RESEARCH REPORT

External Research Program

Residential Street Pattern Design

Canada

CMHC SCHL
HOME TO CANADIANS

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) has been Canada's national housing agency for more than 60 years.

Together with other housing stakeholders, we help ensure that Canada maintains one of the best housing systems in the world. We are committed to helping Canadians access a wide choice of quality, affordable homes, while making vibrant, healthy communities and cities a reality across the country.

For more information, visit our website at **www.cmhc.ca**

You can also reach us by phone at 1-800-668-2642
or by fax at 1-800-245-9274.

Outside Canada call 613-748-2003 or fax to 613-748-2016.

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1-800-668-2642.

RESIDENTIAL STREET PATTERN DESIGN

Fanis Grammenos
Senior Researcher, Research Division
CMHC, 700 Montreal Road
Ottawa, ON, Canada

Julie Tasker-Brown
Consultant in Community Planning
Montreal., Quebec

The suburban experience points to better models for street design

Streets connect the private with the public domain and also link different parts of a neighborhood. These linkages support social interaction and exchange—both vital functions. Street design contributes significantly to the quality and character of a community since appropriately designed street create safe, quiet and healthy environments, particularly for children.

Current thinking on street pattern design appears to be divided between concern for the efficiencies of infrastructure and traffic, and a consideration of aesthetics. This generally translates into a battle between conventional suburban loops and cul-de-sacs, and "traditional" grid models. The latter approach typifies smart growth, New Urbanism, and Traditional Neighborhood Development. The goal of this study is to suggest street patterns that balance efficiency and quality, and reconcile functionality and aesthetics. This requires identification of the positive attributes of conventional suburban development while utilizing current technology and satisfying consumer preferences.

HISTORIC MODELS

Conventional suburban street layout evolved from plans of early cities and suburbs. These plans were shaped by: the mode of transportation of the day; the current models of city planning; and, the recent explosion of city growth. The first type of suburb to emerge at the urban fringe were streetcar suburbs. Since streetcar suburbs relied chiefly on pedestrian traffic, they borrowed their street patterns--grids--from traditional pedestrian cities. The use of grids, sometimes with diagonal avenues, was convenient for streetcar stops which were directly accessible from all parts of the suburb. The areas around the stops soon emerged as hubs of commercial and social activity. The layout of streetcar suburbs reflected a strong transportation logic: efficient long-distance commuting and convenient short-distance pedestrian access.

The move away from the cluttered and often unsanitary city, intensified the suburban dweller's desire for rural, natural settings. This desire, in some cases, found an expression in street layouts that resembled stylized village plans in a modified grid with winding, picturesque streets and dense vegetation. Access on foot and a rural imagery were the driving forces; the model was the tried-and-true grid.

The emergence and rapid popularization of the automobile as personal transportation made virtually all the urban periphery equally accessible, dissolving the traditional planning constraint of walking distance. At the same time, the automobile introduced new constraints: noise, fumes, and pedestrian safety. In addition, automobiles required streets designed for speed and driving safety, attributes that were lacking in the traditional pedestrian street. These new requirements found their clearest expression in the Radburn model, named after the pioneering suburb of Radburn, N.J., begun in 1928. Radburn replaced the grid with "superblocks" that excluded through car traffic by grouping houses around cul-de-sacs, served by collector streets, and separated by common parkland. Traffic was directed to wide collectors or divided arterials on the perimeter and incorporates a "spine" of open space in the middle of the superblock. This new model of circulation retained the key ideas of rural setting and foot accessibility, but people walked on landscaped footpaths, while streets were given over to the automobile. Most later suburban subdivisions followed the Radburn model, although over the years pragmatic adaptations such as the introduction of looped streets, the elimination of the footpaths and the parkland, increased development efficiencies while reducing the overall attractiveness of the original model.

EFFICIENCY AND QUALITY

Efficiency is chiefly the result of combining two standard street types—loops and cul-de-sacs--with long blocks. Contrary to popular opinion, the curvilinear streets that are typical of conventional suburban subdivisions are not inefficient; they reflect an aesthetic preference and have little impact on land consumption. While irregular lot shapes do not pack efficiently, this is of relatively little consequence at low densities. In fact, for comparable residential densities, loop and cul-de-sac street patterns are more efficient than traditional gridiron geometry (which is why they are preferred by most developers). According to the technical literature on street planning, conventional suburban street layouts consume 16-25 percent less land than the traditional grids advocated by New Urbanism (see Fig. 1.)

	Square Grid. (Miletus, Houston, Portland etc.)	Oblong grid. (most cities with a grid)	Oblong grid 2 (some cities, or in certain areas)	Loops. (Subdivisions - 1950 to now)	Cul-de-sacs. (Radburn, 1932 to now)
Percent of area for streets	36.0%	35.0%	31.4%	27.4%	23.7%
Percent of buildable area	64%	65%	68.6%	72.6%	76.3%

Figure 1. Comparison of area used for streets, among five typical patterns.

Loop and cul-de-sac street patterns have evolved from 1900 to the present (see Fig.2). Their geometry is adapted to the automobile, excluding traffic at the local street level, and permitting good flow at the collector and arterial levels. By contrast, the traditional grid patterns that predate the automobile have required major adaptations such as one-way streets and traffic lights in order to achieve good automobile traffic flow. Without such adaptations, congestion is inevitable. The grid, both in theory and in practice, is an inefficient carrier of car traffic. At each grid corner there are 16 possible intersecting paths for which priority has to be deciphered by the driver (or controlled by traffic lights). By comparison, T-intersections, common in conventional subdivision plans, have only 3 intersecting paths, where priority is easily grasped. Grid intersections occurring at every 200 feet, or every 6 to 8 seconds at typical car speeds, undermine the car's main advantage--rapidity of travel. Thus the grid compromises either speed or safety or both and, at high traffic volumes, even with traffic lights and stop signs, the grid begets gridlock.

On the other hand, when congestion occurs on arterial roads in a loop and cul-de-sac system, it is generally caused not by the street network but by the segregation and concentration of homogeneous land uses such as regional shopping malls, or office parks. However, street patterns like the loop and cul-de-sac, which are designed for the automobile are poorly adapted to the pedestrian. Their discontinuity inhibits pedestrian access to facilities and amenities, while their curvilinearity lengthens and confuses walking trips.

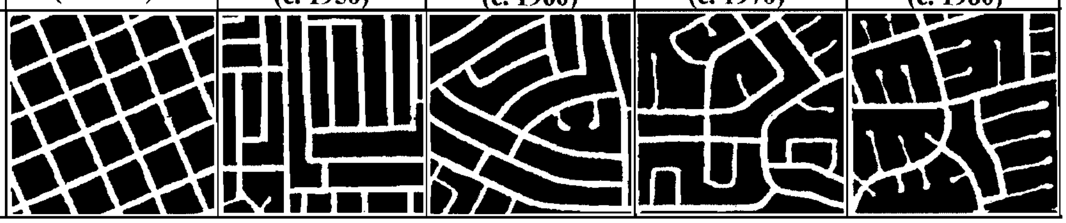
	Gridiron (c. 1900)	**Fragmented Parallel (c. 1950)**	**Warped Parallel (c. 1960)**	**Loops and Lollipops (c. 1970)**	**Lollipops on a Stick (c. 1980)**
Street Patterns					

Figure 2. Evolution of street patterns since 1900 showing gradual adaptation to the car. (M. Southworth , 1997)

A recent study by the IBI Group for the Canada Mortgage and Housing Corporation concluded that the top three determinants of the amount of suburban car use are: the number of people per household; the distance of the subdivision from the Central Business District; and, above all, the number of cars per family. Car ownership is related to: the number of persons per household; household income; and, house size (an indicator of household wealth). Thus, car ownership, family size, and household location have a far greater influence on auto travel than the type of street pattern, which ranked ninth in influence. While street patterns influence car use, they do so only insignificantly.

There is no correlation between street pattern type and residential density, although density has a strong impact on land usage, and is also related to the presence of amenities within a district. The strongest predictor of residential density is land price, with higher densities occurring where land prices are high. Household affluence is the primary indicator of land consumption, followed by a household's stage in the life cycle. The higher the income of a household, the higher the likelihood that it occupies a single-family detached house. Similarly, the presence of children is closely linked with the consumption of a detached house. Street patterns have never been associated with a specific residential density.

STREET QUALITY

The perceived quality of a street depends on both physical and operational attributes, some of which are incidental, and some of which are designed. Street life, visual complexity, social status and the density of people are incidental attributes dependent on culture and history. On the other hand, safety, security, comfort, and a sense of enclosure, are functions of design. In addition, physical attributes, whether designed or incidental, may be reinforced--or undermined--by operational attributes such as the level of maintenance and cleanliness. Taken as a whole, these attributes produce a memorable image and a pleasurable feeling in the user, expressed as sociability, walkability, and delight to the pedestrian, and driving ease and safety to the driver.

The *sociability* of a street is critical to its quality. Informal contacts that develop into social networks are at the root of feelings of belonging and security, which are prime factors in resident satisfaction. Street activity cannot be designed but it can be encouraged--or inhibited--by certain street characteristics. The most negative influence on sociability is heavy car traffic, whose negative effect is proportional to its volume. To the extent that a street pattern encourages speed (as in wide through-streets) it will invite more traffic. To enhance sociability, particularly with regard to children's safety and play, most traffic experts recommend discontinuous street patterns of the kind found in conventional loop and cul-de-sac suburbs. Such street patterns consistently show a lower rate of accidents and a higher level of perceived security.

Satisfaction surveys of suburban residents often mention *walkability*. Walkability implies comfortable access to amenities such as schools, recreation, retail, and workplaces. The presence of these amenities can be affected by a street pattern but clearly not determined by it alone. However, in many conventional suburbs discontinuous, indirect, and confusing street patterns of loops and cul-de-sacs compromise accessibility. In addition, collector and arterial streets are inhospitable and unsafe because of high traffic volume, discouraging pedestrian use. Recent New Urbanism-type subdivisions that have adopted the grid pattern, create clearer and more direct pedestrian routes. Yet the amenities in these communities are generally beyond the five-minute walking distance desired by today's consumers. Walkability demands both a conducive street pattern and, equally important, a proximate arrangement of land uses.

Viewing nature, whether it is in the form of parks, boulevards, or treed avenues in an urban environment is a source of *delight*. Green space has been found to have social and psychological benefits that explain the strong consumer preference naturally endowed sites, and for house locations facing parks, open space, golf links, lakes, and so on. Green space provides visual relief and opportunity for relaxation, becomes a place for

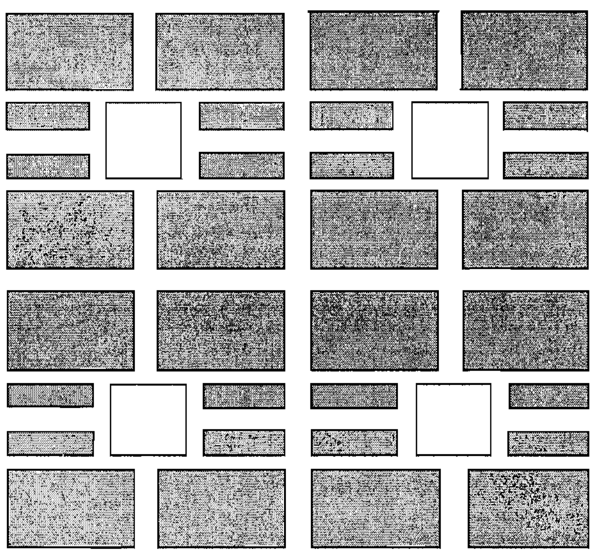


Figure 3. Plan of Savannah wards (1733)

casual contacts, and forms a haven for kid's play. (However, poorly designed and supervised, it can become a locale for crime and drug use.) Green space also has environmental benefits: it cools the air, recycles carbon dioxide, and retains rainwater. Due to these benefits, it emerges as a key element of quality in a residential development. Quality open space has been shown to make increased residential density more acceptable to residents. Though most subdivisions incorporate open space in their plans, ranging from 2 to 16 percent of the area, only a few stand out for their effective design and use of open space.

One of the most successful examples of open space use in an urban plan remains the eighteenth-century plan of Savannah, Georgia. Savannah's public open space is distributed, accessible and peaceful. It delivers its benefit to the largest possible number of city dwellers. The city plan is organized in repeatable 675 foot-square "wards," with a square in the center (Fig. 3). This square is visually accessible by at least half the houses in the ward and in close proximity to all. It is protected from heavy traffic since through-streets are located at the boundaries of the ward, leaving the center relatively calm for casual strollers.

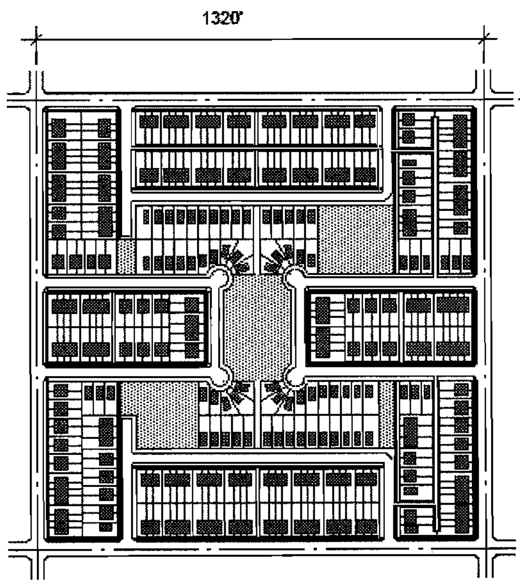


Figure 4. A 40-acre building block (quadrant , cell) of residential districts

A city dweller behind the wheel expects as much pleasure out of driving as out of walking. Narrow, twisted and crowded streets may please pedestrians, but they frustrate drivers. To be enjoyable, driving requires unimpeded flow, perceived safety, and rich visual experiences on a large scale. These qualities are generally achieved by reducing and simplifying intersections, increasing lane widths, lengthening straight stretches, dividing traffic lanes, widening curves, and completely separating opposing streams of traffic by man-made or natural dividers. Treed boulevards acquire some of these qualities but the road that encapsulates all these positive attributes best is the urban parkway.

THE BEST OF BOTH WORLDS

For users, the two predominant suburban street pattern alternatives--loop and cul-de-sac, or grid--have distinct advantages. Discontinuous streets with loops and cul-de-sacs provide safety, sociability and efficiency; continuous grid patterns provide connectivity and easy orientation. To create streets that provide all these attributes, requires combining the two patterns. Such a combination would have the following characteristics: it would return to orthogonal geometry for clarity of organization and directness of pedestrian access; it would provide loops and cul-de-sacs for local streets for safety, tranquillity, sociability and land use efficiency; it would use open space as a structuring element of the layout for connectivity, relief, comfort, water retention, interaction and delight; it would adopt a road hierarchy of local, collector and arterial, for distributing and moving car traffic effectively; and it transforms arterial roads from mere traffic conveyors to activity generators. The aim of this new combined street layout is: to prevent nonresident through traffic; to maximize the number of houses on cul-de-sacs and loops; to situate open space for maximum accessibility; to accommodate a range of housing types.

The fundamental building block of this proposal is the residential quadrant (Fig. 4). It is roughly ¼ mile square (40 acres) and can be crossed on foot in five minutes. The quadrant is bounded by two collector streets and two arterial streets. Within the quadrant, residential streets are laid out in a modified grid so that cars cannot cross the quadrant, eliminating non-residential traffic. The use of looped, narrow streets reduces the speed of all vehicular traffic. A continuous pedestrian footpath system provides several direct route options to parks, public transit, retail, and services. The pedestrian system is generally overlaid on the streets. In one of twelve possible layouts, three parks are laid out diagonally and act as connectors. Connections made on foot are established by way of an extensive and accessible network of open space and parks. Eight percent of the area is devoted to open space; 26 percent is devoted to streets. By exchanging street space for open space connectivity is enhanced, walking is made visually rewarding and developable land increases (Fig. 5).

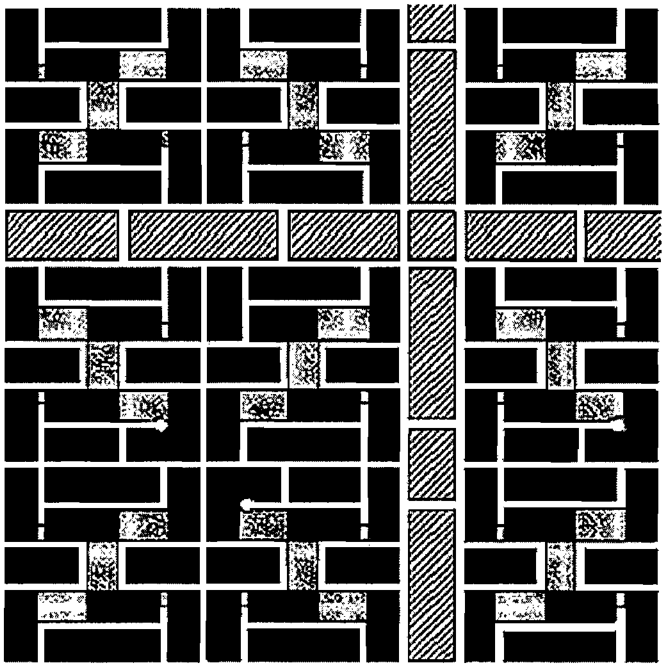


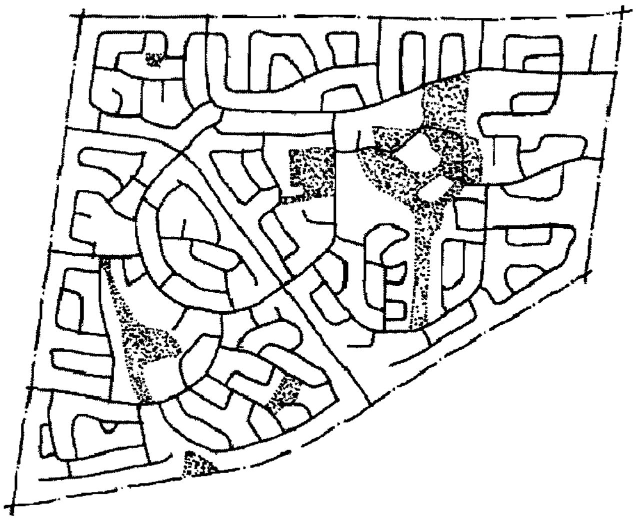
Figure 5. A quadrant framed by a multi-use zone which lies between one-way arterials

The overall residential density of a quadrant may vary. Highest density would be at the edge of the quadrant adjacent to the arterial streets, intermediate density adjacent to the collector streets, and moderate densities in the center; lots facing the park could be developed at intermediate densities.

COMPARISON

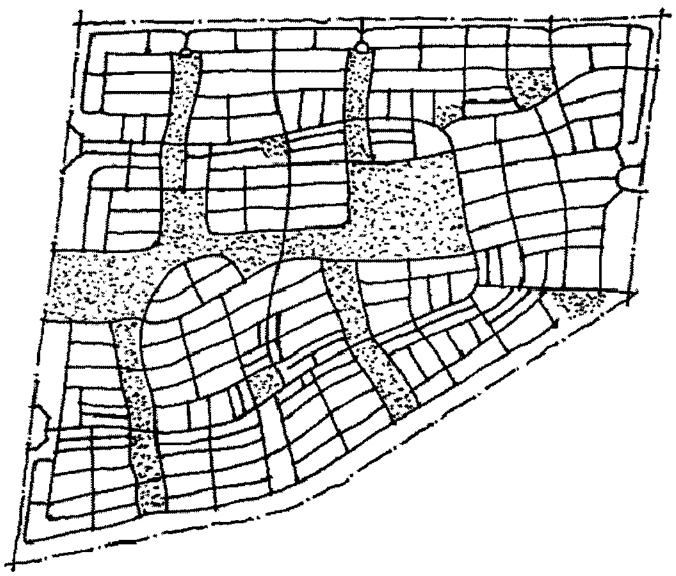
The Residential Quadrant concept was overlaid on an existing 1970s subdivision, Barhaven, in Nepean, Ontario (outside Ottawa), to test its applicability to a large site and compare the results with respect to efficiency and quality. The Quadrant plan was also compared to a Traditional Grid layout on the same site. The three site plans and their essential characteristics are shown below (Fig.4).

Figure 4. Comparison of 3 plans



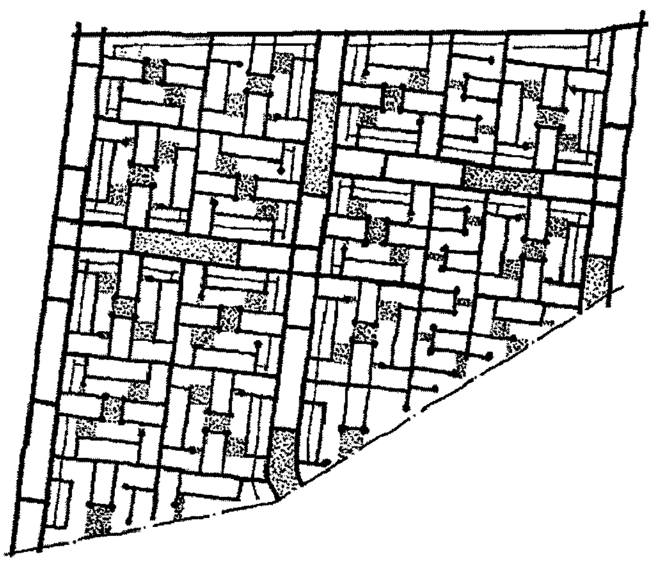
1. Conventional Loop & Cul-de-Sac

- Hierarchical, with arterials, collectors and local streets.
- Curvilinear at every level
- Discontinuous for pedestrian and vehiclesOpen space is located beyond walking distance for most residents



2. Traditional Grid

- A modified grid
- No loops or cul-de-sacs
- The grid becomes discontinuous at the edge of each "neighborhood"
- One collector-type road links site to regional arterials
- Most open space is located at the perimeter of "neighborhoods"



3. Residential Quadrant

- A continuous, open grid of arterials
- A discontinuous grid of minor collectors and local streets
- A continuous, open network of pedestrian streets, spaces and paths
- No through traffic in residential quadrants
- Corridors of mixed-use zones
- Open space within each quadrant part of the path system

Table 1. Comparison of land use distribution among three alternative site plans

	Conventional Loop & Cul-de-Sac acres	percentage	Traditional Grid Acres	percentage	Residential Quadrant acres	percentage
Residential	454.5	54.5	390.3	46.8	435.3	52.2
Commercial & Institutional	31.7	3.8	55.0	6.6	55.0	6.6
Recreation and Open space	84.2	10.1	100.9	12.1	100.9	12.1
Streets	240.2	28.8	264.4	31.7	220.2	26.4
Vacant land	22.5	2.7	22.5	2.7	22.5	2.7
TOTAL LAND AREA	834.0	100	834.0	100	834.0	100

In terms of efficiency the Quadrant option rates better that the Loop & Cul-de-Sac and the Grid layouts. When the three prime uses--Residential, Commercial, and Institutional--are combined, the Loop & Cul-de-Sac plan develops 58.1 percent of the land, the Grid plan develops 53.4 percent, and the Quadrant plan develops 59.8 percent, that is, the Grid plan decreases the amount of developable land while the Quadrant scheme marginally increases it. The Loop & Cul-de-Sac plan devotes 54.4 percent to residential uses versus 46.8 percent in the Grid and 52.2 percent in the Quadrant. The 2.2 percentage points difference between the Quadrant scheme and the Loop & Cul-de-Sac plan can be explained by the 2.8 percent increase in commercial and institutional uses.

The amount of land devoted to streets shows how a plan can optimize land consumption and minimize infrastructure costs. The Grid plan consumes the most land (31.7 percent) for streets while the Quadrant scheme the least (26.4 percent); the Loop & Cul-de-Sac plan represents a median between the two (28.8 percent). This difference would be higher if the rights of way for the Grid plan were kept constant. It is also worth noting that streets in a Grid, which are accessible to through traffic, must meet higher design standards than cul-de-sacs and loops, which increases the cost of infrastructure. In the Loop & Cul-de-Sac plan some inefficiency is due to backlotting on collectors, a practice that places two parallel roads on either side of a half-depth block.

The quality of the three alternatives can be compared on the basis of four criteria: tranquility, safety, connectivity, and visual delight. Tranquility is achieved by minimizing potential intrusion at the lot and house level and can be measured by the number of houses located on loops and cul-de-sacs. A measure of safety is the number of T-intersections. Connectivity is the accessibility on foot to various parts of the community, and the links between the neighborhood and adjacent neighborhoods, and can be measured by the frequency of connecting elements. Delight can be calibrated by the frequency and proximity of open green space.

The Grid plan scores low on tranquility due to the absence of cul-de-sacs or loops. The Loop & Cul-de-Sac plan has 30 loops and 16 cul-de-sacs, and the Quadrant plan has 62 loops and 34 cul-de-sacs. With respect to safety, the Grid scores low and the Loop & Cul-de-Sac high. The former has the largest number of intersections (273) and the highest proportion (31 percent) of the four-way type. There are ten times as many four-way intersections, and twice as many intersections of all types, in the Grid as in the Loop & Cul-de-Sac plan. However, scarcity of intersections can also be interpreted as measure of lower connectivity. A balanced resolution of these opposing requirements is offered by the Quadrant plan whose connections are made through parks, rather than on additional streets. The Quadrant has only 20 four-way intersections versus 86 in the Grid plan, but achieves the same degree of connectivity. With respect to delight, though all three plans have an equal amount of open space, the Quadrant plan makes it proximate to the largest number of residents. By comparison, the major green spaces of the Loop & Cul-de-Sac plan are beyond walking distance of most residents. The Grid plan brings open spaces within walking distance but makes them visually inaccessible to most houses. Given that green spaces are mostly also play spaces, proximity is a valuable attribute.

CONCLUSIONS

This study draws lessons from recent subdivision street pattern designs and from street patterns of historic cities. It examines how they function, how they fulfill residents' needs and expectations, and how they accommodate environmental concerns. In developing an alternative pattern that integrates the most important and desirable attributes of each approach, the study concludes: first, that it is possible to maintain the efficiency and quality of the conventional suburb while adopting the geometry of the grid; and second, that it is feasible and desirable to combine the tradition of the main street and the convenience of the commercial strip in a zone of mixed land uses that both relies on and supports transportation. By fusing the street patterns of conventional suburbs with those of the traditional grided city, and by recasting the arterial street in the light of its activity generation potential, it is possible to create communities that are efficient, viable, livable, healthy and highly marketable.

References

Hygeia Consulting. *Changing Values Changing Communities - A Guide to the Development of Healthy,Sustainable Communities.* Ottawa :Canada Mortgage and Housing Corporation, 1995

Essiambre-Phillips-Desjardins Associates Ltd et al. *Conventional and Alternative Development Patterns - Phase I: Infrastructure Costs*. Ottawa: Canada Mortgage and Housing Corporation, 1997

IBI Group Ltd. Greenhouse Gas Emissions from Urban Travel:*Tool for Evaluating Neighbourhood Sustainability.* Ottawa: Canada Mortgage and Housing Corporation, 2000

Fanis Grammenos
is a senior researcher with Canada Mortgage and Housing Corporation specializing in affordable housing, bulding and community sustainability, and user needs. He can be reached at :
fgrammen@cmhc-schl.gc.ca

Julie Tasker-Brown
Master's in Urban Planning, is a planning consultant who specializes in sustainable community development, affordable housing and municipal regulations. She can be reached at: juliet askerbrown@sympatico.ca

The authors wish to thank the editors of the Wharton Real Estate Review for their helpful comments and generous permission to publish variations of the article that appeared in WRER.