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1. INTRODUCTION

Theories of New Urbanism and Smart Growth usually point at accessibility as one of their most significant principles. Although they are similar in some ways accessibility and mobility are different concepts. Accessibility is defined as the ability to connect activities while mobility is a measure of the vehicle-miles or person-miles involved in travel. In most cases higher values for mobility could be an indicative of congestion whereas increasing accessibility is associated with reduction of congestion.

Finding efficient street configurations for sustainable developments in suburban areas is basically an accessibility problem. If street configurations are made in such a way that they provide effective intermodal access to a significant portion of the population, it will make developments more livable and sustainable in the future. Attempting to forecast accessibility or street patterns for the year 2050 is quite difficult since they depend on many other factors that nobody cannot control or predict. Instead it is better to set some goals for the future looking at past experiences and current trends.

Accessibility could be as broad as one can imagine. This chapter will focus on suburban developments and two specific accessibility issues: street spacing and connectivity. These topics can be controversial. For example, some people may think that having two lane arterials spaced every ½ a mile will be the best solution for solving problems of congestion while others would prefer four lane arterials spaced every mile. Likewise, providing a street layout that improves connectivity will generate a number of benefits, such as encouraging bicycle and pedestrian trips and decreasing vehicle miles, but critics state that the problem of congestion remain unsolved because increased connectivity attracts more trips to the network.

2. GOAL

The goal of Transportation Accessibility is to find the most efficient way to connect our origins and destinations, provide street designs that promote different modes of transportation, reduce congestion and create livable neighborhoods with sustainable transportation.
3. STREET CONNECTIVITY

“Over the past century American conceptions of the residential street network have changed dramatically from the interconnected rectilinear grid of the turn-of-the-century, to the fragmented grid and warped parallel streets of the 1930s and 1940s, to the discontinuous, insular patterns of cul-de-sacs and loops that have preferred since the 1950s.”\(^1\) However, it has been demonstrated that grid design, known as Neotraditional Design, and cul-de-sacs, commonly referred as Conventional Design, have both advantages and disadvantages. An efficient street design should be developed to satisfy the needs of society by taking the benefits of these two concepts.

Figure No 1

3.1. Institutionalization of Standards

In 1936 the Federal Housing Administration (FHA) confirmed its preference for a hierarchical structure in street layouts by the publication of standards that encouraged curvilinear, cul-de-sacs and courts layouts. At the same time the FHA criticized the conventional grid pattern for residential neighborhoods commonly used up until that decade because of the monotony and elevated costs of its construction.

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The following standards were taken from publications of the FHA by that time:

- Layouts should discourage through-traffic;
- Streets should follow the topography to reduce costs, create interesting vistas, and eliminate the monotony of long straight rows of houses;
- Cul-de-sacs are the most attractive street layout for family dwellings.

The idea of the new street pattern was to locate convenient stores on the neighborhoods edges along arterials, whereas schools and common areas in the middle.

Later in 1965 the Institute of Transportation Engineers published a paper “Recommended Practice for subdivision Streets” aimed to increase standards of livability. This paper continues ideas of the Federal Housing Administration in 1936, where they criticize grid patterns and support the idea of cul-de-sacs and curvilinear street designs. Some of these principles were as follows:

- Local streets should be designed to discourage excessive speed through the use of curvilinear patterns and discontinuities.
- There should be minimal intersections with preference for T rather than four-leg intersections.
- Local streets should be related to topography.  

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² Southworth / Ben Joseph, pg. 93
3.2. Comparison of Street Patterns

Although several variables must be included in a comprehensive comparison of streets patterns, this analysis will emphasize on certain factors that differentiate the Neotraditional and the Conventional Designs in terms of connectivity. Accidents, social benefits and economics issues will be briefly described only as a reference.

- Traffic Capacity

Improving connectivity in a network not only makes origins and destinations closer to each other, which is obvious, but also increases traffic capacity.

Different authors have mentioned that NTD has superior traffic capacity over Conventional Designs arguing that traffic capacity in a given network depends almost entirely on its intersections rather than on the capacity of the streets. The increasing number of intersections available in the NTD makes traffic volumes to spread out in a more uniform manner throughout the entire network and therefore only a small portion of the total volume concentrates at a particular intersection.

Walter Kulash brought up the following example at the 11th Annual Pedestrian Conference in Bellevue WA to better understand the difference between Neotraditional and Conventional Street Designs in terms of capacity.

(Photos and Caption, ENR, May 9, 1994.)
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Due to the lack of access points in the Conventional Street Design large traffic volumes meet at intersections which commonly have a four-lane divided and six-lane divided arterial street: each having left-turn lanes and protected left-turn signals.

If we assume a traffic volume of 3000 vph on the six-lane street and 2000 vph on the four-lane street, and turning movements of 300 and 200 vph, respectively, for the major left turn movements, the intersection would be operating at upper limit of level of service E. The same traffic volume on the same amount of pavement can be accommodated by a pair of two-lane streets intersecting three parallel two-lane streets.

As it is shown in the figures one single intersection in the Conventional design is replaced by six intersections in the TND using the same number of lanes.

“This large number of intersections reduces the turning movement load at any given intersection to a fraction (one-sixth in this example) of the turning movement load that exists in the Conventional Suburban Development Pattern. Consequently, the entire system can carry greater traffic volumes at the same level of traffic service.”

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If it is true that traffic capacity is function of the intersections capacity at the same time the critical point in intersections capacity is the number of left turns that go through the intersection in a certain period of time.

The increased number of intersections in the TND provides numerous opportunities for a particular driver to make a left turn. In reason that the traffic is spread out in the network left turns can be easily made using acceptable gaps provided by the opposing traffic flow.

Advantages for turning movements of the TND over the conventional design could be summarized as follows:

- In the Conventional Design vehicles gather at few intersections, which represents higher traffic volumes and smaller gaps between vehicles in the opposing flow. This situation requires the use of traffic signs and signals, which can create excessive delays for the opposing traffic and reduce capacity.

- Larger intersections in the conventional design mean that more lanes will be introduced at any specific intersection. In order for a gap to be acceptable vehicles must be pair in each lane so that vehicles waiting for the left turn will be able to go through.

- As it is seen in Figures No. 3 and 4 while the Conventional Design have three lanes at each approach the NTD only have two. This means that left turning vehicles in the conventional design will have to clear twice the distance than any turning vehicle in the NTD. This creates longer cycle times and thus more delays at intersections.
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- Pedestrian Access

Although some Conventional neighborhoods have pedestrian paths, their designs usually require pedestrians to walk distances greater to what they want to walk. “The distance Americans will walk for typical daily trips is limited, varying from 400 feet (120m) to about ¼ mile (400m). Untermann found that 70 percent of Americans will walk 500 feet (150 m) for daily errands and that 40 percent will walk about 1/5 mile (320 m); only 10 percent will walk ½ mile (800m). Similarly, Barber found that the distance people walked for typical trips varied between 400 and 1200 feet (120-370 m).”\(^4\)

The problem with cul-de-sacs is not only that pedestrians are forced to walk long distances but also that they do not have many options for their trips. Accessibility is then still an issue for pedestrians and non-motorized travel in general because when their trip purpose is other than pleasure travelers want to reach their destinations in the faster and most convenient way.

The principal advantage of the Neotraditional Design over the Conventional Design in terms of pedestrian access is that Neotraditional neighborhoods have more mixed land uses. For this reason an increased number of origins and destinations are located within a walking distance so that people who want to go to the grocery store, the library or a coffee shop can choose between going walking or use their cars. This would not be possible in neighborhoods under the Conventional Street Design since residential developments are isolated to other land uses and most of the trips are depended of the automobile.

\(^4\) Southworth / Ben-Joseph, Pg. 107
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- Other Issues

Another important advantage of NTD is that real-time route selections are most likely to happen. That means that during peak hours, for example, people can change their path selection and traffic congestion can be avoided. This is not possible under the street configuration of the conventional design.

Accidents

Since 1950’s traffic engineers have paid special attention to the relationship between street design and crashes. “One of the first engineering studies on street safety in residential subdivisions, conducted in Los Angeles between 1951 and 1956, examined the accident rates in developments with a grid pattern, as compared to the prevailing FHA limited-access and curvilinear patterns. The study results showed that accident rates were substantially higher for grid-pattern subdivisions: Fifty percent of all intersections in the grid pattern had at least one accident during the five-year period. In contrast, only 8.8 percent of the intersections in the limited-access pattern had accidents during that period. Overall, T intersections were found to be fourteen times safer than in the grid tracts.”

Although the study was not sensitive to neighborhood density and traffic volume it became a strong argument to support the hierarchical pattern set by the FHA.

Traffic speed, which is one of the principal causes of accidents, is a controversial point for NTD and Conventional Design supporters. Authors like Walter Kulash affirm “the travel speed profile for a NTD generally shows a lower peak speed and shorter, more frequent intersection delays than on a Conventional design. The Conventional Suburban Development trip, made mainly on major arterial streets, is typified by a pattern of high speeds for short segments of road, interspersed with long traffic signal delays at individual traffic signals.” On the other hand, the Conventional Design supporters claim that despite of the speed in the arterial streets, low traffic volumes and reduced speeds in the cul-the-sacs make the Conventional Design safer for children playing in the streets.

Beyond the controversy of which street design is better in terms of safety recent studies show that high speed not only causes an increased number of accidents on the roads but it also influence the severity of the accident by itself. “In Limpert’s Motor Vehicle Accident Reconstruction and Cause Analysis, it is shown that the probability of a pedestrian being killed when a vehicle is traveling at 15 mph is 3.5%. And when you go to 44 mph you are suddenly at an 83% probability of being killed.”

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5 Southworth / Ben-Joseph, pg. 92
7 Margaret A. Kubilins. “Designing Functional Streets that Contribute to Our Quality of Life”
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Social Benefits

One cannot easily compare grid patterns and cul-de-sacs in terms of social benefits because the latter ones have an advantage over the conventional grid design. Factors, such as high speed and aesthetics make grid patterns inconvenient for most people. However, if the analysis is made between cul-de-sacs and grid patterns under specific conditions like traffic claming, the comparison becomes pertinent. Grid patterns under those conditions promote a civic spirit, encourage multimodal transportation since bicycles and walking becomes a convenient alternative, and create areas where kids can play and neighbors have a closer interaction.

Even though benefits of cul-de-sacs are often controversial, nobody can argue, for example, that Conventional Design does not provide more safety in access roads where traffic volumes are considerably lower. Furthermore, it has been demonstrated that criminals prefer neighborhoods with more street choices (grid patterns) where they can escape easily after committing a felony than cul-de-sacs where they spend some more time finding their way out.

3.3. Related Research

The following analysis made by Michael Southworth illustrates the difference between a Neotraditional (Elmwood) and two Conventional Neighborhoods (Kentlands and Laguna West):

As it is shown in Table No.1 equal and squared analysis areas of 2000 feet per side were selected for each development so that a comparison between neighborhoods with different characteristics would be possible. The criteria selected for this analysis was established carefully so that differences in terms of accessibility could be easily found between the neighborhoods in analysis.

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8 Mayo, J. 1979. “Suburban Neighboring and the Cul-de-Sac Street.”
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**Table No 1**

<table>
<thead>
<tr>
<th></th>
<th>ELMWOOD (1905)</th>
<th>KENTLANDS (1969)</th>
<th>LAGUNA WEST (1990s)</th>
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<td><img src="image" alt="Street Patterns" /></td>
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<td><img src="image" alt="Intersections" /></td>
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<td>24,000 (alleys 7,000)</td>
<td>19,000</td>
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<tr>
<td><strong>Number of Blocks</strong></td>
<td>23</td>
<td>24 (w.o. alleys 14)</td>
<td>16</td>
</tr>
<tr>
<td><strong>Number of Intersections</strong></td>
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<td>41 (with alleys)</td>
<td>20</td>
</tr>
<tr>
<td><strong>Number of Access Points</strong></td>
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<td>22</td>
<td>14</td>
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<tr>
<td><strong>Number of Loops &amp; Cul-de-sacs</strong></td>
<td>1</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

(Southworth / Ben-Joseph)
Transportation Accessibility

From the table it is concluded that even though Kentlands and Laguna West have different linear feet of streets, number of blocks, intersections and access points, they have a similar number of loops and cul-de-sacs and that is the principal reason why they are considered to be in the same group of conventional street design.

“In terms of access into the study area from outside, Kentlands has 22 points of entry to the study area, while Elmwood has 16, and Laguna West has only 14. However, when the entire development is examined compared with Elmwood, both Kentlands and Laguna West are weakly connected with the surrounding urban context.”

Results from this study are difficult to interpret. It seems like either the criteria used in the analysis does not clearly relate to connectivity or that the selection of neighborhoods are not representative of Neotraditional and Conventional Designs. Neotraditional neighborhoods, Like Elmwood, are suppose to have more linear feet of streets, an increased number of intersections, more number of access points and therefore better connectivity. Based on the results of the study however, Elmwood is still the one that visually offers better connectivity.

3.4. Connectivity and the Future

Successful street designs that provides connectivity and supply the needs of travelers will be achieved after taking the advantages of both Neotraditional and Conventional Designs. Traffic engineers must find the balance between the convenience of NTD Designs and the safety and social benefits offered by Conventional Designs.

Grid patterns were unsafe in the old set up but new concepts like Traffic Calming can make Neotraditional neighborhoods safer and more convenient for automobiles and non-motorized modes of transportation. The following concepts will play a vital role in the development of cities by the year 2050:

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Southworth / Ben-Joseph (1997), pg. 105
The shared Street Concept

The shared street concept tries to keep the functionality and efficiency of the grid pattern used in the Neotraditional developments and at the same time integrates the safety and livability of the Conventional design. The main goal of this concept is that vehicles, pedestrian and bicycles will share the space in the streets.

Looking at the evolution of the form since its inception, several design characteristics are typical:

- It is a residential, public space.
- Through traffic is discouraged.
- Paved space is shared by pedestrians and cars, with pedestrians having priority over the entire street. Walking and playing are allowed everywhere.
- It can be a single street, a square (or other form), or a combination of connected spaces.
- Its entrances are clearly marked.
- There are no conventional, straight stretches of pavement with raised curbs, and the pavement (carriageway) and sidewalk (footway) are not rigidly demarcated.
- Car speed and movement are restricted by physical barriers and deviations, bends, and undulations.
- Residents have automobile access to their dwelling fronts.
- The area has extensive landscaping and street furnishings.

The shared street idea is based on the grid design concept in the sense that, although in different conditions, it promotes accessibility and not just for automobiles but also for pedestrians and bicyclists.

(Southworth / Ben-Joseph)
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- Interconnected cul-de-sacs

Figure No 7

Interconnected cul-de-sacs provide the convenience of a cul-de-sac and promote other transportation alternatives such as walking and bicycle. The interconnection is achieved by the construction of bicycle/pedestrian paths between cul-de-sacs so that the accessibility neglected to pedestrians and bicyclists by the conventional street design is somewhat improved.

Interconnected cul-de-sacs have been criticized because they will never provide similar values of accessibility for bicycles and pedestrians than the ones achieved by the grid design and the accessibility problems for automobiles remain unsolved.

- Street Closures

Street closures used in neighborhoods built under the Grid Pattern are a way to reduce automobile traffic and promote other transportation modes such as, bicycle and walking.

As it is shown in Figure No 8 the idea behind this concept is to keep the connectivity benefits of the grid design for pedestrians and bicyclist whereas restricting connectivity for automobiles so that they have to drive slower and therefore safely. Critics of this concept argue that more than decreasing connectivity street closures represent inconvenient for drivers who are not familiar with the area. Besides, street closures usually increases vehicle miles and all the problems associated with it.
This street design concept is an alternative to reduce through traffic while promoting transit service in neighborhoods built under a Grid Pattern. The following pictures show some examples on how changes in the streets geometry can be made to reduce through traffic in local roads. Figure 9 shows a grid with limited access to arterials where only few changes are made in the street layout. The following alternative, Figure 10, introduces cul-de-sacs in the street design, which reduces through traffic but at the same time has a negative impact in automobile accessibility. The alternative shown in Figure 11 shows some street closures and the creation of loop streets while Figure 12 introduces the use of internal diagonal streets.

Variation on a Grid gives more opportunities for alternative transportation modes but especially for transit. Despite of the modifications to the grid configuration, pedestrian pathways are direct and the high residential density necessary for a successful transit service remains intact.

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Figure No 9

Figure No 10

Figure No 11

Figure No 12
4. STREET SPACING

Street planning usually focuses on particular locations and almost never analyzes traffic problems in a comprehensive manner. That is the reason why transportation decision makers keep on adding more lanes and changing the geometry of the highway system.

Street spacing, which is an important and often neglected approach for street planning could help transportation planners to make street designs more sustainable in the future. Finding adequate values for street spacing can significantly improve accessibility and mobility throughout the network. Streets that are too close to each other can cause accidents and delays because of the increased number of intersections. Likewise, streets that are too far from each other would decrease accessibility and over concentrate traffic at intersections.

Although connectivity and street spacing are two different concepts both are generally measured using the same criteria. In fact, when streets are efficiently spaced on the network it is very likely to reach higher values of connectivity and vice versa. For that reason this chapter will compare and analyze different methodologies and case studies on how to find values for street spacing.

- Future Highways and Urban Growth, 1961 (11)

The main point of this research prepared by Wilbur Smith and Associates in 1961 under commission from The Automobile Manufacturers Association is that where topographic differences are not significant, freeway spacing will be dependent on population density. However, the study points out that population density is only one of the factors that affect traffic within specific communities since through traffic plays also and important role in traffic congestion and therefore in the whole street spacing configuration.

The figure shows how freeway grid spacing is directly proportional to the number of lanes provided in the network and inversely proportional to the average length of freeway trips and population density. That means that for an increased number of lanes on a freeway grid spacing will be higher and for large values of population density freeway grid spacing will be reduced.

Following the curves, one can say that for a population of 10,000 people per square mile you can choose between a 4 lane freeway spaced 2 miles, a 6 lane freeway spaced 3 miles or a 8 lane freeway spaced 4 miles. Although for this example the number of lanes needed proportionally increases with the freeway spacing, this is not true for other population densities.

The model states that capacity and travel demand are in equilibrium, that when the network reaches congestion either more lanes or less separation between streets is needed.

"The curves may be applied with relatively greater certainty where entirely new developments will take place, and where there are no serious physical or economic controls. The results obtained are generally consistent with the California standard of four-mile freeway spacing in urban areas."\(^{10}\)
- Driveway and Street Intersection Spacing, 1996 (12)

The TRB Circular 456 “Driveway and Street Intersection Spacing” focuses on finding optimal spacing between intersections and not between streets with the same functional class.

As it is shown in figure No 14 if the roadway in analysis is the one located in the upper side of the network then the optimal intersection spacing is calculated between a roadway that provides primary movement and other roadway that provides collection.

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The variables involved in the planning, design and operation of signalized intersections are speeds, cycle lengths and intersection spacing.

It is important to mention that signal timing coordination is not unique and different configurations should be provided so that intersections can handle traffic volumes at different speeds in the most efficient way.

During off peak conditions, for example, a suburban arterial usually operates at speeds between 45 and 55 mph and cycle times of 60 to 80 seconds. Longer cycle lengths are used, 120 seconds in the case of suburban arterials, during periods of congestion so that the lost time is minimized.

A ½ mile spacing (Figure No 15) could be reasonable for an efficient progression in a suburban arterial under different traffic conditions. For a 120 seconds cycle time commonly used during peak hour conditions the traffic flows at 30 mph. Conversely, for a cycle time of 60 seconds during periods without congestion an efficient progression is provided at 60 mph.

- Planning Urban Arterial and Freeway Systems, 1997 (13)

The ITE Report defines trip density, travel characteristics and design and physical characteristics as the most important factors for roadway spacing.

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13 Institute of Transportation Engineers. “Planning Urban Arterial and Freeway Systems.”
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Trip density (vehicle-trip origins per square kilometer) in this case is not only function of population densities but also types and intensities of land-use, income/demographic characteristics, car ownership, and to the quality of public transportation service. Travel characteristics refer to the capacity of the roadway and the volumes and directions of travel accommodated in the peak hour. The following graphic shows the relationship between optimal spacing and vehicle kilometers/miles of travel.

“As an example, considering a suburban city, surveys indicate that 3.3 vehicle trips per person are made on a typical weekday, for a density of 13,200 vehicle-trips per square mile (5,100 per km2) per day. The average trip length is five miles (therefore, 66,000 VMT per square mile). Approximately two-thirds of the VMT is estimated to be carried by the arterial system, for an average of 44,000 VMT/square mile. This would result in a requirement for two lanes arterials spaced at approximately 0.3 mile intervals; or four lane arterials spaced on approximately a mile grid; or six lane arterials on approximately a two mile grid.”

![Figure No 16](image)

(Institute of Transportation Engineers)

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14 Planning Urban Arterial and Freeway Systems, pg. 18
5. CONCLUSIONS

The most important thing when doing urban planning is to understand the needs of the people for whom decisions are going to be taken. Thus, as people have different perceptions the idea of this study was not to find out the perfect street design for every neighborhood, town or city in the United States. Instead, a set of principles is presented so that communities with different characteristics and street designs can achieve reasonable levels of livability and promote sustainability in the future.

♦ Street design should promote multimodal transportation. This idea not only refers to the need of building the infrastructure for all transportation modes but also to set up the conditions so that different transportation modes are equally attractive. In that sense accessibility should be provided for all transportation modes so that origins and destinations are close to each other.

♦ Mixed land use. Even though some people do like to live in areas where the land use is exclusively residential it is possible to limit the size and separation from other land uses of this residential developments.

♦ Local streets should be design to discourage excessive speed. Some of the benefits of this measure are: reduction in through traffic and more safety for children and pedestrians.

♦ Provide enough number of intersections. If possible, there should be a sufficient number of intersections in the network so that automobiles and other transportation modes have multiple path choices and therefore traffic can spread out uniformly in the network. In some cases multiple intersections can make the use of traffic signals unnecessary reducing delays at intersections.

♦ Whenever there is an excessive use of a particular transportation street designs can be adjusted so that the equilibrium between transportation modes can be achieved. Between this concepts are: Interconnected cul-de-sacs, The Shared Street Concept, Street Closures and Variation on a Grid.

♦ Topographic conditions, population density, speed and cycle lengths are the most important factors to consider in a street spacing study.

♦ As it is discussed in the TRB Circular 456 (1996) street spacing studies should consider different traffic conditions. That means that it is possible to find out the most effective street separation for both peak and off peak hour conditions where vehicle speeds and cycle times are different.
6. REFERENCES


