RESEARCH HIGHLIGHT

July 2008 Socio-economic Series 08-012

Taming the Flow—Better Traffic and Safer Neighbourhoods

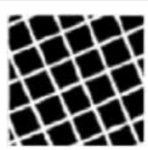
INTRODUCTION

A consensus is emerging that conventional approaches to suburban development are not sustainable. From a transportation perspective, single-use, low-density residential developments with curvilinear, poorly connected road networks limit transportation options to the point that that private automobile is the only choice for many trips. This increases automobile travel and, as a result, fuel use, emissions and transportation costs. With this in mind, municipalities are re-examining neighbourhood layout and land use concepts.

The conventional suburban site layout, the inheritance of the last 50 years of growth, represents one step in the evolution of road network and land use approaches. It was preceded by the grid street pattern, a key feature of the early railway–pedestrian suburbs and of many 19th century cities (figure 1). This progression from the rectilinear, orthogonal, open grid to curvilinear streets and dead ends suggests that there may have been sound reasons for the transition. These reasons include the desire for neighbourhoods and districts that balance the requirements for land-use efficiency, neighbourhood livability and effective transportation, though primarily by private automobile.

Street layouts and land use plans need to evolve to encourage the replacement of car trips with walking, cycling or public transit trips. "Walkability" is emerging as a key characteristic of a good neighbourhood plan. Walkability has three main attributes: connectivity, density and mix of uses. However, while encouraging walkability, street network plans should also allow traffic to flow smoothly. Walkability and traffic flow must be balanced.

CMHC examined the historic transformation of street layouts and developed an alternative model, the "Fused Grid," which attempts to blend desirable elements of the conventional and grid-based street layouts. This model gives priority to walking and cycling at the neighbourhood level, and frees automobile movement at the district and regional scale.

	Gridiron (c.1900)	Fragmented parallel (c.1950)	Warped parallel (c.1960)	Loops and lollipops (c.1970)	Lollipops on a stick (c.1900)
Street patterns					

Source: Adapted from Southworth and Owens (1993)

Figure 1 Evolution of street patterns

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While initial inferences from other models suggested that the Fused Grid would allow more efficient movement than other street patterns, only detailed analysis could establish comparative performance levels.

This study was initiated to provide a comparative assessment of the transportation impacts of three different district street layouts (that is, "Conventional Suburban," "Neo-traditional," and Fused Grid).

The study's main task was a traffic engineering analysis to compare the performance of these layouts, including local, district, and regional streets. Implications for travel behaviour (for example, transit use) and traffic safety were also considered. The comparative assessment was done using the Barrhaven neighbourhood, an existing built-up area in Ottawa, on which two new layouts were overlaid.

RESEARCH CONTEXT

To frame and direct the traffic analysis, a literature review summarized current discussion about street layout design from a transportation perspective. The literature focuses mostly on issues of connectivity, accessibility, safety and travel behaviour—predominantly in a qualitative manner.

Most current research has focused on walkability as a key indicator of a good neighbourhood plan. However, since street networks must also serve vehicles, a good model should also successfully lessen congestion, reduce travel time and minimize the risk of collisions.

The review also revealed gaps in current research. For example, research is inconclusive about how measures that increase network connectivity may affect other desirable characteristics, such as vehicle movement, delay and safety. Compounding this uncertainty is the fact that most critiques of current street layouts ignore the option for improving pedestrian and cyclist connectivity with pathways and linkages separate from vehicle movement.

In other instances, there appears to be increasing debate and uncertainty about whether street hierarchy is essential for good traffic flow, or whether a more uniform network might improve traffic flow through dispersion. In addition, there is a general lack of empirical data to assess how changes in road network patterns at the local level can affect transit use and vehicular trip generation.

Perhaps the most significant research gap relates to how various street patterns compare in terms of traditional transportation performance measures such as delay, capacity and intersection level of service. The study focused on quantifying the transportation level of service impacts of different street layouts using commonly accepted transportation engineering techniques and models. Insight on questions regarding connectivity, pedestrian linkages and street hierarchy are also provided.

METHOD

To compare street layout concepts, the study used traffic simulation to assess performance under different street layout alternatives and land use scenarios. The method involved:

1. Identifying and characterizing a study area.
2. Selecting alternative street layouts for the study area.
3. Developing land use scenarios.
4. Establishing and applying the transportation demand and traffic modelling approach.

STUDY AREA

Barrhaven, the study area, is a suburb of Ottawa about 17 km (10.5 mi.) southwest of downtown and on the outer edge of a greenbelt. The 520 ha (1,285 acres) study area is mostly residential. Single-detached dwellings are the dominant land use. In 2001, the area supported about 22,000 residents and 2,300 jobs, corresponding to an average gross population density of 42 residents per hectare and gross employment density of 4.5 jobs per hectare.

A comparison with five other Ottawa neighbourhoods showed that Barrhaven characterizes conventional suburban development in many ways (for example, street layout and road density, employment density, transportation mode splits and so on), but is at the upper end of population density range. It can therefore be assumed that if traffic performance for a given street layout is acceptable in Barrhaven, it will likely perform satisfactorily for other locations with similar land use.

Table 1 Comparison of alternative street layouts

	Conventional Suburban	**Neo-traditional**	**Fused-Grid**
			
Street hierarchy	Hierarchical street pattern of arterials, major collectors, minor collectors and local streets.	Hierarchical street pattern of arterials, major collectors, minor collectors and local streets arranged in orthogonal geometry.	Hierarchical street pattern of arterials, major collectors, minor collectors and local streets arranged in an orthogonal manner; one-way couplets for major collectors and twinned arterials.
Block length	Very long blocks (up to 600 m [1,968 ft.]), discontinuous streets with no breaks between lots for pedestrians.	Block sizes of 60–120 m (197–394 ft.) by 120–240 m (394–787 ft.).	Most block lengths are under 200 m (656 ft.), but reach a maximum of 600 m.
Cross-section design	Wide (11 m [36 ft.]) two-lane road cross-sections.	3.5 m (11.5 ft.) lanes and 2.4 m (8 ft.) for parking.	3.5 m (11.5 ft.) lanes and 2.4 m (8 ft.) for parking.
Intersection type	Extensive use of 3-way intersections (T-intersections) and few 4-way intersections; a ratio of 14:1.	Dominant use of 3-way over 4-way intersections in a ratio of 2.6:1.	A predominance of 3-way over 4-way intersections; a ratio of 4.7:1.
Arterial connection	Eight connections.	14 connection roads	11 major roads connecting to arterials.
Bicycle, pedestrian infrastructure	Pedestrian and cycling paths are confined to the school grounds and train tracks.	Integrated pedestrian and cycling path system within the neighbourhood.	Active infrastructure (path network) within neighbourhoods. Clearly defined residential quadrants framed by collectors that do not support through-traffic.

ALTERNATIVE STREET LAYOUTS

Alternative street layouts—Conventional Suburban and Neo-traditional—were chosen to represent current typical street networks. A third was added: CMHC's new Fused Grid model.

The Conventional Suburban layout is most often associated with discontinuous, curvilinear street networks, typified by the existing Barrhaven street network. The Neo-traditional layout, for the purpose of this analysis, is based on the traditional grid, but has been adapted to incorporate a hierarchical network of roads. The Fused Grid adopts the traditional grid at the neighbourhood and district scales while adopting the discontinuous street network approach at the block scale. It also includes strategically located pathways and parks creating connections for non-motorized traffic. Table 1 illustrates and describes the three alternative street layouts for Barrhaven.

In addition to the street networks, a variety of other elements needed to be developed for each layout. This included the functional classification of road facilities and associated designs (for example, number of lanes, speed limit, pavement width and so on), transit service and the location of intersections with traffic signals and stop signs.

LAND USE SCENARIOS

Five land use scenarios were developed, representing increasing levels of population and employment, to explore the transportation performance of each layout under increasing numbers of trips into and out of the district. (Table 2)

In all but Scenario 2, which mirrors existing conditions, population densities were uniformly distributed across the entire Barrhaven district. This uniformity removes irregularities that are not related to the development pattern itself, but reflect site-specific land use. In Scenarios 1–4, employment densities and schools were distributed according to prevailing conditions. In Scenario 5, the large employment increase rendered it impractical to limit employment to the original areas; therefore, it was distributed to areas closest to transit corridors.

TRANSPORTATION MODELLING APPROACH

A two-stage modelling approach responded to the challenges of the study. The first stage relied on the Emme/2 TRANS travel-demand model developed by the City of Ottawa. This model was used for the four-stage modelling procedure to determine the overall traffic volumes expected to travel to, from and within Barrhaven given the varying land use scenarios.

The second stage involved more detailed micro-simulation using the *Corsim* modelling software. *Corsim* was chosen because it simulates many detailed traffic characteristics, such as queuing, acceleration and the tendency for cars to stagger while driving on multilane roads. Accordingly, the *Corsim* model can reflect the differences in traffic performance for the three street layouts.

The modelling and simulation was based on weekday afternoon peak hour conditions for each of the 15 street layout–land use scenario combinations. Modelled results include transit mode splits, vehicle kilometres travelled, delay (that is, congestion plus intersection delay) and intersection level of service.

KEY FINDINGS

- **All layouts exhibit acceptable traffic performance under most land use scenarios**
  The assessment showed that for a wide range of population and employment densities, each street layout allows for acceptable traffic flow. This is evident in the relatively low average trip delay (figure 2), minimal non-local traffic infiltration and acceptable intersection level of service for Scenarios 1 to 4.
- **The Fused Grid layout exhibits the best traffic performance, particularly with increasing density of development**
  The Fused Grid layout exhibits the lowest delay and best signalized intersection level of service under all scenarios, but particularly under the high density–mixed-use land use conditions of the Scenario 5.

  These lower relative levels of delay range from 15 per cent less delay than the poorest performing layout under existing population and employment levels, to 35 per cent less delay for the high density–mixed use scenario.

This is due to two primary factors:

First, the strict hierarchical street system in the Fused Grid layout provides for efficient traffic flow into and out of the neighbourhood.

Second, the Fused Grid's major collectors are designed as one-way couplets. This reduces the number of signalized intersections required and streamlines traffic signal cycle timings.

Table 2 Land use scenarios

Scenario	Description	Population	Gross population density (pop/ha)	Employment	Gross employment density (jobs/ha)
1	Existing population and employment (uniform density)	13,680	40.6	1,640	4.9
2	Existing population and employment (non-uniform density based on prevailing/expected conditions)	13,680	40.6	1,640	4.9
3	Neo-traditional population (uniform density)	20,949	62.2	2,510	7.4
4	Transit-supportive population densities (uniform density)	30,330	90	3,640	10.8
5	Commercial intensification (uniform density)	30,330	90	16,850	50

- **A hierarchical network layout can improve traffic performance**
  All three layouts are characterized by a hierarchical network structure to varying degrees. Of the three, the Fused Grid layout follows the strictest hierarchy, followed by the Conventional Suburban and then by the Neo-traditional layout. The strict hierarchical street system allows for efficient traffic flow into and out of the neighbourhood. The relative benefits of the Fused Grid are most evident in Scenario 5 under elevated traffic volumes.

- **One-way couplets improve traffic flow on arterials and deserve further consideration in neighbourhood design**
  The improved intersection level of service and traffic flow along arterials due to conversion of major collectors into one-way couplets for the Fused Grid layout confirms recent proposals for their use by prominent planners. However, these improvements in traffic flow must be balanced with the tendency for one-way streets to promote higher traffic speeds and more circuitous travel patterns. Cyclists and transit vehicles are particularly sensitive to the latter.

- **The Fused Grid reduces traffic volumes on lower classification streets**
  Looking at the performance of local streets and minor collectors, the analysis shows that the Fused Grid restricts the amount of traffic on them more effectively than the Conventional Suburban and Neo-traditional plans. This is particularly evident in the scenario with the highest traffic volume—Scenario 5, the high population and employment scenario (figure 3).

- For the street layouts considered, intersection density (that is, connectivity) and the presence of loops and cul-de-sacs do not have a strong correlation with traffic performance.

  For example, the high connectivity Neo-traditional layout (0.87 intersections per hectare) provides lower delay than the Conventional Suburban layout (0.48 intersections per hectare), but does not outperform the Fused Grid layout (0.51 intersections per hectare).

  This is in contrast to the literature, which suggests that level of service, particularly on arterials, should improve with increasing connectivity as there are more available routings to motorists. This suggests that other factors, such as the spacing and number of connections to the arterial network, may be more important to traffic performance than overall connectivity or the presence of loops and cul-de-sacs.

- **Increased connectivity reduces average trip distances within a neighbourhood**
  While average trip distances are similar across layouts for each scenario, Vehicle Kilometres of Travel (VKT) for trips within the district are approximately 10 per cent shorter in the Neo-traditional layout than other layouts. This is a result of the higher connectivity in the Neo-traditional layout, which allows for more direct trips. Ideally, intra-neighbourhood car trips should be displaced by walking and biking in a neighbourhood that is laid out to favour active transportation modes.

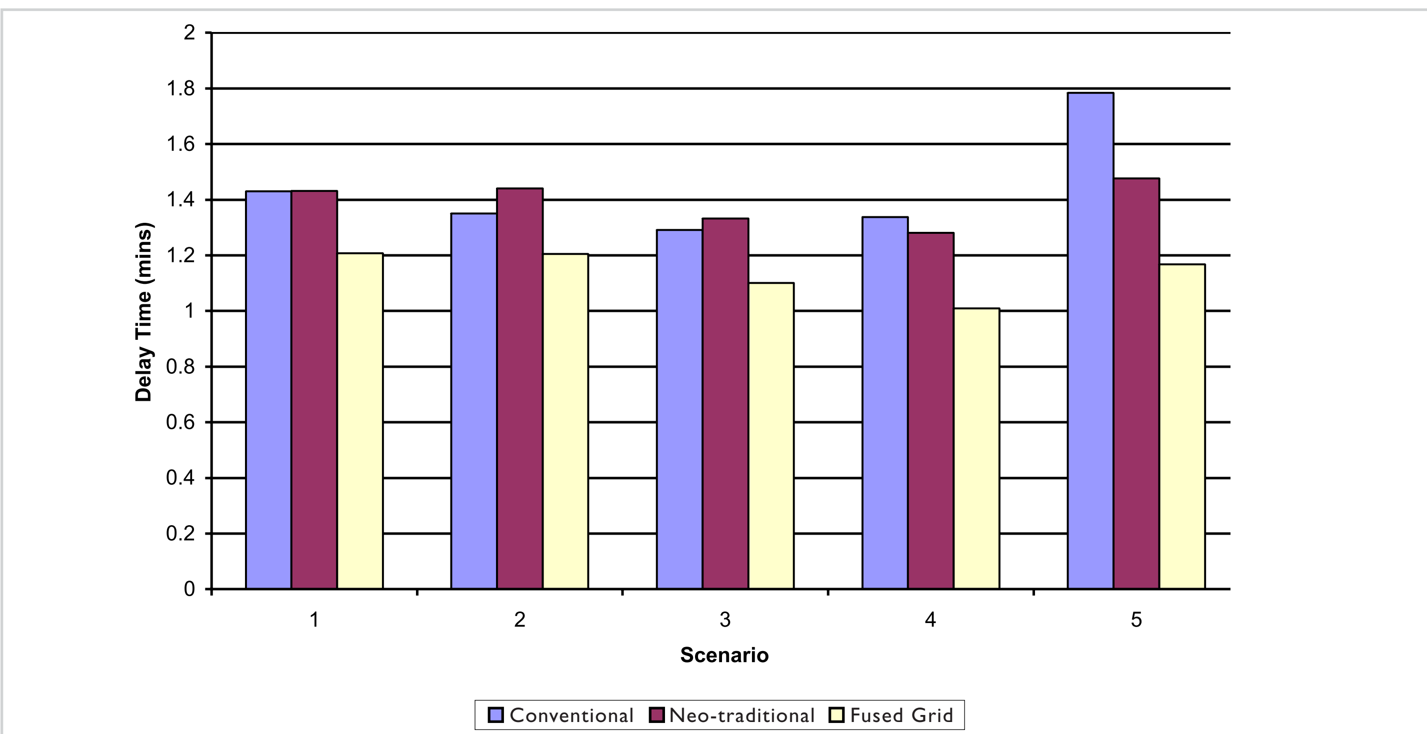

Figure 2 Average vehicle delay time per trip

- **Non-local traffic infiltration is more dependent on route directness and travel time savings offered by specific facilities than generic measures of connectivity**
  Traffic simulations revealed little to no non-local traffic infiltration for every layout and land use scenario. Non-local traffic that did "cut through" the district on non-arterial roads primarily did so using major collectors. Despite the lower overall connectivity of the Conventional Suburban layout, this layout exhibited the highest amount of through-movements by non-local traffic. This is in part due to the fact that a single major collector in this layout is oriented diagonally and provides an efficient routing across the district. These results indicate that, at the individual neighbourhood level, the amount of non-local traffic within the neighbourhood is less related to generic measures of connectivity (for example, intersection density) than to route directness and travel time savings offered by specific facilities.

- **Modal shares are affected more by land use density and mix of uses than by the street layout**
  Estimated transit mode split ranged from 11 per cent to 16 per cent of afternoon peak hour trips between the existing and high density–mixed use land use scenarios. For each land use scenario, however, there are only marginal differences in transit mode split across the street layouts. This supports results from other studies that indicate that although neighbourhood design (including street layout) influences travel decisions, locational and socio-economic variables have a stronger relationship with auto ownership, transit mode choice and vehicles kilometres travelled. Though not quantified in this study, it is expected that differences in street layout may have a stronger influence on the propensity to walk or cycle than they do on transit use.

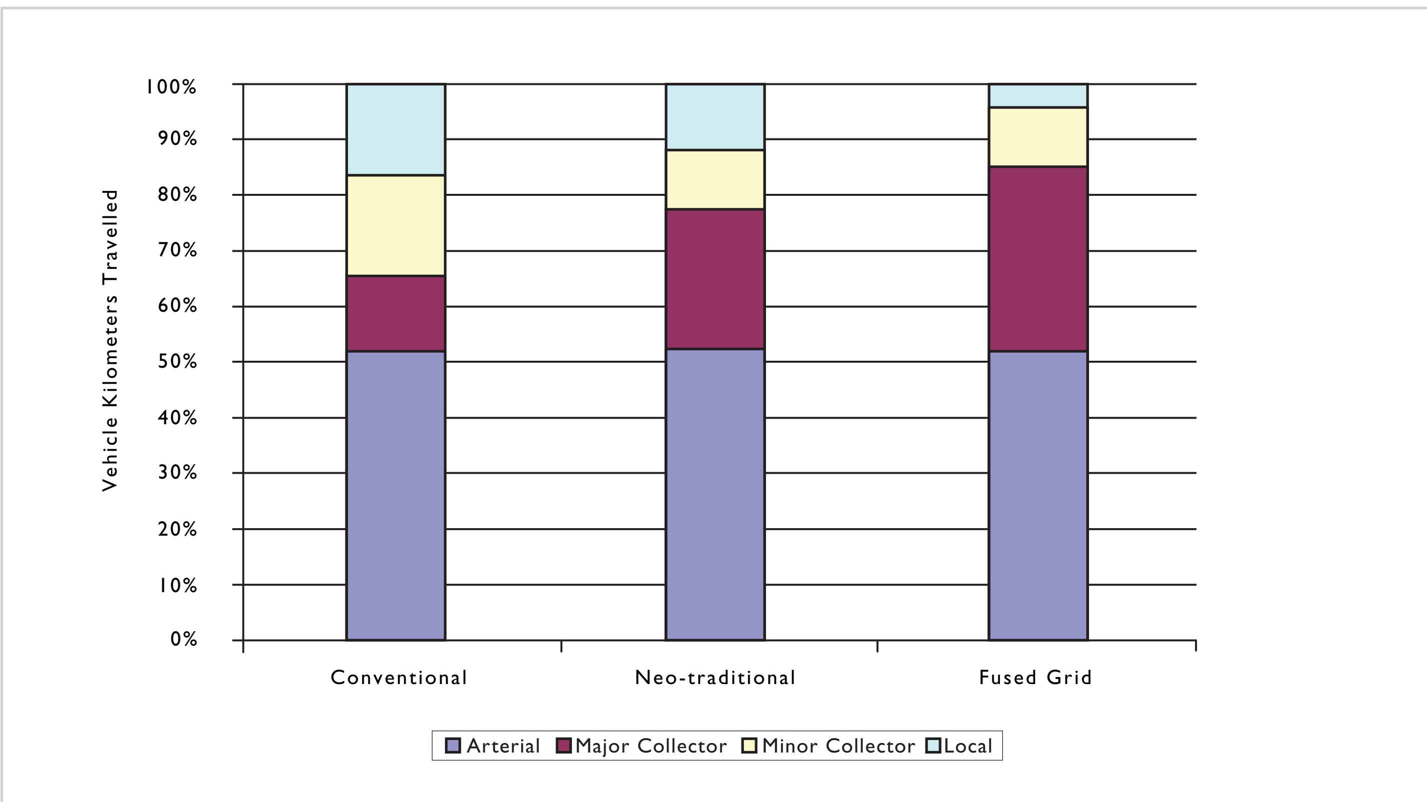

Figure 3 Share of vehicle travel by road type in Scenario 5

CONCLUSIONS

While previous studies have assessed the traffic impacts of increasing street connectivity or commented on the traffic performance of Neo-traditional networks, this the first study to look at the performance of the Fused Grid model and compare it to current alternatives.

This study contributes to neighbourhood design and traffic literature by adding both a new network layout model to the existing repertoire along with an assessment of its performance. Several general conclusions can be drawn from this study:

- Street network hierarchy and the presence of looping streets and cul-de-sacs do not necessarily lead to traffic congestion. Other factors, such as intersection design and the number and quality of arterial connections, must also be considered.
- Differences in traffic performance are most evident in high-density, mixed-use scenarios. Typical suburban land use conditions provide a poor basis for testing and contrasting network patterns.
- The Fused Grid can provide adequate traffic flow over a variety of land use forms.
- The Conventional Suburban layout provides the poorest traffic performance under increasing population and employment densities.
- The search for networks that balance the needs of pedestrians and drivers should continue. Few empirically based answers exist. Inherited network models should be rigorously re-examined.

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Research Report: *Assessment of the Transportation Impacts of Current and Fused Grid Layouts*

Consultant: IBI Group

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