RESEARCH HIGHLIGHT

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Giving Pedestrians an Edge—Using Street Layout to Influence Transportation Choice

INTRODUCTION

Transportation networks are a hotly debated topic, as municipalities and regional governments attempt to balance residents' demands for traffic control and safety with public objectives of healthy activity, compact land-use patterns or better air quality, while maintaining traffic flows. To date, research on travel behaviour and urban form has not isolated the influence of variations in street network connectivity on different travel modes. This study seeks to fill this gap by evaluating the relative effect of pedestrian versus vehicular connectivity on the choice to walk.

Attention to the potential variation in connectivity across modes comes into focus through a variety of strategies to mitigate adverse traffic impacts in existing communities (*see* Figure 1). For example, traffic calming techniques, which include a variety of techniques that slow and limit travel by cars while making walking and biking easier and safer are designed to increase the relative utility of walking and biking in comparison to driving. However, to date, evidence is limited on the performance of specific design solutions that promote non-motorized while constraining vehicle based networks within newly developing and existing communities.

Canada Mortgage and Housing Corporation (CMHC) recognized potential positive impacts of direct pedestrian movement between residential and commercial areas and between neighbouring subdivisions. This has resulted in the development of the Fused Grid street network.

The Fused Grid is a combination of patterns currently in use that presents a proposed middle ground among street network types. It opens the possibility of more optimal solutions than currently exist in planning practice.

In this study, the highest proportion of trips on foot (18%) is found in areas where a path is relatively more direct to nearby retail and recreational destinations on foot than by car. The lowest proportion (10%) of trips occur on foot in places where there is a low degree of pedestrian connectivity. By comparison, places with both high levels of pedestrian and vehicle connectivity have only about 14% mode share on foot. These results suggest that the relative connectivity of pedestrian and vehicular modes is an important predictor of the choice to walk.

Figure 1 Traffic calming techniques–street closed to cars only

The Fused Grid creates environments in which access between neighbourhoods is relatively easier on foot than by car (*see* Figure 2). The hypothesis is that a Fused Grid neighbourhood, which has greater connectivity and continuity for pedestrian travel compared to a vehicular network, will likely encourage more walking. But will it?

In both cases—transforming existing neighbourhoods and applying a new layout model—the question of influence on travel choice remains open.

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The working hypothesis, that connectivity that favours pedestrians will result in more walking, was investigated using a quasi-experimental approach within a rational utility–behavioural framework.

This study[1] contributes to the understanding of how street network design influences travel behaviour. The research applied detailed, parcel-level, land-use road network and pedestrian network databases and it accounted for socio-demographic factors. It builds upon an extensive literature of urban form and travel behaviour research; contributes to the evidence base; and provides some unique methods to understand the role of mode-specific street networks in shaping travel patterns.

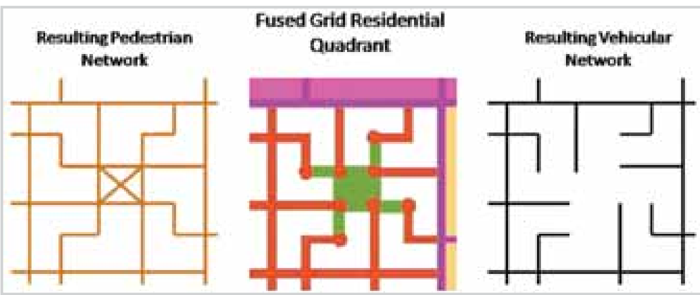

Figure 2 A Fused Grid neighbourhood: higher pedestrian connectivity than vehicular

PURPOSE OF THE STUDY

This study was prompted by the need for evidence of likely travel, environmental and health based outcomes from the Fused Grid. This innovative street network design by CMHC attempts to find a balance between the benefits of street connectivity for transportation efficiency with the use of street space to enhance neighbourhood quality of life for local residents. (*see* Figure 3 and 7)

Research to describe and test the relationship between the built environment and travel behaviour is needed, particularly with regard to street network design. Municipalities want to know the potential of street network design in supporting the attainment of various transportation and livability objectives.

FRAMING THE DEBATE

A review of the planning literature reveals a long-standing debate about street network design—especially about the functionality and impact of traditional, gridiron street network versus loops and cul-de-sac patterns.

It is apparent that differing street patterns could influence travel behaviour and mode choices: whether residents choose to travel by car, bicycle, foot or other means. A grid pattern, with its rectilinear network of intersections, provides more frequent street connections and more direct pathways between destinations.

A dendritic pattern of curvilinear streets and loops generally has more closed streets and indirect routing, with a design that favours more green space, larger lots and privacy. As most existing networks do not differentiate paths between modes, prior research has not been able to clarify how differences in connectivity across travel modes relate to or affect travel behaviour.

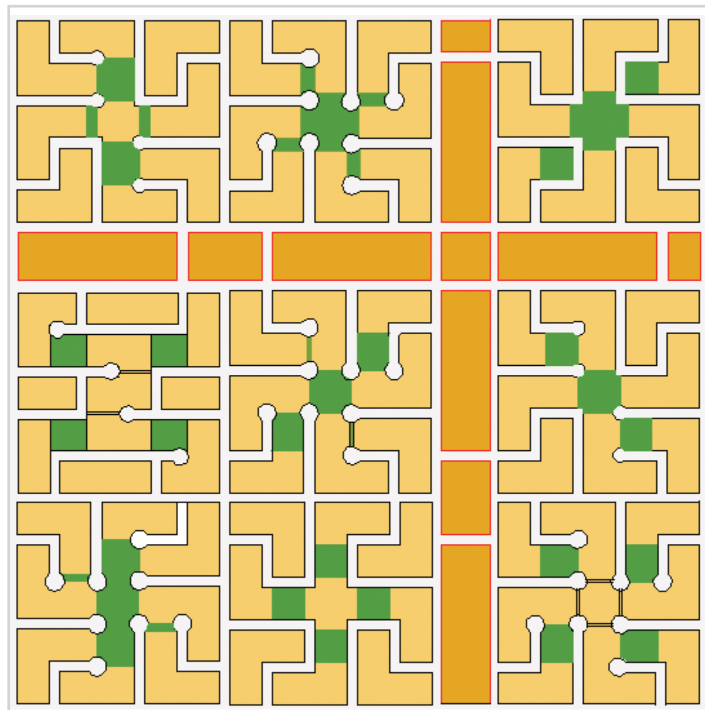

Figure 3 A Fused Grid district diagram showing residential neighbourhoods and zones of mixed use

It is important to understand which street network characteristics will best support the optimal achievement of multiple urban planning objectives. One objective, making urban areas and new neighbourhoods more conducive to walking, has become more important as a result of increased awareness of the health and environmental benefits of walking and conversely the harm of extensive driving. Yet opinion is varied on how best to achieve improved walkability.

[1] Lawrence Frank and Christopher Hawkins (2008). *Fused Grid Assessment: Travel and environmental impacts of contrasting pedestrian and vehicular connectivity*

This study investigates how kilometres travelled, number of trips taken and modes chosen differ among residents of neighbourhoods with varying degrees of vehicular and pedestrian accessibility. It focuses on how observed differences between vehicular and pedestrian access to destinations from where people live predicts travel choice.

Understanding the performance (in terms of travel patterns) of the Fused Grid was enabled by separating out pedestrian and vehicular street networks for a sub-set of households in the Puget Sound Region that completed the 1999 Puget Sound Travel Survey. This allowed the evaluation of how access (directness) to destinations on each network predicted observed travel patterns when adjusting for demographic and other urban form factors (density and land use mix).

NETWORK ROUTING AND CONNECTIVITY

Over the past 20 years, research has attempted to uncover the effects of urban form on travel behaviour[2, 3]. It shows that the built environment most strongly correlates to distance and time travelled, whereas socio-economic factors are more strongly related to other travel behaviours (e.g. car ownership, and frequency of trips).

Research also has revealed that three factors—density, land-use mix and connectivity—strongly correlate with travel behaviour. These factors co-vary and so the challenge for developing a more precise understanding is to isolate connectivity from other urban design and land-use factors.

However, most of the research to date does not include detailed accounting of the pedestrian environment or network patterns when measuring connectivity. Therefore, "connectivity" usually refers to the road network only and often does not clearly specify what is actually experienced by pedestrians.

The most important difference among street network types is the kind of routing that each provides, usually evaluated with a measurement of circuitry or connectivity. Routing and connectivity strongly affect travel distance and as a result the comparative costs (in time and money) of various travel mode choices. This research focuses on empirical investigation of the outcomes from varying levels and disparities of travel network connectivity across modes.

THE SCALE FACTOR

A brief review of the evolution of street patterns (*see* Figure 4) reveals that the impacts of street network design are an issue of scale. Conventional suburban street design does address the desires for safety and livability for local residents. But in a neighbourhood and city-wide context, the results tend toward auto-dependency, traffic congestion—especially on the limited number of collector streets—and externalized costs of negative health and environmental outcomes.

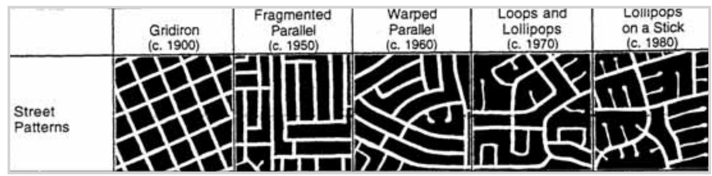

Figure 4 The evolution of street network patterns (adapted from Southworth and Owens, 1993)

Consequently, local governments are caught between competing objectives—improving connectivity for its transportation benefits, such as providing more transportation choices like walking and cycling—but retaining limited access streets for their benefits in improved safety and neighbourhood quality.

Many municipal planners have concluded that the car-oriented configurations of sparse suburban street networks are in need of retrofit and new designs are urgently needed[4]. The Fused Grid provides a potential middle ground as a means of mitigating some of the most adverse safety, environmental, and health impacts of completely auto dependent design approaches.

PREVIOUS RESEARCH AND METHOD CHOSEN

The measurement and evaluation of street networks has generally been centered on motor vehicle movement and level of service. Little attention was paid to the accessibility and mobility of pedestrians, and to a lesser degree bicyclists, which have emerged as key topics of recent research. Perhaps the most significant aspect of street designs that encourage more walking is the connectivity of the street both within neighbourhoods and to nearby destinations.

Research has descriptively (comparing different regions or areas with distinct characteristics) and experimentally investigated the relationship of urban form to travel behaviour. The evidence points to significant effects of land-use density and mix as well as neighbourhood design characteristics, particularly transit.

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[2] Crane, Randall. 2000. The influence of urban form on travel: an interpretive review. *Journal of Planning Literature*. 15, 1: 4-23.

[3] Frank, L.D., T.L. Schmid, J.F. Sallis, J. Chapman, and B.E. Saelens. 2005. Linking objectively measured physical activity with objectively measured urban form. *American Journal of Preventive Medicine*. 28(2S2): 117-125

[4] Frumkin, Howard, Lawrence Frank, and Richard Jackson. 2004. Urban sprawl and public health. Washington, D.C.: Island Press

These studies have argued persuasively that variation of three main factors—density of residences or employment, mix of uses, and urban design (including transportation systems)—at a regional scale does relate to differences in travel behaviour. There have also been efforts to understand the impacts of urban design at a smaller scale.

In exploring the sub-neighbourhood scale, this research faced serious challenges: inadequacy of methods that is, not isolating one aspect of urban form from others; failure to account for residential self-selection; and other confounding factors, including urban form and non-environmental variables, that can affect travel behaviour.

In addition, travel survey data on non-motorized travel is very limited —systematic collection has only recently been done—and there is significant under-reporting on short trips, most of which are by non-motorized modes. Very localized data on the built environment is expensive and hard to collect, and protocols to clean the data to be more reliable are difficult to develop, and to date, have not been validated.

BEHAVIOURAL FRAMEWORK/THEORY AND PEDESTRIAN TRAVEL

The most robust model for explaining travel behaviour is a rational-choice framework that posits travel demand derived from the need to get to and from activities and decisions affected primarily by costs (in time and money). This framework, and related micro-economic theory of travel demand, was adopted for this research.

Walking activity in particular has been shown to be influenced consistently by distance to destinations and by the quality of the built environment. Distance, then, becomes a main cost in this analysis. Walkability has been summarized in indexes that attempt to capture the key dimensions of density, diversity and design. These factors attempt to encompass the whole of urban form, but the interest of this study is the effects of street configuration. In order to capture the effects of streets on travel behaviour, this study addresses some of the existing gaps in methods for measuring street networks.

SELECTION OF METHOD AND SCALE FOR CURRENT STUDY

The current study is unique because it includes a fully detailed assessment of pedestrian and motorized vehicle networks in the Puget Sound Region around households for which data on travel patterns and demographics was available. The unit of analysis is the person, and urban form characteristics are evaluated within a 1 kilometer distance from each person's home.

The study employs two complementary metrics of street connectivity: pedestrian and vehicular route directness and pedestrian and vehicular network density. Characteristics of each mode are directly compared, using a ratio to express relative connectivity and continuity between cars and pedestrians. Including separate measures of the distinct networks available for driving and walking, the research can more effectively and more broadly assess the effects on relative network connectivity to destinations on the choice to walk.

Analytical results were sought that would test the hypothesis that more direct pedestrian routing (relative to vehicular routing) results in higher walking mode share (increase in percentage of trips by pedestrian mode) and less automobile use (lower vehicle kilometers of travel, or VKT).

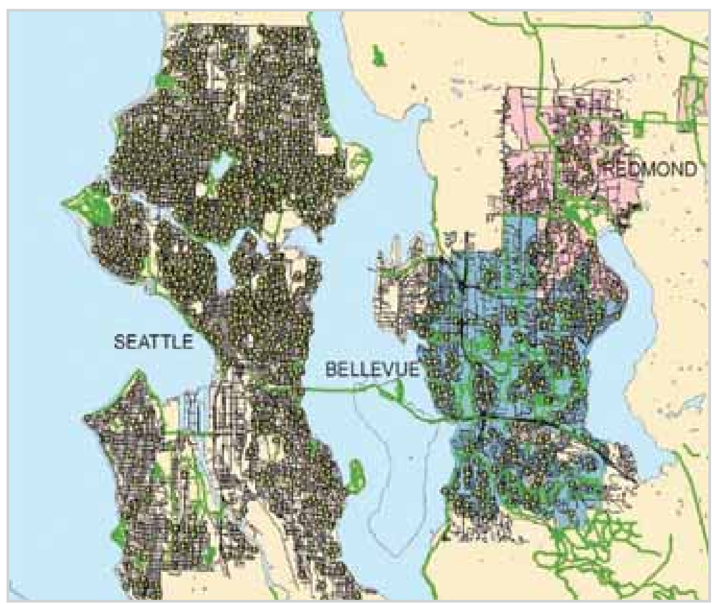

Figure 5 Map showing Seattle, Bellevue and Redmond in Washington

RESEARCH STUDY AREA

The study presents a detailed research assessment of relative vehicle and pedestrian network connectivity within three cities' Seattle, Bellevue, and Redmond, located in the central Puget Sound. The Seattle metropolitan region was chosen for the research because of extensive available urban form and travel behaviour data. The cities of Redmond (41 km^2 [15 sq. mi.]), Bellevue (83 km^2 [32 sq. mi.]), and Seattle (216 km^2 [83 sq. mi.), encompass a land area of 340 km^2 (131 sq. mi.)

The study attempts to deconstruct the fused grid into its component parts by focusing on the relative connectivity between vehicular and non-motorized modes of travel. It evaluates the relative connectivity to the nearest retail and recreational destination between these two modes of travel for a set of households and compares this to self reported travel patterns. The sample was drawn from three cities that possess considerable variation in their street patterns, and in the level of connectivity between vehicle and pedestrian modes of travel.

Disparities between pedestrian and vehicle networks are found in areas with steep slopes resulting in dead end streets to cars but have pathways for pedestrians. (*see* Figure 6) These are also areas where pedestrian connections have been added to cul-de-sac networks increasing the relative connectivity for pedestrian over vehicles to nearby destinations. Conversely, areas exist where pedestrian connections are restricted due to lack of sidewalk provision, even on grid networks where driving is direct. In these areas vehicle based connectivity is higher than that encountered by pedestrians.

Figure 6 Example of pedestrian only connector

Congruence between pedestrian and vehicle networks occurs in areas characterized by urban grids with sidewalks or on cul-de-sacs without sidewalks. This contrast of street connectivity is essential to the process of testing the research hypothesis.

STUDY SUMMARY AND FINDINGS

The results assess the likely performance of the Fused Grid street design on several travel outcomes of interest to urban transportation and community planning. The assessment begins to answer the question of whether new layout configurations and street standards, in addition to the retrofit programs of traffic calming, will result in the desired outcomes of increased levels of walking and decreased reliance on automobiles.

The current study concludes that there is significant relationship between local street networks configuration and travel behaviour, and that modifications to street patterns are associated with changes in levels of walking and driving for local travel.

KEY FINDINGS

This study examines two main measures: relative route directness and relative network density across walking and driving modes. Both measures have associations with odds of walking, odds of driving, distance walked, distance travelled by vehicle, and number of trips.

All else being equal, the results of this study suggest that increasing connectivity on foot relative to in-vehicle travel increases the likelihood that people will walk more and drive less. This result is consistent with the premise of the Fused Grid. (*see* Table 1)

Table 1 Disparate street connectivity and walk shares (by person to commercial)

		Pedestrian Connectivity	
		Low	**High**
Vehicular Connectivity	**Low**	Southeast and Central Bellevue; Southwest Seattle—Loop and culs-de-sac Mean walk share: **10% walking** n = 985	Queen Anne, Capital Hill (Seattle)—Modified grid with connectors Mean walk share: **18% walking** n = 66
	High	North and South Bellevue, North Seattle—Grid and major streets w/o sidewalks Mean walk share: **10% walking** n = 59	Downtown and older Seattle neighbourhoods—Gridiron Mean walk share: **14% walking** n = 966

This study's primary findings demonstrate that relative route directness is associated with increased levels of walking and decreased driving. As well, relative network density—a higher density of walking pathways than driveable streets—generates even greater increases in walking and reduction of driving.

This finding suggests that street designs that improve the directness of routes for pedestrians, relative to those enjoyed by other modes in the network, are associated with more walking. The Fused Grid street design provides a transportation network pattern that achieves a change in relative utility of walking. (*see* Figure 7) Certain traffic calming measures in exiting neighbourhoods would achieve similar results.

The study's correlation and regression analysis indicate that the relative network density measure exhibits a significant relationship with the choice to walk. This suggests that more complete pedestrian pathways to destinations increase pedestrian travel. Directness of connections relates to more walking activity but less so than the density of pedestrian facilities or the presence of retail stores nearby.

Importantly, these two street network factors—the ratio of route directness and ratio of network density—are additive in their effects. That is, designs that create improvement on both measures will generate even larger benefits on travel outcomes. The Fused Grid street design is characterized by a higher density of pedestrian pathways than vehicle pathways. Land use mix and density were held constant in this study as were demographic factors.

Figure 7 Axonometric of a Fused Grid Quadrant bounded by a mixed use zone. Pedestrian paths to common amenities are more direct than vehicular.

For the three Seattle neighbourhoods, the regression model demonstrated that a change from a pure small-block grid to a modified grid (that is, Fused Grid) can result in an increase in odds of a home-based trip being walked by 11.3 per cent.

The modified street pattern, like a Fused Grid, is also associated with a 25.9 per cent increase over street patterns with equivalent route directness for walking and driving, in the odds a person will meet the recommended level of physical activity through walking in their local travel. The same 10 per cent increase in relative pedestrian continuity (network density) associates with a 9.5 per cent increase in odds of walking, all other factors remaining the same.

Finally, the Fused Grid's 10 per cent increase in relative connectivity for pedestrians is associated with a 23 per cent decrease in vehicles miles of local travel, and the improved continuity is associated with increases in both number of walking trips and total distance walked for local travel.

COMMUNITY PLANNING AND DESIGN IMPLICATIONS

Both traffic calming and street layout options that offer increased directness of routing for pedestrians relative to motor vehicles can be used to help achieve increased levels of walking, reduced motor vehicle use, or both. Increasing the extent of sidewalk or other pedestrian pathways, by adding them as stand-alone projects or including a higher density of them relative to street length in plans for new neighbourhoods, is likely to be useful in achieving the same walkability outcomes.

These changes to travel network patterns are also associated with walking a sufficient amount to have a healthy level of physical activity. These kinds of measures will be particularly effective when they result in both reductions in the connectivity of the motor vehicle network (that is, street closures or other interruptions in the network for motorized vehicles) relative to the walking network and increase the pedestrian network's extent relative to the vehicular network.

Emerging evidence about environmental impacts, livability and public health are setting the stage for new street network designs based in better understanding of travel behaviour. Past designs and retrofitting of newer streets, while part of the solution, may not provide the most satisfactory results.

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