Assessing the Fused Grid residential street design: Travel and walking levels associated with disparate pedestrian and motor vehicle connectivity

Chris Hawkins, MA Planning Candidate, UBC School of Community and Regional Planning; Active Healthy Communities Coordinator, Thurston County Public Health & Social Services; Olympia Safe Streets Campaign

Contact Information:
Chris Hawkins
412 Lilly Rd. NE
Olympia, WA (USA)
98506
hawkinc@co.thurston.wa.us

Abstract

Residential street design is widely considered to be an important feature of urban form that affects local travel behaviour, yet there is little consensus about which forms of street design offer the best results on transportation outcomes. Neo-traditional designs, conventional dendritic street layouts ending in culs-de-sac, and others vie for being considered the street standard most supportive of livability and sustainability goals. This paper reports on research that attempts to assess street network patterns in relation to travel outcomes.

The Fused Grid street design, offering a well-connected travel network founded on gridiron composition while adding network treatments that provide pedestrians relatively greater extent of pathway and more direct routing than vehicles when compared to typical street patterns, remains largely untested regarding its implications for travel behaviour. This study assessed the Fused Grid, building on research that has investigated travel behaviour's association with urban form. It used empirical, quasi-experimental methods to develop evidence for the likely outcomes associated with street layouts that improve relative pedestrian connectivity. Using GIS, researchers measured the connectivity of streets, along with other influential urban form, around travel survey participants' households. The resulting data was matched with self-reported travel and demographic factors to test for relationships using correlation and regression statistics. Methods for investigating urban form were advanced through developing and testing new variables that measure the disparity in connectivity across modes – a ratio of network density (length of sidewalk to length of street) and a ratio of route directnesses (length of pedestrian route to nearest commercial versus vehicular route length to same destination). The local travel of persons in the sample households was found to be significantly associated with the level of relative density of the local pedestrian network and the relative pedestrian connectivity of that same network of streets and paths.

Previous research has established the importance of residential density, mix of uses and community design to the transportation patterns in contemporary urban areas. Many of these same studies have produced evidence of street connectivity as a factor associated with travel behaviour. This study adds to the evidence-base an understanding of the importance of more detailed, mode-specific connectivity: local travel, by foot and by car, as well as the choice of which mode to travel by, is associated with the disparity between pedestrian and vehicular transportation networks in the home neighbourhood.

Chris Hawkins currently fosters policy and built environment change to support increased walking and bicycling, part of Washington State's comprehensive chronic disease prevention. He studies planning at University of British Columbia, serves as a board member for local NGOs, and formerly advised Olympia City Council on bike/ped and planning issues.

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Introduction

Purpose & Overview

Empirical measurement of connectivity in relation to travel outcomes (vehicle use and amount of walking) can offer a basis for answering questions about which street designs will support increased walking and help achieve other transportation objectives and public priorities. This research sought to provide additional evidence about which patterns of residential streets would be most walkable and supportive of a shift in travel from driving to walking.

Research has demonstrated the importance of some main dimensions of urban form that affect walking, at least for utilitarian travel, and these have been described as 'density, diversity and design' (Cervero & Kockelman 1997) or 'connectivity and proximity' (Frank, Engelke & Schmid 2003). Street design primarily affects the convenience of routing, certainly influencing the routing for all modes of travel and how close or accessible are the various destinations people seek in the urban environment.

Street design and street standards

Streets are a critical aspect of urban form for walkability, and for much of the exchange and interaction that are the primary purposes of cities and urban form. Though varying widely among different cities, and often within a single metropolitan region, street rights of way and transportation infrastructure typically constitute a quarter and sometimes more than a third of all land in urban areas (Shoup 1998), and an even higher proportion of the publicly accessible space available. They are how we meet the needs of high concentrations of people to get to and from desired activities and destinations, how we truck good and services to markets. Yet streets do not in the main function as we would like them to in the present era of high concern for quality of life and encouragement of physically active forms of transportation. The process by which we have gotten to the current prevailing street patterns of latter part of 20th and early 21st century residential developments deserves discussion before exploring possible antidotes.

The local government planning rules, which for the last century have guided the development of urban areas, emerged at a crossroads around the start of the 20th Century in the thinking about urban development: 1) concerns about public health in urban agglomerations that included factories and unimproved or unsanitary streets (Southworth & Ben-Joseph 1997) and 2) the onset of popular use of the automobile. Each phenomenon contributed to a tendency toward cleaner, wider streets and more dispersed development. In the case of the health paradigm, such new suburban or 'garden city' streets and urban form were thought to allow more light and air to the ground level, thereby improving the health of the persons in and along residential streets. Movement by car required rapid conversion to paved surfaces. Both ways of thinking considered the gridiron street pattern, the fundamental form of urban development to that point, to be dysfunctional - too 'congesting' for contemporary living. There were several other prominent strains of cultural and institutional momentum that influenced the adoption of street standards – such as development occurring more rapidly and in larger 'subdivisions', where public agencies struggled to keep pace with development and to have influence or provide guidance. By and large, these standards considered the need for orderly development, maximizing use of the available developable land and providing for ease of the new traffic (i.e. automobile) flow.

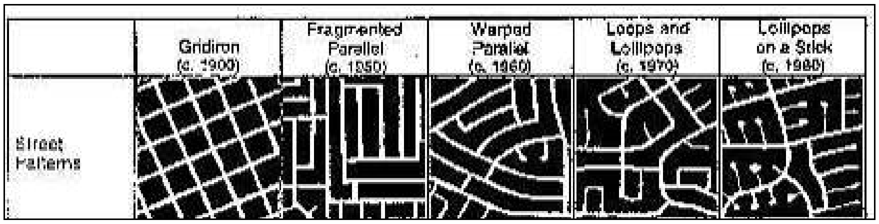


Figure 1 20th Century Street Network Patterns

From Southworth & Ben-Joseph 1997

Because they do not have a basis in more current goals of encouraging more walking and improving pedestrian safety, the standards have resulted in, and continue to result in, a prevalence of dendritic patterns - the street hierarchy, long blocks and culs-de-sac which can be seen in most neighbourhoods built since 1940. Just as Level of Service (LOS) standards for major roads are geared to motor vehicle movement and LOS is often set higher for roads on the periphery or at the arterials, trunk routes, and highways (Marshall 2005) - encouraging exurban or strip development and highly unwalkable built environments – these standards inadvertently create the sorts of traffic flow problems that multiply undesirable outcomes.

The environmental and public health concerns of the last quarter of the 20th century have called into question how communities are planned, and streets have not escaped the scrutiny. Various voices, beginning with Jane Jacobs and continuing to the present, have pointed to the need to curb automobile traffic and create more pedestrian-supportive environments. The debate in street design now is not so much what to aim for (compact, low-impact, liveable, and walkable neighborhoods) but what designs best create this new healthy environment or how would existing communities best be retrofitted. There are some inherent tensions in this transformation of the built environment, particularly as regards streets, as the two tables below reveal.

Culs-de-sac and modern dendritic street designs are popular with developers and residents, and are often considered to be safer/more neighbourly, but impose penalties on pedestrian movement and thus have undesirable travel outcomes.

Table 1 Poor Outcomes from Conventional Subdivision Streets

Contributing to route indirectness: • Pedestrian routes are elongated due to dendritic (sparse) street pattern • Fewer choices of route for motorists
Increase in bicycle/pedestrian personal safety risk: • Pedestrian pathways, if kept separate from streets in an effort to improve their directness, have reduced natural surveillance • Separate pathways frequently result in mixing of bicycle-pedestrian modes without appropriate design treatments, creating conflicts and higher likelihood of collision (especially when paths meet or cross a roadway)
Curvilinear streets are disorienting, and thus discouraging to walking activity
Disconnected local access streets focus traffic onto larger classification streets

closer to residences: • Diminished accessibility for pedestrians (larger streets to cross with higher volumes of traffic) closer to home and often between home and shopping or other destinations. • More difficult left turns for motorists due to infrequency of intersections, larger collector streets, and higher traffic volumes on limited number of major streets (sparse network)

Traditional neighborhood designs, which have New Urbanist adherents, are seen as a solution in that gridiron patterns offer a choice of routes and usually good directness to destinations, but these too have problems.

Table 2 Poor Outcomes from Gridiron Streets

Contributes to dispersion of vehicular travel to all streets, even for pass-through travel purposes, and hence increased traffic impacts on neighbourhoods, including: • Pollutant emissions due to higher automobile volumes in close proximity to residences • Exposure to safety risks to children at play and pedestrians from increased volume of traffic
Frequent four-way intersections also increase traffic impacts: • Congestion, and associated increase in air pollutant emissions from frequent stops and starts, (especially as traffic volumes increase) • Exposure to safety risk for both motorists and pedestrians due to complexity of turning movements
Monotony: if unaccompanied by design requirements for the surrounding streetscape and building frontages, gridiron networks can be uninteresting in their regularity and discouraging to pedestrians

The truth of which patterns best support neighborhood quality of life is elusive… both types of street network have their advantages and flaws. The Fused Grid, and other modified grids that provide a variety of route options for both modes but decidedly more direct and convenient routing for pedestrians (and bicyclists), are proposed middle-ground solutions. But will they work? For public health interventions, and the shifting of scarce public resources to invest in transportation projects, more evidence is needed as the basis for action on livability and walkability initiatives.

Literature & Evidence on Street Pattern Influence on Travel

The desire to reduce auto- and fuel-dependence is matched today by several consonant goals: improving environmental quality (air and climate change; water and aquatic habitat), reducing crash risk and time spent in cars, and increasing levels of physical activity. These goals lead, because of the relationship of driving to each of these outcomes, to a focus on vehicle miles traveled as an indicator of the extent of car use. Another main travel outcome is whether amount or choice of walking is affected by urban form. These become the dependent variables in experiments through which urban form's influence can be assessed (Ewing & Cervero 2001).

A wide array of ways to measure urban form, including street design, have been attempted. This paper will not attempt to describe them all. Good literature reviews are available in transportation (Ewing & Cervero 2001) and public health (TRB/IOM 2005). The evidence regarding street patterns is still advancing but increasingly indicates the importance of connectivity in relation to travel behaviour. The following measurements have been utilized in previous studies as explanatory variables in assessing the influence of street patterns:

- Block size or shape – number of blocks within a given area
- Intersection density – number of street intersections for a given area
- Link to node ratio – the number of street segments relative to the number of intersections, an indication of connectivity or route choice
- Network length – sometimes done by mode
- Route directness – ratio of distance on street network for an origin destination pair to the crow-fly distance
- Service area – the total area or buffer that is within a specified distance on the street network of particular origin points; another variation is "effective walking area" which establishes a walking distance buffer on the network (ordinarily just using the street system) and then identifies how many destinations are within the buffer.

The conclusions of the bulk of literature and reviews of research in this area show that further analysis is needed, particularly in the attempt to establish causal links between behaviour to environments. Ewing & Cervero (2001) for instance deem the studies of transportation networks to be inconclusive – some showing that walking trips but not walk trip-share are related to the extent of sidewalk infrastructure. Intersection density has been shown to relate well to vehicle usage and amount of walking in studies from Toronto and Seattle.

Most recently, street connectivity indicated through a index of measures, and more specific measures such as block length and presence of trails near home residence has been associated with people's walking levels. Guidance for practitioners has been developed from this evidence base (APA 2006). Also important, though less thoroughly explored, are design details of the street environment, such as streetscape and formal elements like 'enclosure'. It is important to note that these studies have been conducted almost exclusively using cross-sectional methods, meaning they do not track the behaviour changes due to environmental changes over time. They cannot, therefore, be used to infer causal relationships.

Describing Street Networks

While previous studies have linked street network patterns with levels of walking, none to date have empirically tested the contrasting availability of each distinct modes' networks, either in terms of connectivity or in terms of continuity (though some have approximated these measurements). This research set out specifically to test whether a disparity between walking and driving connectivity, or in the sheer density of their respective networks, would relate to differences in travel behaviour outcomes.

Southworth & Ben-Joseph (1997) in their work to describe the development of different street network types and the institutional framework compared street networks in the following ways:

Table 3 Street Network Types Adapted from Southworth & Ben-Joseph 1997.

Street Pattern Types	Lineal Feet Of Streets	# of Blocks	# of Intersections	# of Access Points	# of Loops & Culs-de-Sac
Gridiron (ca. 1900-1920)	20,800	28	26	19	0
Fragmented Parallel (ca. 1950)	19,000	19	22	10	1
Warped Parallel (ca. 1960)	16,500	14	14	7	2
Loop and Cul-de-Sac (ca. 1970)	15,300	12	12	6	8

Fused Grid street networks, an example of which is shown in Figure 2, along with some other modified grid patterns, provide enhanced connections and a more dense pathway system for walking than for cars. This distinguishes it from both traditional grids (where car and pedestrian have equivalent networks) and from culs-de-sac and superblock, which, depending on availability of sidewalk is at best equal, and very often more connected or conducive network for the automobile travel mode. See Figure 3 below.

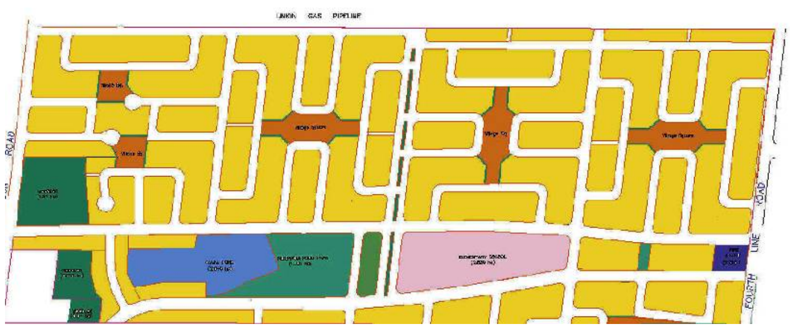


Figure 2 Fused Grid Street Design (Grammenos et al. 2005)

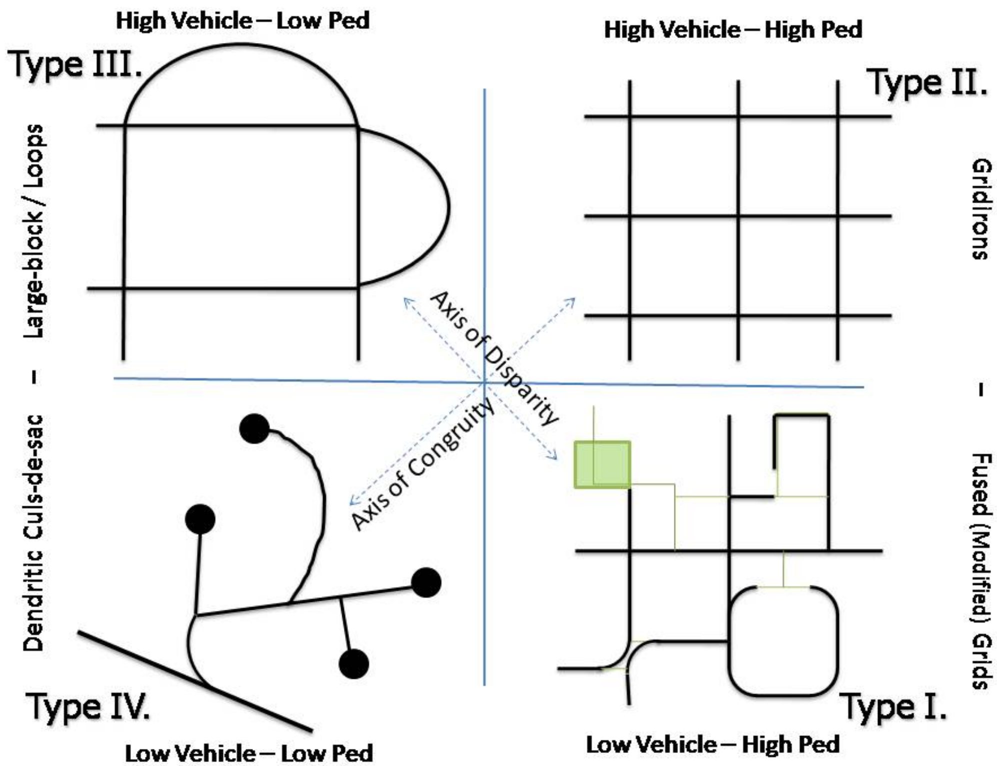


Figure 3 Different Types of Street Networks – Contrasting or Equivalent Connectivity

This research sought to test the relationship between the circuitry of a variety of neighborhood street patterns, specifically the contrasting route directness and density of the street networks across pedestrian and vehicular modes, measured to the location of residents participating in a major U.S. metro travel and activity survey. Some preliminary descriptive results are included in ‘Findings’ below.

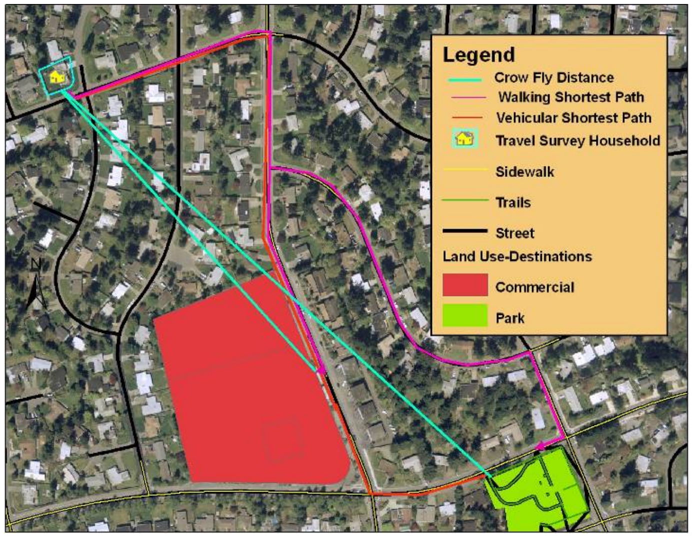


Figure 4 Process for Measuring Route Directness by Mode

Route Directness Disparity: showing contrast in pedestrian to vehicular modal networks to nearest commercial and parks. A curvilinear network with discontinuous sidewalks favors driving, even for short trips. Both modes' routes are longer than crow-fly distance by almost 2:1, but driving is still more convenient. Orthophoto by permission of MDA Corporation.

The study not only measured street networks and sidewalk connectivity to nearest commercial and park destinations, but also accounted for trails and connector paths, as well as residential density and mix of uses in preparation for regression analysis (see Figure 5).

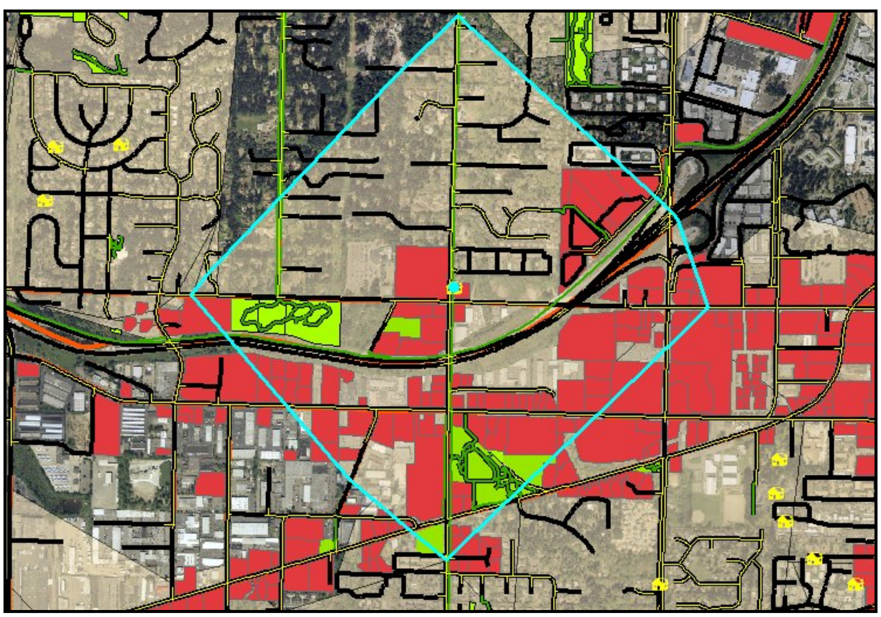


Figure 5 Sample of Buffer within which Land Use and Urban Form was Measured
Seattle, WA region land use and street GIS data (cities of Seattle, Bellevue and Redmond)
Orthophoto by permission of MDA Corporation.

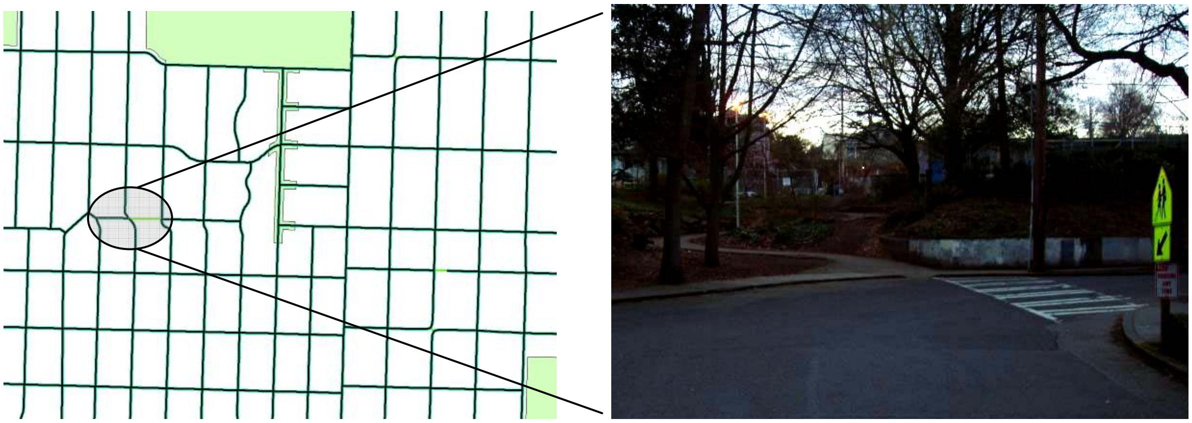


Figure 6 Capital Hill Modified Gridiron *w/* Pedestrian Connector: approximating the Fused Grid

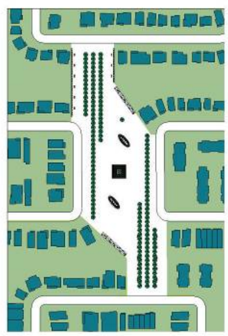


Figure 7 Fused Grid design detail (Grammenos et al. 2005)

Seattle (Queen Anne) Bellevue (East) Redmond (South)

Figure 8 Contrasting Networks, Seattle Region Study Area (same scale)

Table 4 Measurements of Fused Grid Street Design Connectivity

	Intersection Density (# / sq. km)	Ratio Route Directness	Ratio Sidewalk-to-Street
Range	70 to 85 / km^2	0.61 to 1.0	1.19 to >1.4
Mean		0.89	1.3

Measurements were obtained by hand measurement of Fused Grid designs for Barrhaven in Nepean, Ontario (Canada) and the basic pedestrian quadrant, averaging repeated measures of 1 sq. km areas applied to the designs.

This project described the usual route directness for pedestrians and also the typical ratio of the two modes' route directnesses (and network densities) for several street network patterns.

Table 5 Measurements of Street Networks

Type	Street Network Classification	Typical Pedestrian Route Directness	Typical Ratio of Route Directness
I. Low veh, hi ped	Modified gridiron with pedestrianization; proxy of Fused Grid	<1.5	<.95
II. Hi veh, hi ped	Classic Gridiron	1.4-1.6	1:1
III. Hi veh, low ped	Superblock (longer major street segments) loop & cul-de-sac	>1.6	> 1.05
IV. Low veh, low ped	Loop and cul-de-sac, warped parallel or sparse modified grid	>1.8	1:1

A sampling of Fused Grid designs was similarly measured for where they fell on the spectrum of contrasting connectivity and continuity. The table below summarizes measurements of the Fused Grid on the connectivity parameters, the one from previous studies (intersection density) and the new variables (ratio of route directness to nearest commercial and ratio of lengths of sidewalk and major trail to street segments).

Findings

An initial description of reported walking behaviour associated with high and low levels of connectivity across the two modes is presented in the tables below.

Table 6 Walking Mode Share and Street Connectivity

Disparate Street Connectivity and associated Walk Shares **(by person to commercial)**		***Pedestrian Connectivity*** Low	***Pedestrian Connectivity*** High
Vehicular Connectivity	**Low**	SE and Central Bellevue; SW Seattle – Loop and Culs-de-Sac ***Mean Mode Share:*** **10% walking** n = 985	Queen Anne, Capital Hill (Seattle) – Modified grid with connectors ***Mean Mode Share:*** **18% walking** n = 66
	High	N and S Bellevue, N Seattle – Grid and major streets w/o sidewalks ***Mean Mode Share:*** **10% walking** n = 59	Downtown and Older Seattle Neighbourhoods – Gridiron ***Mean Mode Share:*** **14% walking** n = 966

Table 7 Walking Distance and Street Connectivity

Disparate Street Connectivity and associated Distances Walked (by person, in home neighbourhood)		***Pedestrian Connectivity*** Low	***Pedestrian Connectivity*** High
Vehicular Connectivity	**Low**	SE and Central Bellevue; SW Seattle – Loop and Culs-de-Sac ***Mean Travel Distance:*** **.49 miles walked** n = 714	Queen Anne, Capital Hill (Seattle) – Modified grid with connectors ***Mean Travel Distance:*** **.74 miles walked** n = 47
	High	N and S Bellevue, N Seattle – Grid and major streets w/o sidewalks ***Mean Travel Distance:*** **.32 miles walked** n = 41	Downtown and Older Seattle Neighbourhoods – Gridiron ***Mean Travel Distance:*** **.66 miles walked** n = 766

These tables show the top two quartiles of connectivity (route directness by mode to nearest commercial) as high connectivity and the bottom two as low. There are comparatively few cases of disparity (low-high or high-low). The reported mean values, for share of trips by walk mode and total walking distance traveled, are home-based travel from travel survey data aggregated to the person level. Neighbourhoods listed are examples of where this street pattern was often found.

The indications from inferential analysis, using the same connectivity measures and other factors known to be influential to walking and driving behaviour, are that relative route directness and relative network density across modes is associated with increased travel by the favored mode.

Conclusions & Recommendations

Contrasting pedestrian and vehicular networks appear to matter in the travel outcomes relating to street patterns, with those that provide more direct routing for one mode in contrast to the other resulting in increased mode share for the favored mode. This may seem axiomatic; however, solid evidence of outcomes in driving and walking levels is needed. This study is providing part of the necessary basis for shifting practices and standards in directions that will be more likely to produce desired results in transportation and physical activity levels. Previous studies have linked the connectivity or density of networks, mainly using streets as a proxy for measuring actual pedestrian infrastructure, to travel outcomes – showing that the denser and more connected a travel network, the more likely it will be for someone to walk (LFC, Inc. et al. 2005). With more detailed measurement of the networks available to pedestrians, and its contrast to that available to motorists, we gain a greater understanding of the forces at play. This has several implications for the design of new communities and the improvement of existing ones.

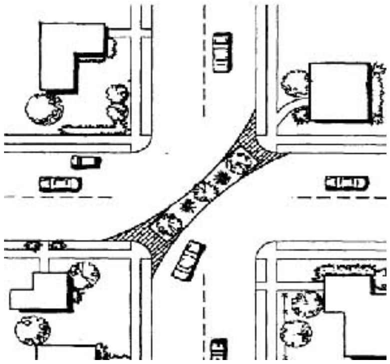
Design

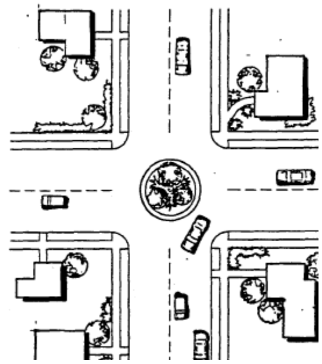
The overarching implication of this study vis-à-vis street design is that is important to plan for excellent pedestrian connectivity – not just connected streets. A couple of specific recommendations relate to this:

- Retrofitting neighborhoods by adding connectors restores grid-like route directness and ensures ample routing options for pedestrians and opportunities for walking.

Figure 9 New Pedestrian Only Neighborhood Connector. Olympia, WA

- Traffic calming measures can offer even greater effect if they are designed in such a way as to create routing advantages to pedestrians in addition to physically slowing vehicle traffic. This is to say that diverters offer the potential of dual benefits (versus other devices that only slow but do not redirect automobile traffic, such as traffic circles – see Figure 10 below).





Traffic Diverter (redirection of autos – direct walking maintained)   Traffic circle (slowing but no diversion)

Figure 10 Differing Traffic Calming Approaches (from Ewing 1999)

- Street patterns like the Fused Grid, offering comparative advantages to pedestrians in routing, are more walkable and more likely to result in desired transportation outcomes.

Policies

Streets made narrow by design are a usual first step in pedestrianizing street standards, however, this may not be the optimal walking encouragement that local governments can achieve. The development of policy around the following should become a priority:

- Connectivity should be an explicit element of standards for the design and placement of street infrastructure – particularly for sidewalk or other pedestrian facilities.
- Off-street trails and connectors, which can often be constructed in otherwise unused street right-of-ways, play a critical role in ensuring excellent pedestrian connectivity and, in part because they afford improved relative route directness and network density, may be an influential factor in travel mode choice – steering people toward more walking.

Research

This study involved a single metropolitan region with a limited array of street network types and few areas with contrast between the networks available to the two travel modes. At a minimum this study should be replicated in other regions. Further research is needed – developing a more robust way to measure route directness on local streets (a larger set of origin-destination pairs for each household in a travel survey, for example), testing other measures of mode-specific connectivity (see research by Jennifer Dill and colleagues: http://web.pdx.edu/~jdill/research.htm#Connectivity), and examining other modes' networks as well (bicycling and transit). Ways of assessing the implications of street design, including crossing quality, and controlling for perceptions of safety would also enhance the conclusiveness of this analysis. Finally, longitudinal methods are needed to begin to establish causality in the relationships of environment to behaviour.

Summary

Getting urban form right is a critical element in ensuring future livability in the form of active and safe communities. The same elements that contribute toward walkability are those that foster travel patterns that achieve a number of other public policy goals. Street standards have origins in a time with different attitudes and a different paradigm of understanding about what shape healthy cities and streets should take. This element of community planning, along with the important complementary measures in zoning and design/development codes, should help our cities and towns become more supportive of walking by dealing explicitly with the key factors of connectivity and proximity – bringing people closer to where they want to go, and ensuring that they have continuous, high quality facilities, is likely to result in a shift in travel and the achievement of public health, environmental and livability goals. Providing pedestrians with a relatively better environment than motorists is also likely to contribute to such mode shift (and vice versa). The Fused Grid street network pattern is a design that, based on these findings, should result in increased levels of walking.

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