Chapter 3: Design an Interconnected Street System

[Figure 3.1 in margin near here]

Street systems either maximize connectivity or frustrate it. North American neighborhoods built prior 1950 were rich in connectivity, as evidenced by the relatively high number of street intersections per square mile typically found there.[1] Interconnected street systems provide more than one path to reach surrounding major streets. In most interconnected street networks two types of streets predominate: narrow residential streets and arterial streets. In this book, for reasons explained in chapter two, we call these arterial streets in interconnected networks “streetcar” arterials.

On the other end of the spectrum are the post WWII suburban cul-de-sac systems where dead end streets predominate and offer only one path from home to surrounding suburban arterials. This cul-de-sac-dominated system can be characterized as *dendritic* or “treelike”, the opposite of the web of connections found in interconnected systems. Streets in this system all branch out from the main “trunk”, which in Canadian and U.S. cities is usually the freeway. Attached to the main trunk of the freeway are the major “branches”, which are the feeder suburban arterial streets or minor highways. These large branches then give access to the next category down the tree, the collector streets or the minor branches in the system. Collector streets then connect to the “twigs and branch tips” of the system, the residential streets, and dead end cul-de-sacs.

The major advantages of the interconnected system is that it makes all trips as short as possible, allows pedestrians and bikes to flow through the system without inconvenience, and relieves congestion by providing many alternate routes to the same place. The major disadvantages of the interconnected street system is that no homes are completely cut off from the irritation of outside traffic and it uses more linear feet of street per standard size lot than does the dendritic system.

The major advantages of the dendritic system is that it shifts trips away from homes lucky enough to be located at the ends of cul-de-sacs, allows cars to flow easily through the system if optimally designed, and requires fewer linear feet of road length per standard sized lot. The major disadvantages of the dendritic system is that almost all trips are made longer than they would be if the system was interconnected, and is prone to congestion since it provides no alternative routes away from main intersections.

Despite these disadvantages, the dendritic system has become a ubiquitous feature of urban districts built since 1950.[2] The complex industry that creates new communities is so thoroughly committed to the dendritic street system that alternative thinking is no longer supported. Most municipal and regional transportation planners and engineers speak only in the language of the "street hierarchy", or the hierarchical categorization of streets.

[Figure 3.3 in margin near here]

Challenges of the Dendritic Street System

Jurisdictions often have a full set of regulations that assume all road systems are dendritic, making it impossible for interconnected streets to be understood. For example, the Salem, Oregon planning department requires new developments to assign categories from this hierarchy to all the streets in a proposed land subdivision proposal before it can be approved.[3] In 2003 the proponents for a sustainable new community at the former Fairview State Training Center in Salem argued that their interconnected street system proposed was essentially without a flow-concentrating hierarchy, but rather was designed to distribute traffic throughout the network. Unfortunately city planners and engineers did not have the discretion to accept this argument, feeling that their own policies made a categorization unavoidable. Having failed, the proponents reluctantly identified the community's proposed "High Street," where shops and community facilities like libraries and schools were proposed, as the "arterial." Unfortunately this designation triggered a reaction at the school district where one of their policies prohibited elementary schools located across "arterial" streets from the majority of its students. Here too the school officials felt that they had no discretion in the matter, and could only accept a plan where the school was placed less accessibly on a "quieter" part of the site. They recommended putting the school at the end of a cul-de-sac, with ample space for "mothers to drop of their children in cars every morning". At no point did they take the master plans imperative that the school should be "centrally located to make walking convenient and to make the school the symbol of the community" seriously.[4]

A second example: In 1998 the City of Surrey BC, partnered with the UBC Design Center for Sustainability to design a new "sustainable community" based on principles similar to the ones in this book. An interconnected modified grid system was designed. All of the charrette participants understood and supported the logic of the interconnected grid, including the consulting engineer. But when the engineer was required to model the performance of the system she had to artificially assign a hierarchy to the road system or the traffic flow software simply would not run. Thus even the modeling software only acknowledges one kind of system—the dendritic.

These decisions, driven by a deeply flawed street taxonomy and a tendency to narrowly focus on one issue to the exclusion of all the related sustainable community demands, has left us with neighbourhood configurations were people are forced to drive more than they should. Studies show that the dendritic configuration forces residents to drive more than 40% more than residents in older streetcar suburbs. This results in a 40% increase in GHG per car, and given that households in these systems are likely to own two or more cars, their GHG contribution per household is easily double that of residents of traditional streetcar districts.

The basic problem with the dendritic system is that all trips collect at one point, usually at the major intersection of two suburban arterials or the on ramp to the freeway. With all trips in an area feeding to one point that intersection will typically receive up to four times more trips than an equivalent intersection in an interconnected system.[5] With all of these trips forced through one pinch point, congestion is inevitable. It is only through dramatically widening these intersections that such congestion can be alleviated. Huge expenditures for widening suburban intersections are now routine, with nine or ten 13 foot lanes and 200+ foot wide right-of-way intersections.[6] While many of these intersections admirably handle the turning motions and through trips for 60,000 or more car trips a day, they are almost impossible to cross on foot, particularly for the infirm. **[Figure 3.4 in margin near here]** One study of pedestrian deaths in the Orlando area identified just such a landscape as a pedestrian death hotspot, the worst in the region.[7] Apparently many customers were foolhardy enough to try to trek on foot from the Ground Round restaurant to T.G.I.F across the 10 lane arterial street that separated them, and there they met their end. It would have been infinitely more intelligent to drive.

Transit systems seldom work well in dendritic systems either, since the passenger drop off point is still hundreds of yards away from their destination, separated from the street by acres of sun scorched or wind-blown parking lot.

Major streets within interconnected street systems often work quite differently than in suburbs. The interconnected Broadway corridor in Vancouver BC discussed in the previous chapter carries 60,000 vehicle trips a day. Were it redesigned to suburban (dendritic) standards, Broadway would require at least nine wide travel lanes, including three turn lanes. It operates with only four narrow through lanes, no turning lanes, and two parking lanes. The parking lanes are used for through traffic during rush hours, a double use of a lane that is common in older communities but unheard of in new ones. Left turns are restricted at many intersections to keep traffic moving smoothly. The lanes are a relatively narrow 11 feet, with a consequent curb to curb crossing distance of 66 feet, less than half the distance of the comparable suburban intersection. Crossing times for pedestrians, even the infirm, are reasonable over this distance. The remaining space is taken up by 16 foot wide sidewalks serving a continuous line of store fronts. The surrounding grid of streets provides alternative options when this intersection is congested, alternatives that do not exist in the dendritic systems. Drivers frustrated from making lefts always have the option of using the adjacent street grid to position their car on a perpendicular intersection and achieve their destination that way.

[Figure 3.5 in margin near here]

Big Boxes

Another consequence of dendritic street systems is that it favors big box developments over other more neighborhood scale-developments. When tens of thousands of trips are made through an intersection per day, the major big box chains take an interest. Their store location formulas depend almost entirely on a combination of two factors: 1) the income range of families in the service area as taken from the census data and, 2) the number of trips per day through the intersection adjacent to the site they are considering.[8] The service-area calculation is based on the distance potential customers might be willing to drive to get to the store (let's say twenty minutes). Obviously the more the public spends on a smooth-flowing, auto-oriented infrastructure the longer the radius line for the service area, the larger the potential customer base, the bigger the store and parking lot should be. In this way we see the connection between ever greater expenditure on suburban road infrastructure and ever larger stores that capitalize on this public expenditure. As more stores locate in busy commercial areas, the gravitational forces these stores exert on the system lead inevitably to congestion, as whatever capacity the system provides is used up by the decisions of big box corporations. Interestingly, Home Depot Corporation has recently changed the way it calculates store locations and size, moving to smaller stores more frequently located in the urban landscape. Why? Because increasing congestion in U.S. and Canadian cities is shrinking the distance consumers can dependably drive in twenty minutes, and as it shrinks the Home Depot "big" box is shrinking as well.

Gated Communities

Whatever one's opinion of "gated communities", they are highly compatible with dendritic systems and generally incompatible with interconnected systems. **[Figure 3.6 in margin near here]** Dendritic systems by their nature require developments to occur in pods, with usually only one access point into surrounding collectors or arterial roads. These arterials are usually unattractive and pedestrian unfriendly, ("car sewers" in the words of the *Geography of Nowhere* author James Howard Kunstler). The gate serves less to insure safety than to mark a congenial and attractive inside from the threatening and often very unpleasant exterior of the suburban arterial. Social critics often remark on the insularity and inherent inequity of gated communities, but seldom link their emergence with the dendritic street network which makes them inevitable.[9]

On the other hand, interconnected systems leave development increments that are usually too small for gated communities. Even exclusive projects located on typical five acre urban blocks cannot be truly gated, and are therefore less appropriately subject to the criticisms leveled at typically much larger gated projects in suburban dendritic street systems.

[Figure 3.7 in margin near here]

Cul-de-sacs

It is often said in defense of dendritic systems that people like the enhanced perception of safety from crime and the much reduced traffic flows in front of their houses on cul-de-sacs, and then cite these points as justification for the dendritic system. While the evidence of that is not universal there is no doubt that many people do prefer the dead end street for these reasons. **[Figures 3.8 AND 3.9 in margin near here]** It is also understandable that given the hostile environment that characterizes the arterial and even collector streets in dendritic systems it is quite rational to want to be as far upstream from these traffic impacts as possible. Unfortunately it is just not possible to design these urban landscapes such that everyone lives at the end of a cul de sac. An achievable number might be in the order of 25% of all people living on streets that serve fewer than 100 homes and their 12 trips per family a day by car (for a total of 1,200 cars past your window or one every 40 seconds). Thus those unfortunates who reside between the cul de sacs and busy arterials will have to tolerate many more cars past *their* homes than would the average resident living within an interconnected street system. Thus the advantages of the cul-de-sac are paid for to the penny by residents less fortuitously situated, proving yet again that there is no such thing as a free lunch.

Four Types of Interconnected Street Systems

Given that interconnected street systems are walking and transit friendly, reduce VMT, and are compatible with community scale “streetcar city” corridors, they are the more sustainable approach. When most people think of interconnected systems they think of the classic gridiron pattern of perfectly straight streets arranged at 90 degree angles to each other. Certainly this is the most common form, but not all interconnected streets systems are grid patterns. In addition to the grid there are at least three other identifiable and distinct but still interconnected systems: the radial system, the informal web, and the warped grid.

The Gridiron

As the name suggests the gridiron pattern is the highly uniform grid pattern of straight streets at ninety degree angles usually aligned with the cardinal axes. The pattern is most common in the US and Canada in cities built between 1850 and 1950. This block pattern is best understood as a finer grain subdivision of the larger agricultural 40 acre quarter section. Typically one 40 acre quarter section would be subdivided into two 640 foot segments in one direction and four 320 foot segments in the other, resulting in 8 blocks of 5 acres each. This pattern has two principal advantages over all others. It automatically aligns all intersections perfectly at even right angles and can be extended infinitely in all directions as the city grows. It is often criticized as dull but can be extremely dramatic in some circumstances. Manhattan, Vancouver, and San Francisco are three good examples. It is also easy to get oriented in a grid system and provides vistas to distant parts of the city or countryside down the uninterrupted visual corridors of the street. **[Figure 3.10 in margin near here]**

The Radial System

Washington DC is the best North American example of this pattern. It is a highly interconnected system but the major streets do not often align with the cardinal axes. Rather in this system the major streets typically radiate from significant squares or public monuments. Orientation is not to the north south east or west but to key landmarks in the urban fabric. Blocks are not cut evenly from the fabric of 40 acre quarter sections in this pattern, but are typically close in size to the 320 foot by 640 foot module of the gridiron. It is undoubtedly a dramatic pattern and can function as well as the gridiron. However, moving traffic and pedestrians through complex intersections where more than two main arterials intersect can be difficult. **[Figure 3.11 in margin near here]**

The Informal Web

Boston and Cambridge Massachusetts are two characteristic U.S. examples of this pattern. In the absence of the organizing grid of 40 acre squares, earlier U.S. and Canadian cities organized themselves around a web of streets that connected key villages and crossroads. This resulted in a web of major streets that connected these key locations using whatever street angle necessary. The spaces between these major connections were eventually filled in with generally rectilinear blocks, again in the natural increment of between 250 and 350 feet in width and 400 and 700 feet in length. Navigation in such a system is from one city "square" (they are seldom square) to another. For example, in Cambridge, Massachusetts the main streets connect Kendall Square to Inman Square to Harvard Square to Scolly Square etc. **[Figure 3.12 in margin near here]**

The Warped Grid

Grids don't need to be rectilinear and aligned with the cardinal axes to be grids. The grid can be twisted and warped so the streets curve, usually to match the contours of the landscape. When twisted and warped like this, the blocks will naturally vary somewhat in size. Warped grids create more opportunities for dramatic landscape features than gridirons. This form is usually associated with the romantic period in American city design with Frederick Law Olmsted as its most significant proponent. No complete American city is designed this way unfortunately. However, most cities have at least one district built in this style, usually dating from the period between the1860's and 1930 when this style was popular. The Chicago suburb of Riverside Illinois, designed by Frederick Law Olmsted and Calvert Vaux in 1868 is the most famous of these. **[Figure 3.13 in margin near here]**

Block Size

The land left inside surrounding streets is called a block. Traditional cities have blocks of about five acres including street space and between three and four if one only counts the developable land outside of the right of way. Many exceptions exist of course, notably Manhattan with its much smaller 200 foot wide by 500 foot long blocks of less than three acres each, and Portland with its extremely small but very walkable blocks of only 200 foot square, or just less than one acre each.

At the other end of the size spectrum is the suburban "super block", a large block with attributes that are a bit harder to describe and understand. Super blocks are always very large but frequently 40 acres **or more**. Super blocks are **even** as large as one square mile, the norm in Phoenix and much of Florida. **[Figure 3.14 in margin near here]** Whether blocks are 200 feet wide urban scale, or a quarter mile or full mile superblock scale, blocks are still defined as the land inside a **continuous** surrounding road. Developable land inside the large super blocks most often requires additional streets to access interior parcels, so they result in dead end **i**nterior road networks that could connect across the block but don't. In the case of Phoenix almost all of the streets on the one mile grid serve a variety of essentially gated complexes inside the one mile squares. The result is a city where the through streets on the one mile grid are all heavily loaded with traffic and generally incompatible with pedestrian friendly commercial uses. They simply accept too much traffic load from the interiors of the one mile superblocks they serve.

Why is the Interconnected System Better?

Trips on an interconnected street system are more efficient and shorter than those on the artificially lengthy and circuitous denditric systems. A five minute walk covers much more ground in interconnected street systems—easily as much or more than twice as many total acres—making it much easier to provide services or recreational amenities that are accessible without a car. If an intersection in an interconnected system is congested, parallel streets allow for "rat running", obviating the need for expensive intersection widening and associated expensive property takings. While residents don't like "rat running" it occurs only during times of peak congestion, can be slowed, and is much less damaging to neighborhood quality and much less expensive than adding lanes to main intersections. Interconnected street systems are also safer for pedestrians. A landmark study by Peter Swift determined that pedestrian injuries were four times more likely on wide dendritic suburban streets than on typically narrower interconnected urban streets (street width issues are discussed below).[10]

Finally, it must be admitted that arterials in interconnected systems must be designed for slower speeds than in dendritic contexts. This is because frequent intersections are an elemental feature of interconnected systems and the streetcar arterials that serve them. This frequency of intersections requires that the streets be designed for lower average speeds and that stops be more frequent. Thus under ordinary circumstances a suburban arterial will deliver drivers faster to their destinations than will a more traditional streetcar arterial street. Here suffice it to say that slower average speed in a system that resists congestion and is compatible with urban uses is probably a good thing, not bad. As mentioned above, the Home Depot decision to downsize their stores is instructive. As speeds are slowed in a system, the scale of enterprises shrink with them. If our objective is to reduce distances between desire points it would seem that a strategy which allows for smooth flow but not necessarily fast flow has a certain utility value.

The superblocks created by the denditric system have the advantage of excluding through traffic across the block, provide more options for parcel configurations inside the block, and require less road length to serve parcels than gridirons. On the other hand, by blocking through movements across the block they force traffic onto arterials and overload arterial intersections, prevent congestion flows from exercising any optional routes, make pedestrian trips frustratingly indirect, provide bicycles no option but to compete with cars and trucks for road space on the arterials, and degrade the value of parcels fronting arterials for pedestrian friendly commercial use.

Traditional smaller urban blocks are much more permeable for both car and pedestrian traffic and allow for more frequent “streetcar” arterials (Vancouver for example has a streetcar arterial every half mile on average, which means that you are never more than a five minute walk from a commercial “streetcar street”).The distribution of traffic and the more frequent provision of streetcar arterials within walking distance make this form inherently more compatible with a strategy to promote transit, biking and walking. For example, bikers who are not enthusiastic about keeping pace with traffic on the arterials can take advantage of the parallel street network for a safer and slower ride without sacrificing directness. Vancouver has a very successful network of designated bike streets that typically run parallel to the streetcar arterials.

Parcel Size

Block size of course determines the range of parcel sizes possible. It is remarkable that in cities like Seattle or Vancouver every single land use has somehow been fit into parcels that fit inside traditional 660 x 330 foot blocks. Accounting for lanes this means almost all development parcels in the city are less than two acres in size. Thus 40 story towers and single family homes and everything in between have been fit onto the same size block. So while block size will limit the range of parcel sizes and types, it is astonishing to see how many different ways they have been designed and utilized.

Single-family Home Parcels

The most pressing issue in sustainable urban design is probably the single-family home parcel. This parcel type has been the driver for many if not most of the symptoms of illness described in chapter one. Some have argued that the single-family home is anathema to sustainability and should be eliminated entirely. Yet the desire for single-family homes remains very strong and it is unlikely that this will shift dramatically in the next few decades, despite ups and downs of the real estate market. Fortunately there is a way to configure the single-family parcel that is compatible with sustainable community design and that is by building on the small lot. Traditional streetcar cities were largely organized around small single-family home lots, in neighborhoods that are pedestrian friendly and where options to the car exist. **[Figure 3.15 in margin near here]** The secret is the 3,630 square foot lot. Virtually all lots in Vancouver are 33x110' **[Figure 3.16 in margin near here]**. At this size the lot yield is about 32 lots per block. The gross (inclusive of street space) density of the block would thus be approximately 6 to 7 parcels per acre. Since duplexes and secondary suites are allowed throughout the city the density, when computed in dwelling units rather than parcels, is typically over 10 units per gross acre. Our analysis of two traditional Vancouver blocks that appeared to be all single-family homes, actually had a density of over17 units per gross acre.[11] The secret was that most of the homes actually had a hidden secondary suite and some of the homes contained three units. By using small lots for detached homes it is easily possible to preserve the single-family home option, and certainly the single-family home "feel" of the street, and still create sustainable communities. Single family home lots can be as small as 2,500 square feet if the footprint of the new home is small and the home is high rather than wide or deep. This issue is discussed further below under the "different dwelling types on the same street" principle.

Ideal Block and Parcel Size

Various arguments have been forwarded favoring the small "Portland Block" (200 feet by 200 feet street center line to street center line) for its abundance of corner opportunities and its walkability. **[Figure 3.17a and b in margin near here]** The longer but equally thin "Manhattan Block" has been promoted for similar reasons. However, those two blocks have very shallow parcels, never deeper than 80 feet, tightly constraining the building form options available and making it almost impossible to provide lanes in the middle of the block for service and secondary access. For this reason Portland residential neighborhoods are afflicted with driveways that cross sidewalks every house lot, compromising the safety and comfort of the sidewalk and eliminating at least a third of on street parking spots. In downtown Portland, lacking lanes, all loading and delivery must compete for space with pedestrians on the sidewalks. The same is true in Manhattan. Conversely, in Vancouver and Seattle, where blocks are the more common

640 x 320 foot increment, parcels can be over 110 feet deep, even after subtracting 20 feet for the rear lane. These somewhat larger blocks have provided suitable footprints for the proliferation of new condominium high rise buildings for which Vancouver is now famous. Ideally these towers should be between 60 and 80 feet square. Any smaller and they are uneconomic, any larger and they are too fat to get natural light into the core of the building (not to mention ugly). The point tower on the podium base pioneered in Vancouver would not have been possible on a much smaller or much larger block. Indeed, in Portland where new tower developments are now coming on line, the smaller block is creating a trend toward single building blocks, were a whole block is occupied by one podium building of about 150 feet on a side and a usually somewhat fat tower in the middle of the base. **[Figure 3.18 in margin near here]** While some good results are possible with this form it tends to predetermine design outcomes more decisively than the larger Vancouver block and would in time lead to a city of single buildings surrounded by a square of streets; probably not a good thing. **[Figure 3.19 in margin near here]**

In residential areas, the larger Vancouver block allows for a rear lane to keep driveways from crossing sidewalks and the front façade of homes free of garage doors. Narrow lot homes have many advantages but most of them are compromised if half or more of the frontage is given over to wide driveways and garage doors. The phenomenon of the “snout house,” a house that is all garage and no façade to the street, is common in California for this reason, where small lots are popular but rear lanes are not. **[Figure 3.20 in margin near here]**

Finally, the deeper lot allows many creative options for the site, including front to back duplexes and lane houses, and/or generous rear yard gardens.

There is a limit to how deep the lot wants to be however, and thus how wide should be the block. If blocks were 400 feet wide rather than 320 feet you gain rear yard space but would end up with no additional frontage, and thus fewer 33' wide parcels per gross acre.

What about block length then? Here there is more flexibility. The breaking of the quarter mile into two even 640 foot increments makes a certain intuitive sense and has proven itself to be walkable, but it is by no means a universal increment. One can reduce the length down to 400 without tremendous loss in land use efficiency or up to 800 before the blocks become a very serious barrier to easy pedestrian movement or start to compromise the overall permeability of the system.

Road Width

No single feature of sustainable community design is more important than road width. Prior to 1940 most residential streets in the U.S. and Canada were less than 28 feet, measured curb face to curb face. **[Figure 3.21 in margin near here]** Most of these streets allowed parking on both sides of the street in seven foot wide parking lanes. This left only 14 feet of travel lane in the middle to handle two-way traffic. The typical car is about six feet wide, so two cars approaching from opposite directions, on a street where cars are parked on both sides, are going to have to go quite slow to avoid hitting each other. This presumably unsafe condition motivated a change in standards after 1950, when typical curb to curb width became 34 feet, comprised of two 10 foot travel lanes flanked by two seven foot wide parking lanes. This width allowed free flow of two way traffic without the need to slow down when cars approached from opposite directions. As time passed, many municipalities decided it would be a good idea to widen residential streets even more, allowing additional space for parking and travel ways such that 40 foot wide suburban residential streets are found in many parts of North America.

There have been a number of unanticipated negative consequences associated with this road-widening trend. Most surprising is that streets that were made wider to be safer turned out to be much more dangerous. A study by Peter Swift associates, *Residential Street Typology and Injury Accident Frequency*, found that wide suburban residential streets were associated with four times more pedestrian deaths per unit population than were narrower traditional urban streets. How can this be explained? The answer appears to be induced speed. Pedestrians hit by cars traveling 35 miles per hour are ten times more likely to be killed than pedestrians hit by cars traveling 20 miles per hour. Wider suburban streets designed to allow two free flowing two way traffic and generous parking strips signal drivers that it is ok to travel at speeds much higher than narrower traditional streets.[12] This phenomenon is even more extreme when one considers that the parking strips on most suburban streets are rarely used since these landscapes also include generous driveway space. Thus drivers are provided with as much as 40 feet of clear width to command when driving. Even when these streets are posted with 20 mph speed limits, as they often are, it takes a tremendous act of will to slow to that apparent crawl when the freeway scale generosity of the road width invites speeds twice that fast.

It took decades for the engineering community to begin to come to grips with this phenomenon and to coin a term to describe it. The term is “side friction”.[13] Traditional urban streets have high side friction because the travel way is too narrow for passing oncoming cars at speed, the abundance of parked cars on both sides, the trees in the boulevard, the pedestrians on the sidewalks that one may or may not be able to see behind the cars and trees, all of these things conspire to create an atmosphere of uncertainty and caution in the mind of the driver. **[Figure 3.22a and b in margin near here]** Thus the driver responds by driving slow, no matter what the posted speed.

Alternatively, wider suburban streets have low side friction. The travel way is generous enough to pass oncoming cars at speed, parked cars are rare providing an even greater enticement to move quickly, and nothing is hidden from the driver's field of view by trees. All of these things conspire to psychologically license the driver to feel safe at speeds much higher than those posted. Increased pedestrian fatality is the result.

Fire Access

Pedestrian and auto safety were not the only motivations for wider streets. Fire access was a powerful motivation as well. **[Figures 3.23 and 3.24 in margin near here]** The average size of fire trucks in the U.S. and Canada has been steadily increasing. It is common for ladder trucks to require 15 or even 20 feet of street width to set up stabilizer arms extending from their sides. Concerns about the need to speed to the scene of a fire can lead to demand for 13 foot wide travel lanes in both directions on even short cul-de-sac roads that serve only 20 to 30 homes. A similar concern about cornering at speed can lead to standards for corner curb radii so generous as to seriously lengthen pedestrian crossing distances at intersections and thus compromise their safety.

[Figure 3.25 in margin near here]

Sadly but predictably the increased width in these standards has not led to enhanced safety. The Peter Swift study mentioned above also found no difference in fire-related fatalities when comparing districts with narrow streets to those with wider ones. More depressing still were the results of a study on fire response times in the Boston metropolitan area. **[Figure 3.26 in margin near here]** The study found that response times became dangerously long as one moved away from older streetcar city districts to the suburbs – in exactly those same suburban communities where wider streets were required. It seems that whatever fire-safety benefits were achieved with wider streets, were far outweighed by the difficulty of getting quickly and directly to the fire via circuitous dendritic road systems. Given the overall low density of these landscapes, there isn't sufficient tax base to build fire stations within a short distance of all homes.[14] In other words, an urban service area for a fire station serving 20,000 people might be one square mile. In suburban areas the same population might be spread out over twenty times more land, and thus the fire station serving the area would be further away from homes. This of course suggests a larger contributing symptom to the disease of our unsustainable metropolitan areas. Fire officials are typically called upon to speak only to issues of road width and design. Seldom if ever are they asked to speak to the larger issues of density and interconnectivity—issues which seem more significant to their mission when the operation of the entire urban system is examined.

Queuing Streets

From this evidence it seems that the traditional 26 to 28 foot residential street in an interconnected system is better after all. This kind of street is now called a "queuing" street, a somewhat misleading name that tries to signify that one approaching car will typically pull over (take turns as in a queue) into an empty parking space to allow the other to pass. **[Figure 3.27 in margin near here]** Coupled with short blocks and frequent stop signs, a queuing street is a more effective traffic calming strategy than speed bumps. It saves pavement, and makes for a much more attractively scaled pedestrian-friendly streetscape. A recommended right of way for a sustainable queuing street, capable of handling a large number of car trips but at speeds compatible with pedestrian and bike safety is as follows: 6 foot sidewalk, 10 foot tree boulevard, 7 foot parking lane, 14 foot travel way, 7 foot parking lane, 10 foot tree boulevard, 6 foot sidewalk. All of this fits within 60 feet, which happens to be the most common right of way width found in streetcar city residential districts. Developers will often want to reduce right of way widths even more, to increase the proportion of lands available for sale in comparison to lands reserved for public right of way. Some narrowing can occur in the tree boulevard and sidewalk to get the right of way width below 60' but it is not recommended. Wide sidewalks on both sides are crucial for walkable neighborhoods (presuming destinations have been preserved and created) while tree boulevards, in addition to being beautiful, provide protection for walking and space for green infrastructure as described in chapter seven.

The Corner

Like all elements of street design, intersection design is far more complex and contentious than one at first imagines. But to radically oversimplify, the challenge is to reconcile the issue of moving large vehicles around corners with the need to safely and comfortably get pedestrians across them. The two are in conflict. Fire safety and school bus vehicles, the vehicles that will most often be invoked when setting performance standards for turning motions, have long wheel bases and thus corner more easily when there is a wide radius curve to navigate round. But wide radius curves at corners shave off sidewalks right where you need them most, where people need to stand and look before crossing. Most jurisdictions apply minimum standards for turning radius based on the needs of fire trucks and school busses rather than the needs of pedestrians. As with any other standard, turning radius requirements are seldom absolute, even though they are often presented as if they had legal standing. Municipalities are free to set their own standards even if they digress from practices adopted by the majority of other municipalities, *if* they have a reasonable rationale and their decision has been exercised in an atmosphere of due diligence.[15]

One very effective way to satisfy both the fire truck turning demand with the pedestrian safety demand is by using “neck downs”. Since cars are always prohibited from parking near intersections this space can be given over to sidewalk and boulevard uses. Curbs are extended further towards the center line of streets eliminating the parking bays and allowing for 20 foot curb face to curb face distance used exclusively as a two way travel lane. Changing to a two way travel lane from the 14 foot queuing street is required to allow space for turning or approaching cars to easily fit next to a car that may be waiting at the stop sign. Thus the recommended cross section at the neck down would be 6 foot sidewalk, 14 foot boulevard, 20 foot travel way, 14 foot boulevard, 6 foot sidewalk for a total of 60 feet. The much wider boulevard provides a more generous area to shave back with the radius curve that might be required by fire trucks or school buses. It also pushes the pedestrian safety zone further out to the center line of the street and shrinks the crossing distance. Streets with neckdowns cost more than streets without them however. The additional cost is for the extra curb (if supplied) and the frequent need to double up on storm drain inlets. If neckdowns are absent, proponents of sustainable design should be sure that engineers remember the existence of the parking lane and that measurement of the radius curve is not from the edge of the curb but from the edge of the travel lane. **[Figure 3.29 in margin near here]** Figure 3.29 provides one common configuration for a residential street with neckdowns in place with a radius that has been tested against the longest school bus wheelbase known to man. Of course school buses are both a symptom of the problem (no one walks to school) and a geometric demand that makes it worse (everything must be designed to conform to their monstrous proportions). But here suffice it to say that the school bus issue is just one more example of how intricately nested all of the elements are that conspire to make our new communities unhealthy.

Lanes and Alleys

Most North American cities built primarily between 1850 and 1950 have blocks equipped with rear lanes (I use the term lanes to refer to both rear lanes and what are known as alleys in many jurisdictions). After 1950 when lot frontages increased from 33 to 50 feet or more, lanes were generally no longer required. At a width of 50 feet, there was enough space out front to get the car in and still have a space for the house façade. After 1950 lanes were considered unfashionable to buyers, and developers were understandably unwilling to pay money to provide two public access ways—the street and the lane—to every parcel. Some jurisdictions, notably Calgary, continued to require lanes in more modern suburban areas to preserve utility and fire access, but most did not.

Recently the rationale for lanes has been strengthened. After nearly four decades of steadily increasing lot sizes, starting in the 80s they began to shrink. For two decades the average house lot size in typical middle class subdivisions had been steadily shrinking back toward the original standard 3,300 square foot lot.[16] As average lot sizes shrink the rear lane makes sense again. When lots get this small there are only two choices. They can be configured wide and shallow with frontages over 45 feet but depths of only 73 feet. This leaves room on the façade for the one or two car garage but precious little for the back yard, putting rear windows of houses within 40 feet of each other.[17] The other problem is that driveway curb cuts will occur every 40 feet and be about 20 feet wide meaning 50 percent of the front yard space and street edge will be consumed by driveway, covering nearly half of the front yard space with impervious surfaces and cutting the number of parking spaces on the street by nearly 50%.

The other option is the narrow deep lot with a lane. A 33 foot 3,600 square foot lot is 110 feet deep. This lot requires a lane to avoid the "snout house" effect, where streets are all garage doors and no facades. Installing the lane steals 20 feet from the middle of the block of course; but it eliminates the need for driveways of any kind and therefore does not add to the total amount of pavement required per block. Unfortunately it adds to the *developer's* costs. Typically street infrastructure is installed by the "horizontal" developer who buys the land, subdivides it, and sells off lots to the "vertical" developer or the house builder. If lanes are installed they are a cost to the horizontal developer. If there are no lanes then the cost of the necessary driveways is off-loaded to the vertical developer.

For this and other reasons it can be very difficult to work through the geometric, cost and amenity trade-offs associated with lanes. Fear of crime is often cited as a reason to avoid them, even though in the City of Vancouver we find no correlation between crime rates and the presence or absence of lanes. Municipalities are often averse to lanes for maintenance reasons as well, feeling that it is hard enough to take care of streets without the added responsibility of publicly owned lanes. For this reason many developers who see the attraction of lanes but have fought a losing battle with municipalities to get them accepted as city land will be offered the option of privatization. A city will often refuse to accept ownership of lanes but may approve them if they remain a private responsibility, to be managed and cared for by a neighborhood association. Neighborhood associations, increasingly common in many states and provinces, have neighborhood wide taxing authority (in the form of required association fees enforceable via liens on property) and assume the responsibility for maintenance of all common infrastructure. The political trend, particularly strong in the US, towards citizen initiated voter initiatives to cut local taxes, has forced municipalities to off-load as many formerly city borne costs as possible. Typically any digression from standard street designs will trigger an opportunity for municipalities to suggest developers privatize streets, shifting the cost of perpetual maintenance to the homeowners. Whether the privatization of urban public realm infrastructure is a good or bad thing lies beyond the scope of this book. The important point here is that any discussion of lanes in municipalities that don’t presently allow them is likely to trigger a move to privatize the street system of the proposed development. Citizens and developers should be prepared for this. The tendency of cities to capitalize on any proposal to improve the sustainability of streets as an opportunity to off load costs constitutes a huge disincentive to more healthy urban infrastructure and is yet another in an all too lengthy list of cultural impediments to healthy change.[18]

Greenhouse Gas and Street Pattern

Street pattern has been conclusively tied to increases in GHG production per capita.[19] An interconnected street system inherently reduces trip length, as all trips in robustly interconnected street systems are necessarily by the shortest practical route. When combined with a reasonable minimum residential density of 10 dwelling units per acre, and a fine grain distribution of land uses such that commercial areas and frequent transit are within a five minute walk, per capita GHG production will be reduced by at least 40%. Of perhaps greater significance, neighborhoods with interconnected streets and the proper land uses are already walkable. If a gradual shift is to be made away from auto dominant transportation, these areas are “pedestrian ready”. But in districts with dendritic street patterns (which now cover close to 60% of the North American urban landscape) and widely distributed land uses, it seems impossible for a similar shift to occur. Certainly during periods where gas prices rose quickly, such as 2007, we saw immediate reductions in car use there, but not in car dependence. While residents in areas already served by frequent bus service and walkable design shifted significantly away from car use, residents in auto oriented districts had fewer options. There reductions were achieved by chaining errands, by car pooling to work, and by forgoing weekend family trips. If fuel prices rise as dramatically as is likely in the next ten years, then residents of suburban districts are in for a very rough ride.

But fortunately vast areas of our suburbs are available for retrofitting as complete communities. Most of these lands located on the many auto-oriented arterials that lace these landscapes. Recent dramatic disruptions in global real estate markets have led to the collapse of many of the financial underpinnings of the suburbs, from the economics of strip commercial to the value of McMansions. Certainly the lowest hanging fruit in suburban locations are the hundreds of miles of strip commercial arterials, where commercial projects are fast approaching the end of their useful life and often lie abandoned. These strategically located parcels, close to transit and potentially walkable, are logical locations for intensive densification. Suburban arterials are usually still arranged as some form of grid, usually rectilinear and at half to one mile increments. Whatever new investment occurs in these regions should logically occur on these accessible and geographically well situated arterials, especially given that the demographic forecasts for most metropolitan areas showing a huge new demand for housing for older citizens.[20] Infilling presently underutilized arterials for mixed use transit streets and housing for this burgeoning demographic seems the only possible way to capitalize on our previous investments, meet our housing needs, and retrofit our suburbs for low GHG production. By adding density to these formerly commercial locations the level of land use activity can as much as double adding customers for local services, workers for new jobs, and riders for transit.[21] Through this strategy the land use elements of the streetcar city can be put in place with the expectation of eventual synergy between land uses and transit choices as described in the previous chapter. The market is already confirming the practicality of this trend. The market for “closer in” transit accessible homes in walkable urban locations has been much stronger, in relative terms, than for outer ring residential zones during the first decade of the 21st century than any time since the 40s.[22]

Conclusion

It's a simple idea: interconnected streets good, dendritic streets bad. What gets complicated is unpacking all the unhealthy habits that conspire to block a logical return to interconnected worlds and neighborhood health. The interconnected street system is the very armature of a healthy urban landscape. Preserving interconnectivity in areas where it exists and finding ways to build it into areas where it has been frustrated should always be part of the therapy. In new suburban developments of 40 acres or more, interconnectivity should be a first principle, even if this results in a small island of connectivity in a sea of dendritic pod development. Many New Urbanist projects hold firm to this principle even though the value of internal connectivity is limited in such a context, and good on them. But a 40, 60, or even a 200 acre area of interconnected street systems will do little to reduce VMT if the surrounding area is still dominated by the dendritic road hierarchy. Once you reach the edge of your walkable world you are still stuck needing a car. Thus, a willingness of developers to produce walkable neighborhoods is futile unless policy makers responsible for the larger landscape address rules governing the development of the larger transportation pattern, and find ways to insure that the regional street system stays interconnected.

Portland, Oregon again provides a good example for how to do this. Portland's Metro Planning Council is working hard to impose an interconnectivity standard requiring a through street at least every 600 feet. The brilliance of this standard is its simplicity. It represents a measured and reasonable requirement from the public sector, insuring the public good is represented while not unduly proscribing the actions of the development community. It would lead inevitably to some set of patterns that would emulate the function of the traditional North American 640 x 320 foot block, and the streetcar city districts within which they were situated. Finally it creates a policy framework where individual projects with interconnected internal systems can be integrated into an interconnected whole, allowing new projects to be *extensions* of a predetermined systems, rather than mere *subdivisions* of discreet parcels of land.[23]

Of all the challenges presented in this book getting the street system right may be the most daunting. Once a street is in place it is almost impossible to change. Rome, Italy is a brilliant example of this, where buildings have been built and then destroyed many times on the same parcel, while the streets have stayed the same. While there is still time to adopt a more reasonable standard for necessary *new* development, existing suburban areas dominated by dendritic street systems will always remain obstacles in the way of cutting car dependence, and the greenhouse gases that this inevitably generates. Wherever large areas of dendritic streets exist, ways must be found to mitigate their failures, notably by capitalizing on the latent capacity of arterial strip commercial streets. Wherever existing interconnected streets exist they must be protected and fortified with increased activity. Wherever opportunities for appropriate new Greenfield development exist they must be designed with interconnected streets with an eye toward re-creation of the streetcar city form that has served us so well in the past.

[1] A gridiron street system typically has a greater number of intersections than a dendritic street system. **[Figure 3.2a and b here]**

[2] The street hierarchy was first elaborated by Ludwig Hilberseimer in 1927 and has since prevailed as the dominant model for suburban development (Ford 1999). Between 1930 and 1950 residential street standards became institutionalized by the Federal Housing Administration (Southworth & Ben-Joseph 1997) and by the late 1950s the "normal" suburban street network was dominated by cul-de-sac streets within vast areas of single use residential zoning (Ford 1999).

[3] A key objective of the Salem Transportation Plan (2007) is to "develop a comprehensive, hierarchical system of streets and highways that provides for optimal mobility for all travel modes." This is to be achieved through the creation of a street network made up of: peripheral arterial streets linking outlying districts to each other and the central core area; collector streets that connect local traffic to the arterial system and; local streets that provide property access and neighborhood circulation (Salem Transportation Plan 2007). This is a community that otherwise encourages alternatives to the car and sustainability. The contradictions between the street regulations and the broader sustainability goals are not recognized here in Salem, Oregon or in most other jurisdictions in the U.S. and Canada.

[4] Recollection of author who participated in these meetings.

[5] Allen, Eliot. 1996. "Benefits of Neotraditional Development." Criterion Engineers and Planners, Portland, Oregon.

[6] Contemporary suburban street patterns are characterized by wide spacings of arterial streets that typically provide six through lanes, right turn lanes, and single or dual left turn lanes (Levinson 1999). In his report *Traffic Circulation Planning for Communities*, Marks (1974) specifies that arterial streets should be spaced one mile apart, accommodate 10,000-30,000 vehicles per day, feature 4-6 lanes with a physical median, turn lanes, signalized pedestrian crossing and have considerable building setbacks. On-street parking is prohibited and pedestrian use is meant to be minimal.

[7] Between 1980 and 2000 the number of workers that walked to work decreased by 1,654,000, and the modal share dropped from 5.6 percent to 2.93 percent (Pisarski, 2006). Between 1997 and 2006 pedestrian fatalities declined by approximately 10% (NHTSA, 2008). Despite this decline walking is by far the most dangerous mode of travel per mile. In 2001 the fatality rate per 100 million miles traveled for public transit riders was 0.75, for drivers and their passengers it was 1.3 but for walkers it was 20.1 (Ernst, 2004). From 1997 to 2006 over 66 percent of pedestrian fatalities occurred on principal and minor arterial roadways (NHTSA, 2008). Miles-Doan and Thompson (1999) state that "the long-range solution to the arterial road safety problem begins with reevaluating the planning practice of designing urban arterials as traffic-moving facilities and nothing else." Typically, pedestrians who want to cross arterial streets need to contend with several lanes of traffic making a variety of movements at street intersections. The City of Orlando Transportation Planning Bureau (2002) found that when these discouraging conditions are minimized, by reducing road width, the number of pedestrians crossing the street increased by 56 percent.

[8] Hahn (2000) looked at two case studies of agglomerated big box retailer developments that were thought to be representative of the industry as a whole and found that in both cases the developer chose a location adjacent to a high traffic intersection and in an area where the average household income was above the national average.

[9] Kunstler, J.H. 1993. The *Geography of Nowhere: The Rise and Decline of America's Man-Made* Landscape. New York: Simon & Schuster; Kunstler, J.H. 2005. *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century*. New York: Atlantic Monthly Press.

[10] Swift, Peter, "Residential Street Typology and Injury Accident Frequency." (Longmont, CO: Swift and Associates, 1998).

[11] This study is available online at: http://www.jtc.sala.ubc.ca/projects/ADS/HTML_Files/ChapterTwo/matrix_us_2.htm

[12] Swift, Peter "Residential Street Typology and Injury Accident Frequency" (Longmont, CO: Swift and Associates, 1998).

[13] The first mention of the term "side friction" seems to be in 1936 in a paper for the Highway Research Board (Barnett et al. 1936). Sources in the 1940s and 1950s continue to use it within a highway context (Barnett 1940; Holmes 1958) however, understanding how the concept applied to residential streets took far longer.

[14] Bill Dedman (January 30, 2005) writes in an article for the *Boston Globe*, "Few communities in Massachusetts are adding firehouses to serve new subdivisions" resulting in slower response times, which frequently result in deaths. Communities of all income levels are facing these problems."

[15] Local levels of government generally have a great deal of input when it comes to the adoption and implementation of design standards. In Oregon for example, land use laws allow local governments to establish local subdivision standards for street widths that shall "supercede and prevail over any specifications and standards for roads and streets set forth in a uniform fire code adopted by the State Fire Marshall, a municipal fire department or a country firefighting agency" (Neighbourhood Streets Project Stakeholders 2000). Organizations like West Coast Environmental Law advocate and empower local governmental agencies to adapt their standards and guidelines to be more in line with social and environmental perspectives (West Coast Environmental Law 2002).

[16] In 1976 the median lot size of new one-family houses sold in the United States was 10,125 square feet. In 2008 it was 8,854 square feet (US Census Bureau, 2009). **[Insert Figure 3.28a and b]**

[17] For more information on the relative benefits of providing lane access versus driveway access for family cars owned by residents of homes on small lots see the James Taylor Chair in Landscape and Livable Environments Technical Bulletin No. 7, January 2001 available online at: http://www.jtc.sala.ubc.ca/bulletins/TB_issue_07_Lot_edit.pdf

[18] The City of Chicago's Green Alley program is a notable exception to governmental resistance to alternative infrastructure. The program began in 2006 as a pilot and as of 2008 more than 80 Green Alleys have been installed with permeable pavement, catch basins and high albedo, recycled materials.

[19] Ewing, Reid, Keith Bartholomew, Steve Winkelman, Jerry Walters, and Done Chen. 2007. Growing Cooler: Evidence on Urban Development and Climate Change. Chicago, IL: Urban Land Institute; Burchell, Robert, Anthony Downs, Barbara McCann, Sahan Mukherji. 2005.*Sprawl Costs*. Washington DC.: Island Press; Patrick Mezza and Eben Fodor, 2000, "Taking its Toll: The Hidden Costs of Sprawl in Washington State" (Seattle, Washington: Climate Solutions); Todd Litman, 2001, "Land Use Impact Costs of Transportation, (Victoria, BC: Victoria Transport Policy Institute).

[20] Berlin, Ryan, Andrew Ramlo and David Baxter. 2006. "Seniors' Housing Demand in British Columbia over the Next Thirty Years." Urban Futures Report Number 65, January 2006.

[21] Between 2001 and 2056, the average persons per household is expected to drop from 2.6 to 2.3 and the percentage of households with children in the region is expected to drop from 41 percent to 36 percent. Given these trends, and the existing supply of ground oriented housing, by 2056, ground oriented single family units are expected to constitute only 15 percent of new dwelling units in the region (Design Centre for Sustainability 2006). Research recently conducted by the Design Centre for Sustainability found that using mid-rise mixed use development along existing corridors and higher density around

key nodes, Vancouver could accommodate over 360,000 new dwellings within the existing infrastructure of the city (Condon and Belausteguigoitia 2006).

[22] Leinberger, Christopher. “The Next Slum?” *The Atlantic,* March 2008; Dunham-Jones, Ellen and June Williamson. 2008. *Retrofitting Suburbia*: *Urban Design Solutions for Redesigning Suburbs*. New York: John Wiley and Sons Ltd.

[23] Prior to WWII cities commonly predetermined a simple road network geometry that developers were bound to follow. Gridded street systems, classically laid out as numbered streets in one direction, and numbered avenues in the other (as in Manhattan), could be easily completed incrementally by *extension*. As each new development occurred, developers would simply *extend* whatever street ends were at the edge of their parcel across it, making the same streets ready for attachment when adjacent parcels were later developed. Gradually after WWII the extension system was replaced by the *subdivision* system, where typically developers were not required to extend a predetermined road system, only to attach their internal road system to an existing arterial. The *subdivision* system is thus part and parcel with the hierarchical , dendritic road system pattern, and incompatible with an interconnected street system pattern. To effect long term interconnectivity into our new and retrofitted districts will require a return to something akin to the land extension system employed extensively and ubiquitously throughout the early 20th century.