THE BEGINNING OF THE END OF SPRAWL

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Urban infrastructure investment is a hot topic not only because many regions are clamouring to have their infrastructure debt addressed but because urban investments reflect long term policy goals, especially with respect to climate mitigation. Not only are there a range of prescriptions for addressing climate change at the local level, but many of the decisions and investments we make in today's cities have enduring impacts, and therefore act as commitments with large implications in the future. Underlying all of these investments in urban infrastructure is the basic layout of cities, which determines and reflects where people live and work. While the term "urban sprawl" has been applied to features at all geographic scales from the layout of local neighbourhoods to the spatial extents of metropolitan areas, cutting across various possible definitions is the idea that cities have been increasingly designed, at all these scales, to accommodate cars, rather than people.

In fact, car-oriented urban sprawl has long been under attack from urban planners and new urbanist visionaries, but more recently the problems with urban sprawl are increasingly being articulated in hard-nosed economic terms. While for most of human history towns and cities of all sizes were walkable, some prominent American urban economists have tended to extol the virtues, rather than the costs, of sprawl, calling it “the natural, inexorable result of the technological dominance of the automobile” and claiming that “the problem of sprawl lies not in the people who have moved to the suburbs but rather the people who have been left behind.”[1]

For most Canadians, at least, this point of view may seem archaic or misguided, given the dense, desirable, and residential urban cores of cities like Vancouver, Montreal, and Toronto, not to mention examples south of the border or countless old and new cities around the world whose downtowns bring to mind many things besides inner-city blight. Indeed, the same sprawl-defending economists have in more recent work begun to focus somewhat more on the negative social costs of sprawl, and on the agglomeration benefits of dense cities.[2]

I. THE INEXORABILITY OF SPRAWL

Before examining some of the existing economic arguments for more proactive intervention against the continued expansion of urban sprawl, consider the following more empirical argument against the inexorability of the process: it has already changed direction. This is the finding of my and my colleague’s recent work looking at the urban street network in the United States.[3] Underlying all the other physical features of urban form is the street network itself. It is the backbone which constrains the form and location of future buildings. It sets the ease or difficulty of walking versus driving to get somewhere useful, and determines the accessibility of future transit systems. Importantly, it also fixes permanently the accessibility of potential commercial and public services which could move in to create a mixed-use development out of a purely residential one.

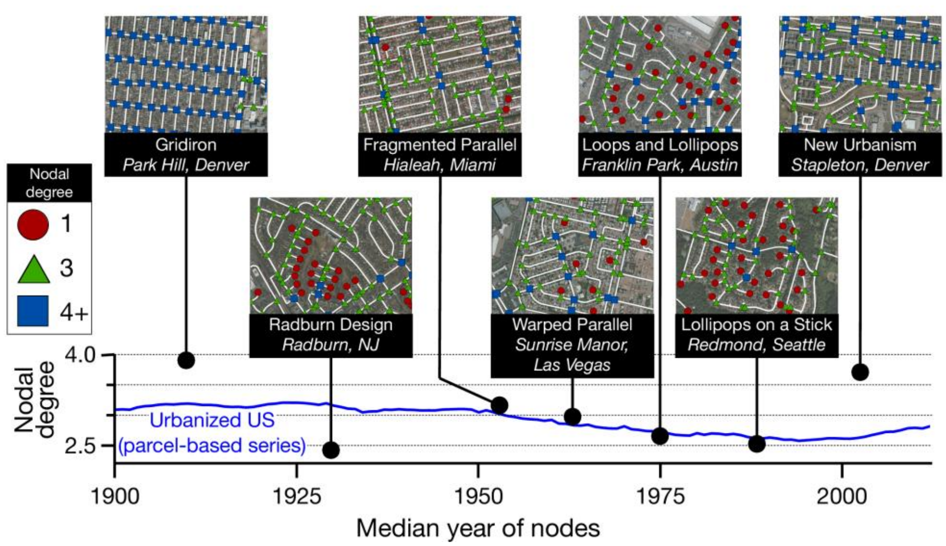

Figure 1: The evolution of street-network connectivity in new developments in the U.S., 1900–2012, taken from Barrington-Leigh and Millard-Ball (2015).

We use "street-network sprawl" to refer to the interconnectedness of roads. Street-network sprawl is characterised by low connectivity in street networks, which is associated with car-oriented transport as well as segregated land-uses and low-density, static, and sprawling residential development.

This street-network connectivity is measured by the number of legs in each intersection. Thus, for our study of the U.S., we classified every street intersection in the country into one of three types, according to its nodal degree, a term taken from network theory. Dead ends, or cul-de-sacs, are considered an intersection of degree 1; three-way intersections are assigned degree 3; and we treat all intersections with four or more connected road segments as degree 4.

Thus, high-connectivity local street networks tend to look grid-like, while low-connectivity neighbourhoods are full of cul-de-sacs and three-way intersections. If you have had a view while flying in to the Calgary airport, for example, you were looking down on one development after another with low-connectivity street networks, designed to incorporate numerous loops and dead ends[4] and to minimise the ability to travel straight through any neighbourhood.

Plenty of evidence shows just what one would expect: that this circuitous arrangement is associated with more demand for cars and that those cars are driven more, even after controlling for other aspects of urban form such as distance to transit, distance to downtown, and population density. Less connected, more circuitous streets make travel less attractive to pedestrians. Public transportation also cannot easily or cost-effectively penetrate into such developments both because of their low population density and because walking routes to potential transit stops are long and indirect.

Using detailed information on housing construction dates, we were also able to determine the approximate construction year of each street for a large number of U.S. cities. This enormous dataset reveals that the average connectivity of the streets built in conjunction with new developments was on the decline since before WWII, but began its more precipitous decline after 1950. Figure 1 shows the U.S. national average urban street-network connectivity over time, from 1900 to 2012. As the car became a ubiquitous feature of household material accumulation, the style of suburban development tended more and more towards the "lollipops on a stick" extreme of the 1980s, characterised by cul-de-sacs and three-way intersections — that is, low nodal degree and low connectivity.

However, remarkably, this downward trend in the connectivity of new developments underwent a major reversal in the mid-1990s. Since then, new urban road construction has become increasingly grid-like, with our quantitative measure of connectivity recently returning to values typical of 1960s neighborhoods. In fact, urban residential development design trends have for well over a century followed fads and new theories, in addition to being shaped by changing technology. Dating back at least to England's 1875 "Bye-law Ordinance" and the Bedford Park development two years later, the layout of urban streets has been driven by theories about its impact on social ills, health, and changing ideals about Nature.[5] Figure 1 shows samples of more recent styles, some with names, from this continued evolution of fashion. Most recently, ideas about "complete communities", social capital, and health are more informed by quantitative data and economic outcomes and are encapsulated in the New Urbanism movement. The 1993 founding of the Congress for the New Urbanism is not only coincident with the observed turnaround in street-network sprawl, but we find evidence that specific new urbanist policies align with some of the more dramatic local changes towards more connected streets observed in the U.S.

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There appears to be nothing inexorable about urban sprawl. Indeed, as explained further below, the only inexorability may be that once a new development is laid down, its street network is unlikely to change over time, even as prices, surrounding infrastructure, and buildings do.

II. THE NATURALNESS OF SPRAWL

A recent study enumerates a range of hidden costs of urban sprawl, and quantifies a number of examples in Canada.[6] Cities have tended to undercharge developers for the initial and ongoing infrastructure costs associated with more sprawling developments, and have similarly tended to apply flat property tax rates which do not take into account the extra cost of providing services to suburban and relatively disconnected areas. This is also true of utilities. All of these “incorrect” prices charged by governments and public entities mean that suburban development is subsidized by everyone else. Ultimately, this means that a family choosing where to live, or a developer choosing where to invest, will be encouraged to choose the more subsidized, sprawling location. Similarly, the free availability of some goods, such as roads, represent a subsidy towards those who use them most. The major build-up of roads at government expense over several decades, and the $27 billion per year to maintain them in Canada, facilitate the prevalence of long-distance commuting.

Although cities earn extra revenues from increasing their property tax base when incorporating new suburban developments, the costs of sprawling developments appear to massively outweigh the new revenues for a number of Canadian cities. For instance, in Edmonton, the effective sprawl subsidy from the City alone is over $4 billion over the next 60 years for just a subset of new developments already planned.[7] In Calgary, initial capital cost savings from new infrastructure under a plan which reduced the degree of sprawl were estimated at $11 billion.

In addition to these and other subsidies and “mispriced” public services, there is a second kind of hidden cost of allowing or facilitating low-connectivity street networks. Higher use of cars for getting to schools, shops, activities, services, and work mean $27 billion per year of more traffic congestion, local pollution, carbon emissions, and public health costs. The extra health costs come from injuries to drivers, cyclists, and pedestrians on the road, from increased respiratory disease due to local pollution, and from increased cardiovascular disease, obesity, and diabetes due to sedentary lifestyles.

Economists understand these effects in terms of externalities: each and every time someone chooses to drive, their choice imposes costs on others. Existing literature is clear that to the extent that congestion charges, carbon taxes, and other taxes on private vehicle travel are absent or set inefficiently low, the private market will produce too much sprawl. This is the sign for society to step in and impose limits or regulations, or price adjustments, to correct such prices so that the costs faced by individuals and households when making a choice reflect the social costs that driving imposes on others. The existence of these externalities and their enormous magnitudes, now that economists are able to quantify them, are also signs that there is nothing “natural” about sprawl as it currently exists.

III. THE PERMANENCE OF SPRAWL

Beyond all these rather conventional arguments against passive acceptance of urban sprawl as the developer's prerogative, our focus on the underlying street network highlights a deeper concern. Population density, mixed land use, parking regulations, fuel price, and the network of public transit can all shift.

In fact, among the numerous investments involved in urban build-up and expansion, probably none is more permanent than the choice of routes for new roads. While major energy investments such as coal-fired power plants have capital turnover time scales on the order of a few decades, and some other infrastructure such as large dams may last for half a century, the locations chosen for roads have proven to be essentially permanent decisions among modern civilizations, outlasting buildings and large technological, economic, and social shifts. The Great Fire of London in 1666 and the devastation following the San Francisco earthquake of 1906 are just two examples where cities have been rebuilt on an almost identical street network following complete destruction. The reason is likely the fact that land parcels, when owned by many different people, are difficult to change or move all at once. As a result, once laid down, the pattern of streets determines urban form and the level of sprawl for many decades. Buildings may come and go, but the street layout is generally permanent, even in the face of large market and institutional shifts. It is unlikely that planners or developers or even land prices can properly take into account the scale of this commitment when choosing a road network.

This means that the ability of future residents and planners to adapt to new costs and conditions will be limited by the original road network. In particular, in places where the road is highly connected, i.e. grid-like, adding extra density or commercial services or new transit routes can be done later if conditions and prices are suitable. By contrast, developments on street networks with low-connectivity are not adaptable in the same way. Because pedestrian access will never be efficient there, small local shops will not be viable, and transit stops would be unlikely to have a sufficient catchment pool. As a result, the densification that requires some services to be provided outside the home and without the allocation of parking space for each residence, is simply not possible. Even if gasoline were to become expensive, nearby areas were to become dense, or transit were to become available in adjacent regions, the road network would not allow the flexibility for urban form to adapt. Developments characterized by road-network sprawl are density-proof, forever.

IV. CANADIAN CITIES

We can apply similar techniques to Canada as those we used to map street-network sprawl in the U.S. Taking averages of urban street connectivity at the level of metropolitan regions gives the values shown in the “2014 stock” column of Table 1. The maximum possible street-network connectivity value is 4, which would correspond to the perfect grid which does exist in the old, downtown core of many cities. On the other extreme, the metropolitan area of Victoria has an average nodal degree of 2.5, which could describe a network made up of three quarters of three-way intersections and one quarter of dead ends, without any four-ways at all.

Municipality		Mean nodal degree 2014 stock	Municipality		Mean nodal degree new since 2000
Vancouver	BC	3.380±0.010	**Vancouver**	BC	3.434±0.035
Montréal	QC	3.327±0.005	**Winnipeg**	MB	3.296±0.015
Winnipeg	MB	3.282±0.006	**Montréal**	QC	3.244±0.019
Longueuil	QC	3.248±0.011	Oakville	ON	3.205±0.023
Waterloo	ON	3.182±0.013	Markham	ON	3.188±0.015
Saskatoon	SK	3.170±0.011	Oshawa	ON	3.173±0.030
Regina	SK	3.166±0.012	Longueuil	QC	3.167±0.041
Oakville	ON	3.119±0.012	Waterloo	ON	3.164±0.032
Laval	QC	3.107±0.008	**Toronto**	ON	3.158±0.016
Oshawa	ON	3.099±0.014	Burlington	ON	3.137±0.033
Québec	QC	3.092±0.007	**Mississauga**	ON	3.105±0.023
Windsor	ON	3.075±0.015	Vaughan	ON	3.088±0.017
Toronto	ON	3.066±0.005	Guelph	ON	3.082±0.030
Kitchener	ON	3.058±0.011	Québec	QC	3.067±0.022
Trois-Rivières	QC	3.038±0.013	Brampton	ON	3.057±0.014
Guelph	ON	3.034±0.014	**Calgary**	AB	3.042±0.012
Calgary	AB	3.031±0.006	Terrebonne	QC	3.038±0.023
Markham	ON	3.029±0.012	**Ottawa**	ON	3.030±0.013
Terrebonne	QC	3.019±0.014	Saskatoon	SK	3.026±0.027
Gatineau	QC	3.002±0.011	Greater Sudbury / Grand Sudbury	ON	3.000±0.161
Richmond Hill	ON	2.994±0.016	Burnaby	BC	2.998±0.047
Ottawa	ON	2.994±0.006	Laval	QC	2.987±0.021
Brantford	ON	2.989±0.020	Kitchener	ON	2.983±0.024
Vaughan	ON	2.982±0.013	Richmond Hill	ON	2.967±0.026
London	ON	2.980±0.010	St. Catharines	ON	2.941±0.103
St. Catharines	ON	2.973±0.013	Cambridge	ON	2.936±0.038
Thunder Bay	ON	2.972±0.018	Gatineau	QC	2.934±0.024
Edmonton	AB	2.963±0.007	Regina	SK	2.930±0.034
Brampton	ON	2.954±0.010	Whitby	ON	2.924±0.033
Barrie	ON	2.944±0.018	Kingston	ON	2.920±0.050
Sherbrooke	QC	2.917±0.014	Windsor	ON	2.906±0.045
Mississauga	ON	2.913±0.010	London	ON	2.905±0.025
Burlington	ON	2.896±0.015	Brantford	ON	2.887±0.064
Whitby	ON	2.894±0.020	Barrie	ON	2.884±0.033
Cambridge	ON	2.890±0.018	Trois-Rivières	QC	2.878±0.051
Hamilton	ON	2.890±0.009	**Hamilton**	ON	2.824±0.025
Kingston	ON	2.881±0.017	Sherbrooke	QC	2.820±0.034
Saguenay	QC	2.878±0.014	Delta	BC	2.778±0.089
Lévis	QC	2.866±0.013	Richmond	BC	2.769±0.040
Burnaby	BC	2.832±0.018	Lévis	QC	2.761±0.036
Richmond	BC	2.746±0.018	**Edmonton**	AB	2.756±0.015
St. John’s	NF	2.732±0.017	Thunder Bay	ON	2.734±0.119
Delta	BC	2.654±0.019	Saguenay	QC	2.682±0.212
Coquitlam	BC	2.642±0.021	Coquitlam	BC	2.665±0.059
Halifax	NS	2.614±0.009	St. John’s	NF	2.615±0.036
Abbotsford	BC	2.592±0.019	Saanich	BC	2.582±0.122
Greater Sudbury / Grand Sudbury	ON	2.582±0.014	Halifax	NS	2.573±0.029
Surrey	BC	2.536±0.011	Abbotsford	BC	2.491±0.051
Langley	BC	2.511±0.020	Surrey	BC	2.534±0.021
Saanich	BC	2.473±0.019	Langley	BC	2.565±0.044

Table 1: Rankings of municipalities by connectivity of street-network stock. Confidence intervals are indicated by the +- values. Colours correspond directly to the mean nodal degree of the total existing stock of roads (“2014 stock”) and to the additions built since 2000 (“new since 2000”).

The metro areas with populations over half a million are shown in bold. Winnipeg and Montreal top that list, while Edmonton and Vancouver sit at the bottom. "2014 stock" gives a snapshot of the entire road network, old and new. The right-hand column in Table 1 shows our estimate of the connectivity of more recent additions, built since 2000. Similar to our findings for the U.S.A., there is a close relationship between the pattern of what already exists in a region and the urban street network style that developers are using in new construction. However, the exceptions show interesting cases where there is a change in trend. For instance, construction around Trois-Rivieres and Sarnia is more sprawling than existing neighbourhoods, while Ottawa-Gatineau and Kingston are actually constructing slightly more connected streets in their newer developments.

More detailed differences emerge when looking at individual municipalities, some of which constitute the metropolitan areas. *Table 2* shows a list of the largest fifty municipalities by 2011 population. One feature that stands out in this ranking is that Vancouver and its neighbouring municipalities are on opposite ends of the spectrum. Vancouver is the most gridded of all among Canada's large municipalities, while the lower mainland suburbs of Burnaby, Richmond, Delta, Coquitlam, Abbotsford, Surrey, and Langley take up most of the bottom spaces on the list of street connectivity. Indeed, other metropolitan areas in southwestern B.C. - Nanaimo, Kamloops, Chilliwack, Abbotsford, and Victoria - also round out the bottom of the list of Statistics Canada's Census Metropolitan Areas in Table 1. The greater Vancouver region may enjoy an undeservedly favourable reputation for its street layout on account only of the gridded layout of Vancouver proper; the broader region lies at the bottom of the list of the largest 9 metropolitan areas.

By contrast, the second most gridded municipality, Montreal, is surrounded by two other of the most highly gridded cities - Longueuil and Laval, both of which have mean nodal degree above 3.1 (the smaller municipalities of Brossard and Boucherville also have similar high values of nodal degree).

The right-hand column in Table 2 shows signs of improving street-network connectivity in Burnaby and Sudbury, and still worsening trends in Thunder Bay and Edmonton.

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Census Metropolitan Region		Mean nodal degree 2014 stock	Census Metropolitan Region		Mean nodal degree new since 2000
Saint-Jean-Sur-Richelieu	QC	3.328±0.014	**Winnipeg**	MB	3.180±0.015
Winnipeg	MB	3.197±0.006	**Toronto**	ON	3.096±0.006
Montreal	QC	3.112±0.003	Saint-Jean-Sur-Richelieu	QC	3.093±0.036
Regina	SK	3.073±0.011	Guelph	ON	3.073±0.028
Saskatoon	SK	3.068±0.010	Oshawa	ON	3.009±0.021
Granby	QC	3.045±0.017	**Montreal**	QC	3.001±0.008
Kitchener	ON	3.018±0.008	Kitchener	ON	2.999±0.017
Guelph	ON	2.999±0.014	**Calgary**	AB	2.973±0.010
Toronto	ON	2.992±0.003	**Ottawa - Gatineau**	O/Q	2.971±0.011
Trois-Rivieres	QC	2.969±0.012	Saskatoon	SK	2.951±0.025
Brantford	ON	2.963±0.015	Kingston	ON	2.922±0.049
Windsor	ON	2.961±0.012	Red Deer	AB	2.913±0.029
Calgary	AB	2.960±0.005	**Hamilton**	ON	2.897±0.020
London	ON	2.954±0.009	Windsor	ON	2.897±0.034
Oshawa	ON	2.951±0.010	Drummondville	QC	2.888±0.041
Red Deer	AB	2.944±0.016	St. Catharines - Niagara	ON	2.876±0.038
Quebec	QC	2.935±0.006	Regina	SK	2.868±0.029
St. Catharines - Niagara	ON	2.933±0.008	Brantford	ON	2.868±0.050
Lethbridge	AB	2.911±0.016	London	ON	2.865±0.022
Sarnia	ON	2.893±0.018	Barrie	ON	2.856±0.028
Ottawa - Gatineau	O/Q	2.892±0.005	Sherbrooke	QC	2.826±0.031
Drummondville	QC	2.892±0.017	**Quebec**	QC	2.813±0.017
Hamilton	ON	2.884±0.008	Lethbridge	AB	2.792±0.034
Sault Ste. Marie	ON	2.884±0.020	Trois-Rivieres	QC	2.784±0.050
Thunder Bay	ON	2.869±0.016	Granby	QC	2.774±0.052
Barrie	ON	2.863±0.014	**Edmonton**	AB	2.766±0.011
Edmonton	AB	2.858±0.005	Peterborough	ON	2.746±0.073
Sherbrooke	QC	2.832±0.011	Thunder Bay	ON	2.734±0.119
Chicoutimi - Jonquiere	QC	2.832±0.013	Fredericton	NB	2.694±0.047
Moncton	NB	2.795±0.013	**Vancouver**	BC	2.689±0.013
Belleville	ON	2.782±0.018	Moncton	NB	2.664±0.032
Vancouver	BC	2.762±0.005	Sault Ste. Marie	ON	2.625±0.202
Medicine Hat	AB	2.718±0.015	Kamloops	BC	2.594±0.042
Prince George	BC	2.718±0.016	Halifax	NS	2.569±0.029
Peterborough	ON	2.707±0.016	Sudbury	ON	2.558±0.157
Kingston	ON	2.681±0.014	Medicine Hat	AB	2.553±0.029
North Bay	ON	2.679±0.023	Sarnia	ON	2.532±0.079
Sudbury	ON	2.656±0.014	Saint John	NB	2.532±0.062
Halifax	NS	2.613±0.009	Nanaimo	BC	2.523±0.053
Fredericton	NB	2.598±0.016	Belleville	ON	2.522±0.087
Nanaimo	BC	2.575±0.016	St. John's	NF	2.501±0.025
Kamloops	BC	2.564±0.015	Victoria	BC	2.489±0.035
St. John's	NF	2.559±0.013	Chilliwack	BC	2.450±0.039
Chilliwack	BC	2.553±0.020	Abbotsford	BC	2.425±0.043
Abbotsford	BC	2.553±0.016	Chicoutimi - Jonquiere	QC	2.424±0.185
Saint John	NB	2.540±0.013	Prince George	BC	2.350±0.233
Victoria	BC	2.503±0.010	North Bay	ON	2.087±0.226

Table 2: Rankings of metro regions by connectivity of street-network stock. Confidence intervals are indicated by the +- values. Colours correspond directly to the mean nodal degree of the total existing stock of roads ("2014 stock") and to the additions built since 2000 ("new since 2000").

V. POLICIES AND SPRAWL

The discussion above has already hinted at a number of policies that could shift decisions made by households and developers when designing neighbourhoods, and in particular the enduring street networks that underlie and connect them. However, the already-existing stock of urban and suburban streets is enormous, and these cannot easily be changed. They are likely to remain a major impediment to future mitigation and adaptation efforts, as well as to efforts to address health and equity problems associated with the isolation and car-dependence of sprawl.

In the meantime, while strategies for retrofitting the suburbs may evolve gradually, policy can ensure that a rapid end is put to the subsidies and externalized costs of building further low-connectivity streets. Some of these come in the form of prices or levies. Development charges, utility charges, and property taxes could all be designed, in principle, to reflect the full cost of suburban development, based on location. For instance, Kitchener, Ottawa and Calgary now all charge more for new, suburban developments than for central redevelopment.[8] Winnipeg and the City of Terrace charge for water provision based on residential density. Montreal charges less property tax for multi-unit buildings than single-family houses. However, in order to make tax rates vary by location, Provincial regulations regarding property tax rates would require amendment in some provinces.

In addition, transportation pricing can be used to encourage shifts to transit, to car-sharing, and to active transportation — and, indeed, to lessen the huge existing subsidies for motor vehicle use. For instance, increasing fuel taxes and parking fees, implementing distance-based insurance and registration premiums, and implementing automated road, bridge, and tunnel tolls are all feasible and precedented.

However, none of these directly addresses the creation of street-network sprawl which is the initial and binding decision in the expansion of sprawl. This must be given more consideration. Examples of such policies are growing. For instance, Austin, TX and Mecklenburg, NC have policies which explicitly promote more connected streets. Gainesville, FL prohibits cul-de-sacs completely in certain areas, and Tacoma, WA strongly discourages them. The entire State of Virginia enacted standards in 2009 that strongly discourage cul-de-sacs. In fact, these locations are all places which we highlighted marked increases in street-network connectivity in recent years in our US study.[9]

While a range of price signals and pecuniary incentives are vital in shifting decisions, consumption habits, and transportation patterns, the use of regulations and well-publicized standards is also key for ensuring large and steady shifts in markets or behaviour. Provinces and municipalities should be working together to put a quick end to the building of further street-network sprawl, so that we can focus on the long-term policy for managing that which we have already built.

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[1] Glaeser and Kahn, 2004.

[2] Glaeser, 2011.
[3] Barrington-Leigh and Millard-Ball, 2015.
[4] The style in some areas of suburban Calgary does not emphasize cul-de-sacs as much as some other places do.
[5] Southworth and Ben-Joseph, 2003.
[6] Thompson, 2013.
[7] Thompson, 2013.
[8] See Thompson, 2013 for a detailed account of the scope and examples of such policies.
[9] Barrington-Leigh and Millard-Ball, 2015.