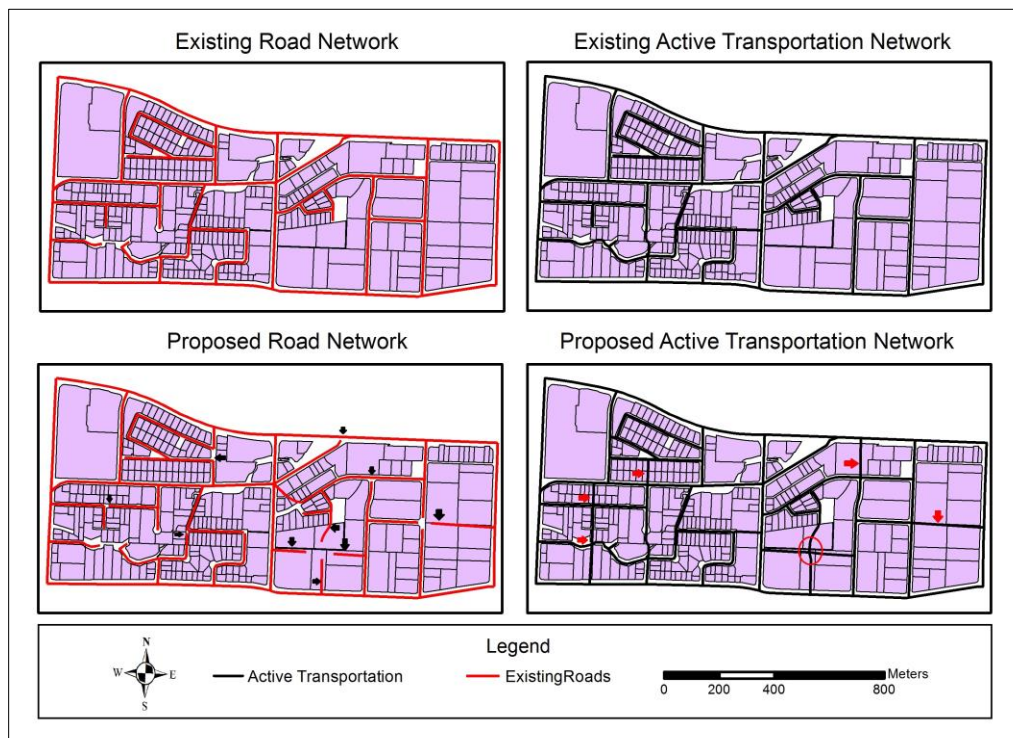


Figure 3: SMARTer Growth road network design alternative

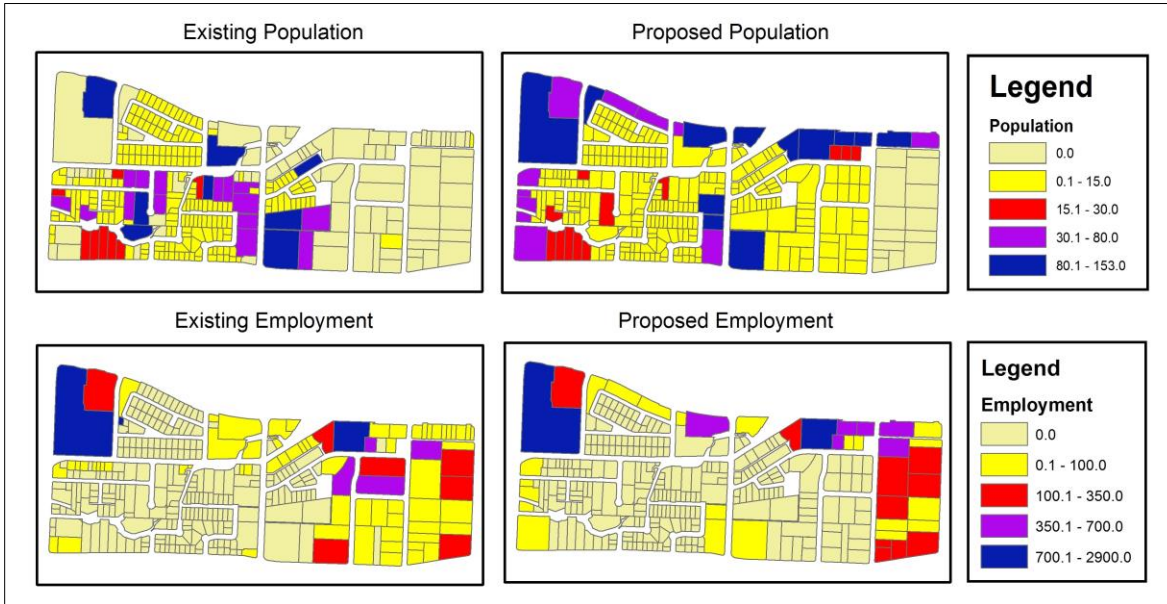


Figure 4: SMARTer Growth land use design alternative

3.3 Mode choice models

In this study, a work-trip mode choice model was developed to estimate modal shift due to applying SMARTer Growth principles (Street network layout and Land use) in the case study area. The 2013 Okanagan household travel survey data was used to develop this model. Work trips in the dataset are defined as trips from home to work/school or vice versa. The data includes socioeconomic, demographic, and mode choice information of approximately 3,050 households and 25,000 trip records in the Okanagan region. The data was cleaned to include only observations where both trip ends are located in Kelowna, and to exclude observations with missing data.

In addition, information about the number of employment and residents in each parcel was used to calculate two land use indicators: activity density and land use diversity. Both indicators were measured using 400m and 800m buffer around trip origins and destinations. Activity density was computed by adding population and employment densities. Land use diversity was computed using population/employment entropy as shown in Equation 1:

$$[1] \text{ Entropy} = \frac{\sum j [P_j \times P_j]}{\ln J}$$

where:

P_j : Proportion of land use development for type (j)

J : Number of land use types.

Four utility functions were estimated for each model as follows: 1) automobile, 2) transit, 3) walk, and 4) bike. The MNL models estimation was done using Biogeme (Bierlaire 2003), with the model specification shown in Table 1. The developed MNL models show that those in the range from 15 to 24 are more likely to take public transit, which could be explained by youth having access to discounted monthly public transit passes (including a mandatory U-PASS program for UBCO students) and having limited regular access to a vehicle. The number of vehicles and bikes per person in the household are positively associated with auto use and bike use, respectively. In addition, the models show that travel distance and time are negatively associated with all travel modes, as one would expect. Moreover, the results indicate that higher activity densities near trip origins and destinations increases the likelihood of active commuting.

Table 1 Mode choice model parameters

Loglikelihood of Mode Choice	-1767.677			
Loglikelihood of Null Model	-5027.606			
Rho-Squared Value	0.648			
Variable	Auto	Transit	Walk	Bike
Alternative Specific Constant	—	-3.47	1.94	-2.32
Age				
Group 3 (15-24)	—	1.34 (8.21)	—	—
Bikes/person in the household	—	—	—	1.35 (13.04)
Vehicles/person in the household	1.61 (10.70)	—	—	—
Female	—	—	—	-0.47 (-3.14)
Household income				
Group 1 (Less than \$25,000)	-0.60 (-3.25)	—	—	—
Group 2 (\$25,000 - \$45,000)	—	0.97 (5.43)	—	—
Group 5 (\$100,000 or more)	0.292 (2.41)	—	—	—
Employment status				
(Work full-time)	—	-0.51 (-2.97)	—	—
Trip Purpose				
(To Work / Work meeting)	0.23 (1.85)	—	—	-0.49 (-2.48)
Activity Density 800m				
Origin	—	—	—	0.0062 (1.91)
Destination	—	—	0.016 (4.44)	0.0071 (2.08)
Bus stop within 400m				
Origin	—	0.57 (1.75)	—	—
Destination	—	0.304 (2.15)	—	—
Travel distance	—	—	-0.49 (-12.81)	-1.88 (-20.01)
Trip time	-0.212 (-10.12)	-0.035 (-6.47)	—	—

values within parenthesis () show t-stat value, — = variable is not statistically significant

4 Results and Discussion

The purpose of this study is to quantify the impact of two primary components of the SMARTer Growth neighbourhood design: network layout and land use characteristics, on mode choice behaviour. First, travel distance and time was estimated for the existing neighbourhood design and the proposed retrofit using the Network Analyst tool in ArcGIS. The results show that the SMARTer Growth transportation network layout resulted in approximately 15 percent increase in driving travel time and a 3 percent decrease in walking and cycling travel distance. The change in travel time and distance levels observed in this study are far below those observed in Masoud et al. (2017). A possible explanation for this might be that Masoud et al. only retrofitted a 16-ha quadrant, not a full-scale neighbourhood (i.e., consists of multiple quadrants); thus, they were only able to examine restricting through traffic on local roads and were not able to consider through mobility between different quadrants.

The next step was to estimate proximity to population and employment in the existing neighbourhood as well as the proposed retrofit. This was done by creating buffers around each trip origin and destination and then aggregating the parcel level data to the buffer level by summing the number of population and employment in all the parcels that intersect each buffer. The results show that the retrofit neighbourhood increased proximity to high population and employment densities as shown in Figure 5. This increase is

achieved only by redistributing population and employment densities according to SMARTer Growth principles while maintaining the same total number of population and employment in the neighbourhood as per existing conditions.

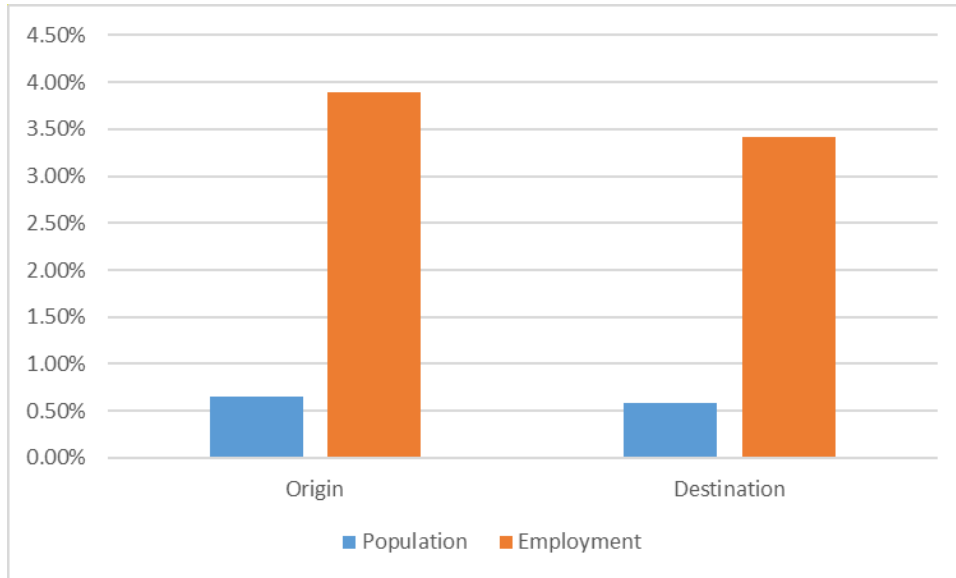


Figure 5: Increase in proximity to population and employment due to retrofitting to SMARTer Growth

The results of the mode choice modelling revealed that retrofitting the study area using SMARTer Growth principles has an impact mode choice behaviour due to the previously mentioned factors 1) increase in driving travel time, 2) decrease in active transportation travel distance, and increased proximity to high and mixed-use developments. Specifically, there is a 5 percent decrease in automobile mode share and 11 percent and 8 percent increase in walking and cycling mode share, respectively (see Figure 6). These differences are significant at a 95% level of confidence statistical test.

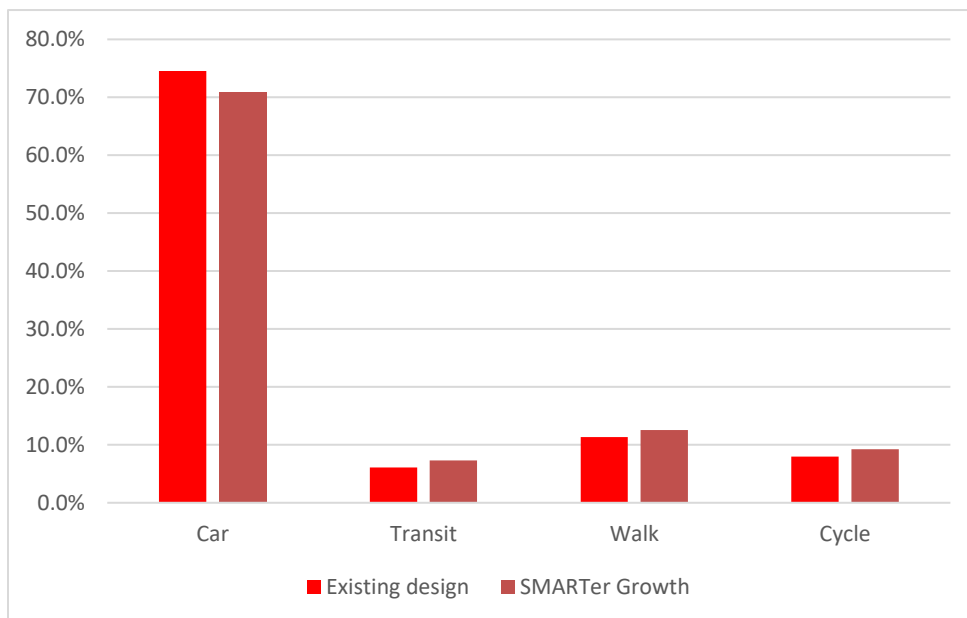


Figure 6: Mode shift

5 Conclusion

SMARTer Growth Neighbourhood Design is a novel sustainable community design strategy developed by CMHC, and refined and augmented in collaboration with UBCO researchers, that aim to promote safer and healthier living at a high quality of life for all Canadians and globally. It combines the best characteristics of the conventional culs-de-sac and traditional grid neighbourhood patterns and features many design elements including compact higher density and mixed land uses, car-free cores, and central greens. The research to date has tended to focus on the street connectivity aspect of the SMARTer Growth design and ignored its land use component.

This research aimed at filling this gap by examining the land use component of SMARTer Growth design on mode choice behaviour by hypothetically retrofitting an existing neighbourhood. The selected study area was the Capri Landmark neighbourhood, which is considered one of the major employment hubs in Kelowna, British Columbia. The SMARTer Growth design alternative was generated through a series of local road closures and green space and pathway insertions. In addition, population and employments were re-distributed within the neighbourhood, such as high density and mixed land uses are located on the perimeter arterial and major collector corridors. The results of the mode choice modelling show promise, as applying SMARTer Growth principles in this case study was successful in reducing auto use and increasing the use of transit and AT modes for work trips.

In addition, it is somewhat interesting to find that the correlation between mode choice and land use variables vary significantly with different buffer distances. Thus, it is suggested that future research employ a distance-decay variable selection model to find the optimized buffer distance for each land use variable.

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