

ANALYSIS OF THE EFFECTS OF LOCAL STREET CONNECTIVITY ON ARTERIAL TRAFFIC

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ABSTRACT

Perhaps one of the most difficult issues a community can face is the question of street widening. This topic can create extensive debate between local government officials, transportation engineers and citizens. Road expansion is opposed because of concerns about the costs and impacts of widening by some communities while it is ironic that same communities often take steps in their land development process that inevitably lead to the widening they oppose. This is the case of the street connectivity in residential developments located in suburban areas. In recent years such developments have been built using a street design concept that uses poor street connectivity. This street pattern does not provide travelers with alternative paths to complete their trips and therefore the traffic concentrates on the arterials. This phenomenon reduces the capacity of the entire network and may make it necessary to use highway widening to provide extra capacity and avoid congestion.

The objective of this paper is to examine how the connectivity of local residential streets relates to the traffic volumes on nearby arterials. For that purpose a method to assess how local connectivity affects nearby arterial traffic volumes was developed. Detailed network descriptions of local streets and land use were used with in conjunction with a regional travel forecasting model to assess traffic shifts under different conditions on local and arterial streets. This was done using a case study of Tallahassee, Florida region. The study revealed that improved connectivity can reduce arterial traffic levels depending on the relative speed on the arterial vs. that on local roads and the extent to which the arterial road carries through traffic. Impacts are the greatest when the speed differential between the arterial and local streets is small and there is limited through traffic.

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1. INTRODUCTION

Over the past half century the street design concept in American cities has evolved into a fragmented street pattern characterized by the extensive use of cul-de-sacs and isolated subdivisions with poor connectivity. This has happened because real estate market factors may have disadvantages in terms of convenience of transportation to reach destinations, especially when using alternative transportation modes, and the overall traffic performance to other parts of the network.

Advocates of New Urbanism and Smart Growth have stated that better connectivity and accessibility can be a key method to control or reduce traffic. They say connectivity will allow traffic to diffuse in a network and lead to less concentration on arterials. A key distinction is the difference between accessibility and mobility. Accessibility is defined as the ability to connect activities, while mobility is a measure of the vehicle-miles involved in travel. High values for mobility could be an indication of congestion whereas increasing accessibility is usually associated with reduction of congestion. Providing better connections in local streets has been cited as a way to improve accessibility. This can also generate a number of benefits, such as encouraging bicycle and pedestrian trips and decreasing vehicle miles. It can make developments more livable and sustainable in the future.

Accessibility deals with topics such as street connectivity, land use mix and building orientation. This paper concentrates in street connectivity and compares two street designs, Neotraditional Design and Conventional Design and how they impact traffic conditions. For the purpose of this study, Neotraditional Design (NTD) is defined as an interconnected rectilinear grid patterns such as was commonly used before World War II in the U.S. and Conventional Design as a discontinuous pattern of cul-de-sacs common since the 1950s.

As Southworth and Ben-Joseph stated, "American conceptions of the residential street network have changed dramatically from the interconnected rectilinear grid pattern of the turn-of-the-century, to the fragmented grid and warped parallel streets of the 1930s and 1940s and the discontinuous, insular patterns of cul-de-sacs and loops that have preferred since the 1950s"(1). Traffic modeling work by Kulash, Anglin and Marks (1990) predicts that a connected road network reduces VMT within a neighborhood by 75% compared with conventional designs (2). Kulash states that more capacity can be attained in an interconnected street pattern since there are more intersections per unit area in a neighborhood with a Neotraditional Design (grid pattern) than in one with Conventional Design (cul-de-sacs). They argue that the increasing number of intersections available in the NTD makes traffic spread out in a more uniform manner throughout the network and therefore only a small portion of the total volume concentrates at a particular intersection. For that reason, larger gaps between vehicles in the opposing flow are expected and it would be easier for vehicles to make left turns without the use of traffic signals that increase the delay at intersections (3).

Other authors (Knack, 1989) however, state that trips made on a daily basis are usually completed within a 3000-4000 acres area and for that reason few automobile trips would ever use the arterials in neighborhoods with Neotraditional Design. Some other critics also argue that road networks with improved accessibility might encourage people to make more trips to the point of having the same levels of congestion on local streets found in street patterns with poor connectivity.

Littman (4) argues that better connectivity can reduce vehicle travel by reducing distances and supporting alternative modes such as bicycle and walking. In addition, it can provide more route options for travel and reduce problems is a particular link is closed. He goes on to say that it can lead to conflicts with nearby residents who may be concerned with increased traffic and that it should be done in conjunction with street layouts and designs that use traffic calming, T intersections and short block lengths.

While these debates continue, there has been little quantitative analysis of the subject and limited information on exactly how connectivity could affect traffic conditions in neighborhoods and adjacent arterials. The effect of street connectivity on congestion in a corridor is seldom seriously considered as a planning practice or policy as cities expand and develop. This paper will attempt to add some insight on the topic.

2. OBJECTIVES

The objective of this paper is to examine how the connectivity of local residential streets relates to the traffic volumes on nearby arterials. The hypothesis of this paper is that improved connectivity of neighborhood streets will reduce the traffic volumes on nearby arterials. For that purpose a method to assess how local connectivity affects nearby arterial traffic volumes was developed. Detailed network descriptions of local streets and land use were used in conjunction with a regional travel forecasting model to assess traffic shifts under different conditions on local and arterial streets. This was done using a case study of Tallahassee, Florida region. This paper is part of a larger work that analyzes the relationship between land use patterns and road widening (5).

3. PROCEDURE

The process used in this study involved the development of a detailed travel demand analysis of local street networks as part of a regional travel demand model. First the demographic and employment information had to be disaggregated to provide detailed information on trip origins and destinations. Then local streets were coded in greater detail to show existing street patterns and then new links were added to provide better connectivity. The two networks were then compared using QRSII travel demand software. A network in Tallahassee, Florida, was chosen for the study. This area was used because it provided readily available data with a calibrated regional network.

Demographic Information

The demographic and geographic characteristics of the area selected for the connectivity analysis have a significant influence on the magnitude of the traffic reduction. An area for analysis was selected based on the following criteria:

- Mixed land use. When there is land use mix the trip length for shopping, personal business and recreational trips can decrease. People usually prefer to make those trips where origins are close to destinations, meaning that within an ideally connected network these trips could be completed using local roads thereby reducing the traffic volume on the arterial.
- High levels of activity. When an area surrounding an arterial has high levels of activity (number of households, retail and nonretail) more vehicles will use that arterial due to the high number of trips produced and attracted in that area. In this way, the gross reduction of trips after connectivity is improved will be higher.
- Poor connectivity. If the area under analysis has poor connectivity of local streets, a large percentage of the traffic has to use the arterials because there is not a direct path in the local roads. With improved connectivity some of those trips will no longer need to use the arterial and a reduction on traffic levels on the arterial should take place.

Based on the criteria described above a corridor located on the west side of Tallahassee, Florida was selected for the connectivity analysis. It was identified as an area with poor connectivity and relatively high levels of activity. In order to measure the impact of street connectivity, the spatial precision in the study area was increased. Traffic analysis zones in the study corridor were subdivided into smaller zones. Multiple centroids were created from the original Traffic Analysis Zones (TAZs) so that they contained more detailed information. Demographic information in the desired format was found from the City of Tallahassee GIS web site. Detailed property information data was used to identify property characteristics in the smaller zones.

Network Construction:

The arterial corridor selected for this analysis was divided in 44 segments. Each of these segments corresponds to a road portion between intersections. Figure 1 shows the western portion of the study area before and after connectivity was improved. The network generated after the new links that are shown as wider lines were added is a hypothetical network. It may be that less connectivity could cause a considerable traffic reduction on the arterial but this was not initially analyzed in this project.

The geometry configuration for all the 44 segments is constant in both conditions. That means that the principal arterial has the same operational conditions as far as the number and separation of access points is concerned for both conditions. This is an important consideration since traffic volumes are compared before and after connectivity on each of the 44 segments on the arterial.

The original network of the City of Tallahassee had to be expanded to add all roads within the study area. There were numerous cul-de-sacs in the area that lead to the arterial with very few connections between adjacent roadways. Local roads were coded using the General Network Editor (GNE) as two-way streets. There were no concerns about capacity restrictions on those links and the speed was set at 15 and 25 mph. Since the speed on the arterial will also have an impact on the travelers route selection it was set to: 25 mph, 30 mph, 40 mph and 50 mph. Multiple runs were made with different combinations of speeds to determine how they would affect flows. Major intersections were left as intersections with delay and new intersections connecting local streets were set as intersections without delay.

A final part of the study was a determination of the number of through trips in the study area, i.e. external-external trips. E-E trips were calculated using the select link analysis technique available in QRS II. Select link analysis calculates the trips between pairs of selected links and places that information in the file "SelectM.txt." For the purpose of this paper the selected links corresponds to the links located at both extremes of the corridor under analysis.

Full capacity constrained travel demand analyses of the Tallahassee network were conducted with the two networks using QRSII software. This process assigns traffic to the shortest travel paths on the network considering congestion levels and intersection delay. These were done multiple times with different initial speed combinations to determine how arterial traffic varies with changes in local connectivity.

4. RESULTS

The traffic volume differences were compared for segments along the arterial. These almost always show a volume reduction for the connected network. The magnitude of the reduction depends on the relative speed of the arterial vs. that on the local roads. Very few arterial segments experienced a traffic volume increase.

Traffic Volume Results

The traffic impact along the arterial can be compared by looking to the traffic volume of the 44 segments considered in the analysis as shown in Figure 2 and in Table 1. Figure 2 illustrates the decline in traffic on the arterial with improved connectivity based on the speed assumptions. Traffic declines along much of the route and the impact depends on local land use along the route, especially employment in sub zones. Table 1 is a summary of average traffic volumes calculated by QRS II under different speed assumptions.

The traffic volumes shown in Table 1 confirm the hypothesis that improvements in connectivity of the local streets reduce traffic volumes along the principal arterials. The amount of reduction depends on the relative speed assumed on the arterials vs. that on local streets. When the initial speed on the residential streets is assumed to be 25 mph, more travelers will use the local streets instead of the arterial to reach their destinations. Consequently, there will be a larger traffic volume reduction on the arterial. In contrast, when the initial speed on the residential street is assumed to be 15 mph, fewer travelers will take the local roads to complete their trips and there will be a lower traffic reduction on the arterial. Figures 3 and 4 show this effect. This occurs because of the path finding process of the travel demand software. Travelers are assigned to the minimum time path between their origin and destination. If there is a large speed differential, the shortest time path is shifted to the higher speed links and away from the slower links. If the speeds are nearly the same travelers will use the shortest distance paths and will use more internal links.

As shown in Figure 5, the traffic volume reduction on the arterial is highly sensitive to the relative speed of the arterial and the residential streets. The highest reduction occurs with an arterial speed of 25 mph and a local roads speed of 25 mph. External-External trips account for an important percentage of the total vehicles traveling along the corridor. Changes in connectivity will reduce trips on the arterial by a fixed amount, but it will appear as a low percentage reduction if there is a lot of through traffic and as a high percentage if there is little through traffic. There are two numbers, provided percentage reduction in total traffic (including E-E trips) and percent reduction in local traffic (without E-E trips). This is illustrated in Figures 6 and 7.

As it is shown in Figure 5 when the speed on the arterial is close to the speed on the local roads, there is a major traffic volume reduction on the arterial. This is because the travel time between origins and destinations is shorter when people use the local roads. When both the speed on the arterial and the local roads is 25 mph the total traffic volume reduction on the arterial is 644 veh/hr. In contrast, when the speed on the arterial is 50 mph and the speed on the local roads is 15 mph, the traffic volume reduction drops down to only 10 veh/hr.

Figures 6 and 7 provide a different interpretation for the traffic volume reduction on the arterial. In this case the traffic impact is measured as a percentage for the two scenarios: with or without external-external trips. The traffic volume reduction has the same tendency as in Figure 6. When the speed on the local roads and the

arterial are similar the traffic volume reduction on the arterial is higher. In this case, an 85% reduction of local trips (51% of all trips) on the arterial occurs when the speed on the arterial and the local roads is 25 mph.

How much connectivity?

The results point out an interesting contradiction in the role of local streets in neotraditional neighborhoods. These streets are successful in serving internal traffic when speeds on the local streets are close to those on the arterials. However, a second strategy, traffic calming, operating at lower speeds, works against this. Design of street patterns in neighborhoods need to be a very careful process, using tools such as those developed here, to deal with these conflicting goals.

It is clear, that there is a critical balance between connectivity and through traffic. Enough connectivity has to be provided so that residents of a neighborhood can easily move to all edges of the neighborhood and adjacent land uses, but not so much that neighborhood streets become attractive choices for through traffic to avoid congestion and delay on arterials. There needs to be a balance between the extremes of poor connectivity and too many opportunities for through traffic. The importance of this balance is that transportation facilities could be used in a more efficient manner without affecting the livability of the residential developments. By doing that, highway widening can be avoided or delayed and the transportation facilities would be more sustainable in the future.

The study analyzed added an extensive network of local streets to maximize the interconnectivity in the neighborhood. Less connectivity may be able to accomplish the same goal and at the same time avoid the potential for through traffic in the neighborhood. Detailed analysis of traffic volumes on the new links revealed that several had very little volume and are not necessary to gain the benefits of better connectivity. For example, in the test network analyzed, approximately one fourth of the added links had essentially no traffic volume and could be deleted from the network with no affect on arterial traffic. This could be used in further analysis to reach a balance between connectivity and the need to avoid through traffic in the neighborhood.

5. CONCLUSIONS

This paper identifies the relationship between local street connectivity and highway traffic flow on nearby arterial streets. Connectivity was evaluated by looking at changes in traffic on arterials on a network with and without connectivity improvements on local streets. It was demonstrated that arterials could experience reductions in local traffic with better neighborhood street connectivity depending on the speeds on both the local roads and the arterial. For example, when the speed on the local roads is 25 mph and on the arterial 40 mph, the total traffic volume reduction would be 10.59% and the reduction in local traffic volume 15.78%. The effect varies from 4.04% when there is a large speed differential to 85.65% when speeds on the local roads and the arterial are equal.

The major benefit of street connectivity is that it redistributes traffic on a network providing an overall increase in the capacity of the system. Consequently, improving street connectivity of residential streets could reduce the need for arterial highway widening by providing more options for local trips. Nonetheless, there is a critical balance between connectivity and through traffic. Enough connectivity has to be provided so that residents of a neighborhood can easily move to all edges of the neighborhood and adjacent land uses but not to an extreme so that residential streets become attractive choices for through traffic.

Based on the results from the case study it is clear that planning for better street connectivity can avoid or delay the need for roadway widening in growing areas. Residential and central business districts that have interconnected street patterns may be able accommodate more traffic. This is very difficult to do after the fact and needs to be considered as development projects are considered. Sound planning practice should encourage good connectivity in multiple directions for new developments. If this occurs at the time of development, arterials can be more cost effective and mobility can be improved local areas.

Planning organizations and government officials could adapt the methodology presented in this paper to deal with congestion and minimize the use of roadway widening in their own communities. This methodology should use a travel forecasting model with a detailed traffic network. For the street connectivity analysis, at least in the area where connectivity is being evaluated, all residential streets must be coded in the network. Demographic information refinement is also needed to obtain precise information on how street connectivity of the local roads affect the traffic volume on the arterials.

Results from this paper reveal that better connectivity of local streets can help spread out traffic volumes more efficiently throughout a network. The question remains open regarding how much traffic neighborhood streets could take so that they do not become attractive choices for through traffic. In that respect more studies about design criteria, safety and livability levels of residential areas with interconnected street patterns are needed so that an appropriate level of traffic will occur.

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TABLE 1 Summary of the Average Traffic Volumes Before and After Connectivity

Condition	Average Arterial Volume (Before Connectivity)		Average Arterial Volume (After Connectivity)	
	Including EE trips	Without EE trips	Including EE trips	Without EE trips
Assumed Speed on Local Roads = 15 mph				
Assumed Speed on Arterial = 25 mph	1,254	755	1,204	705
Assumed Speed on Arterial = 30 mph	1,370	871	1,328	829
Assumed Speed on Arterial = 40 mph	1,532	1,033	1,500	1,001
Assumed Speed on Arterial = 50 mph	1,601	1,102	1,591	1,092
Assumed Speed on Local Roads = 25 mph				
Assumed Speed on Arterial = 25 mph	1,251	752	607	108
Assumed Speed on Arterial = 30 mph	1,364	865	1,087	588
Assumed Speed on Arterial = 40 mph	1,519	1,020	1,358	859
Assumed Speed on Arterial = 50 mph	1,597	1,098	1,515	1,016

TABLE 2 Summary of the Traffic Volume Reduction After Connectivity Improvements in the Local Roads

Condition	Traffic Volume Reduction		
	Veh/h	% (Including EE trips)	% (Without EE trips)
Assumed Speed on Local Roads = 15 mph			
Assumed Speed on Arterial = 25 mph	51	4.04	6.70
Assumed Speed on Arterial = 30 mph	43	3.11	4.89
Assumed Speed on Arterial = 40 mph	31	2.04	3.03
Assumed Speed on Arterial = 50 mph	10	0.64	0.93
Assumed Speed on Local Roads = 25 mph			
Assumed Speed on Arterial = 25 mph	644	51.49	85.65
Assumed Speed on Arterial = 30 mph	277	20.30	32.01
Assumed Speed on Arterial = 40 mph	161	10.59	15.78
Assumed Speed on Arterial = 50 mph	81	5.10	7.42

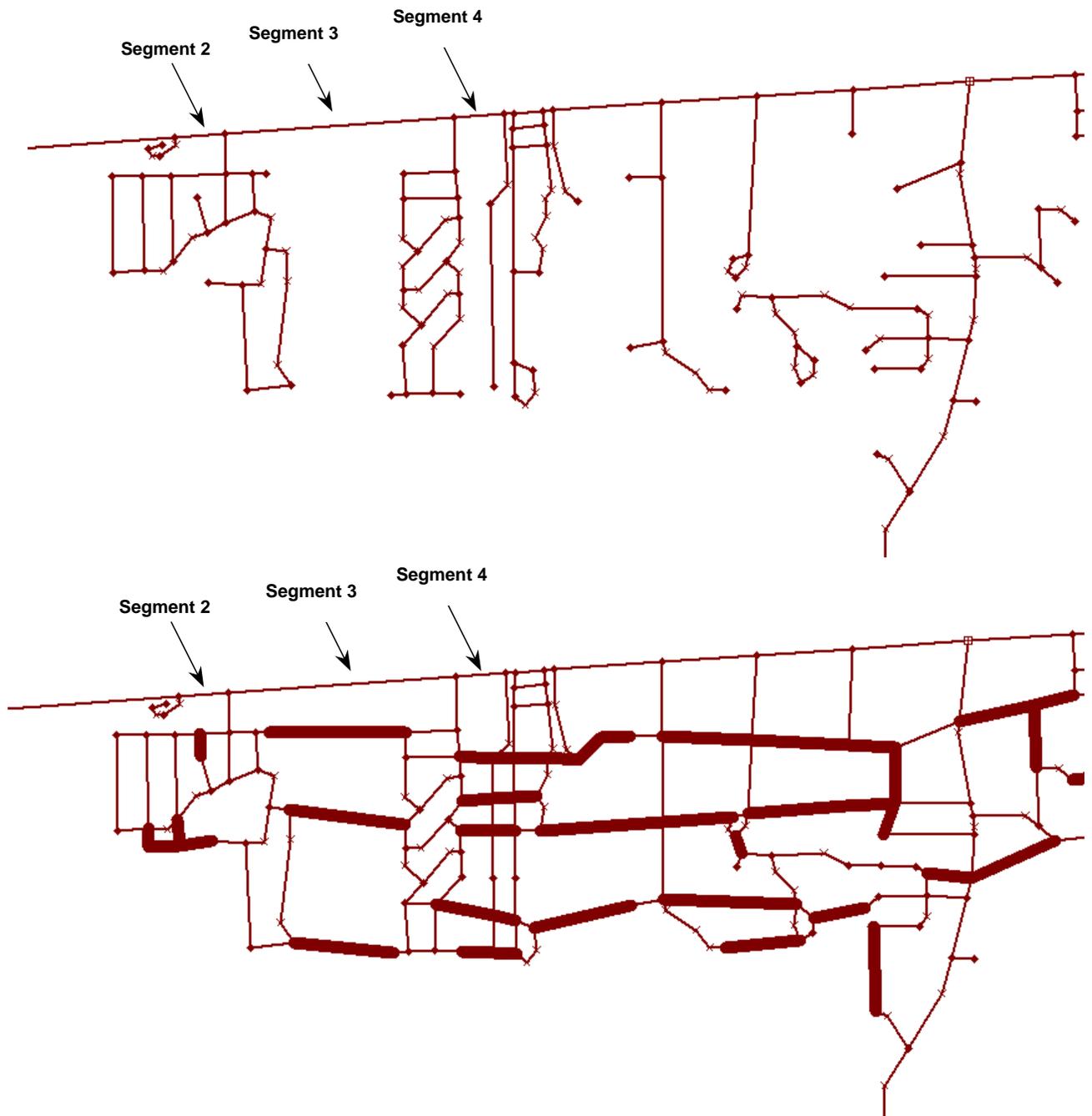


FIGURE 1 Western Portion of the Study Area before and after connectivity Improvements

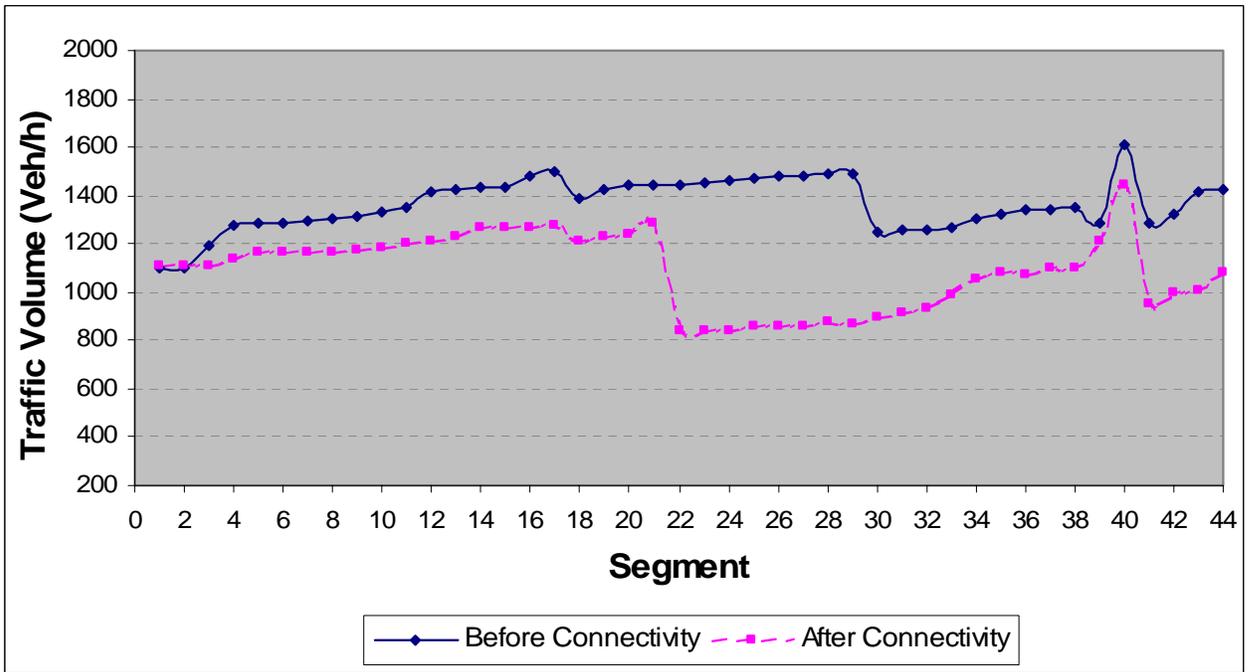


FIGURE 2 Traffic Volumes Before and After Connectivity (Speed on the Arterial = 30 mph, Speed on Local Roads = 25 mph)

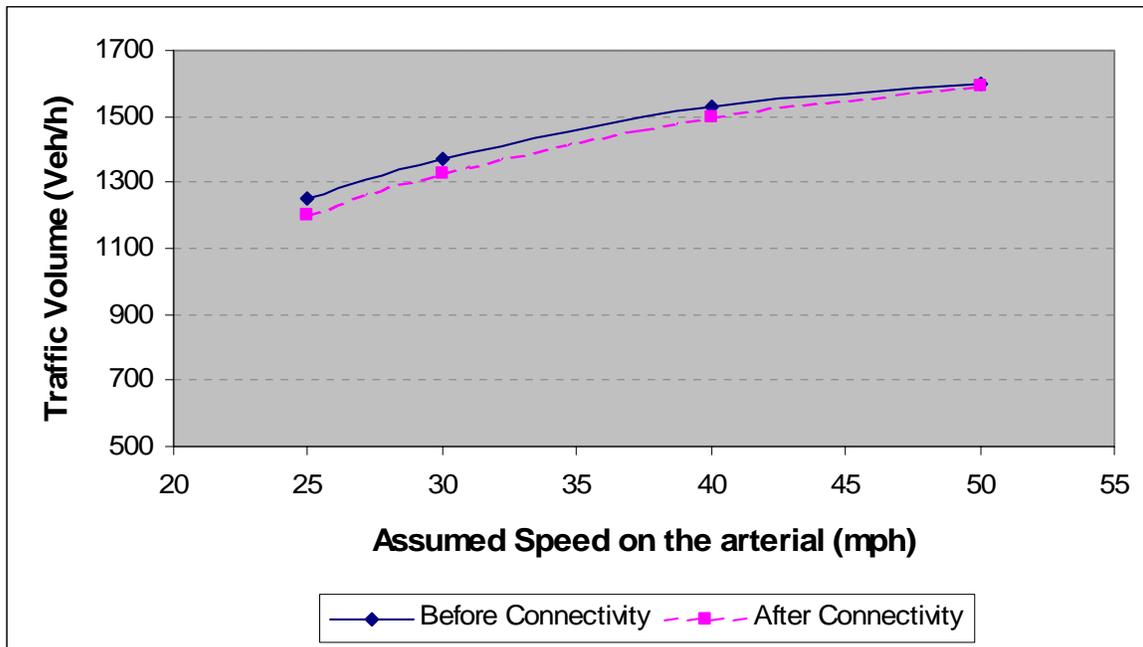


FIGURE 3 Traffic Volume Before and After Connectivity (Speed on the Local Roads = 15 mph)

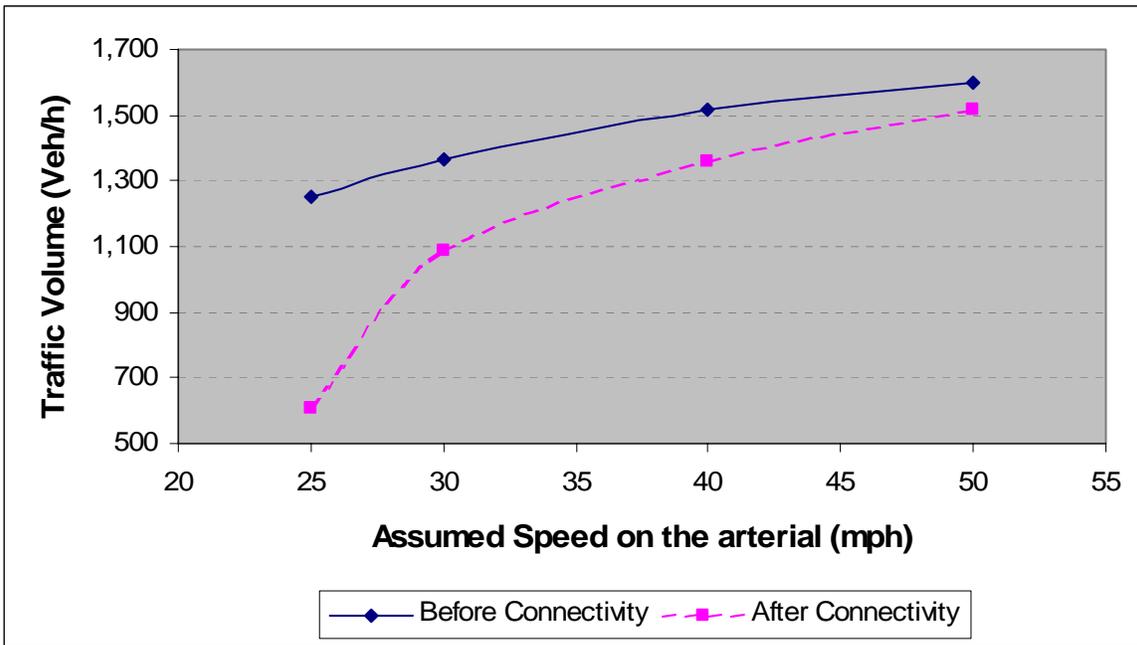


FIGURE 4 Traffic Volume Before and After Connectivity (Speed on the Local Roads = 25 mph)

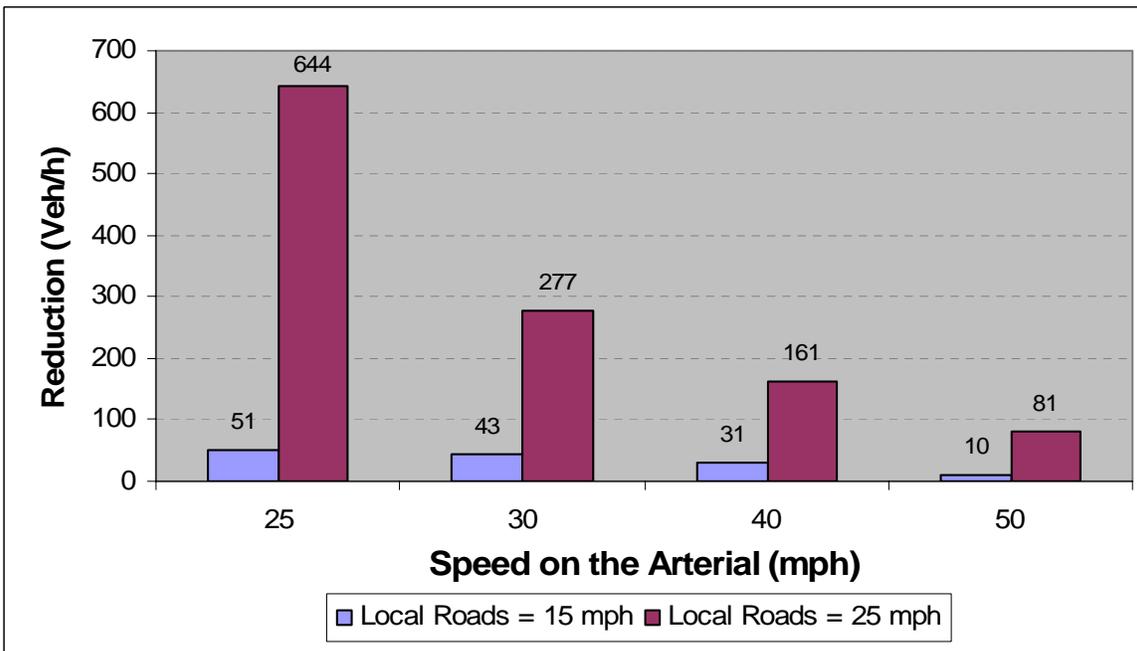


FIGURE 5 Traffic Volume Reduction After Connectivity Improvements

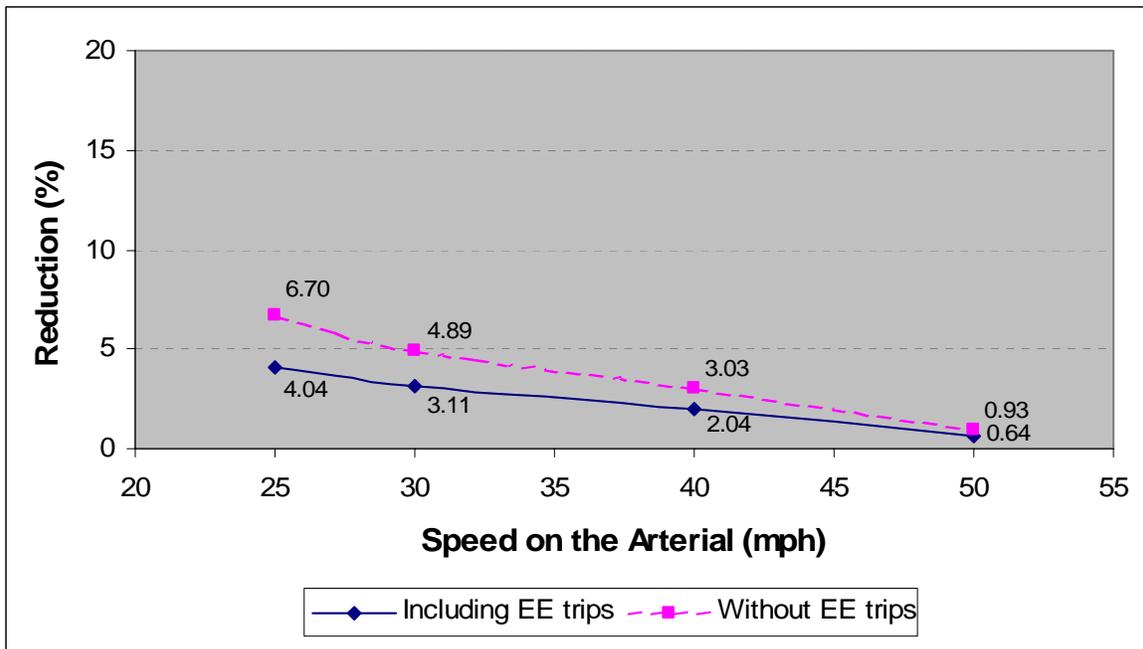


FIGURE 6 Percentage Reduction of Vehicles on the Arterial After Connectivity Improvements (Speed on Local Roads = 15 mph)

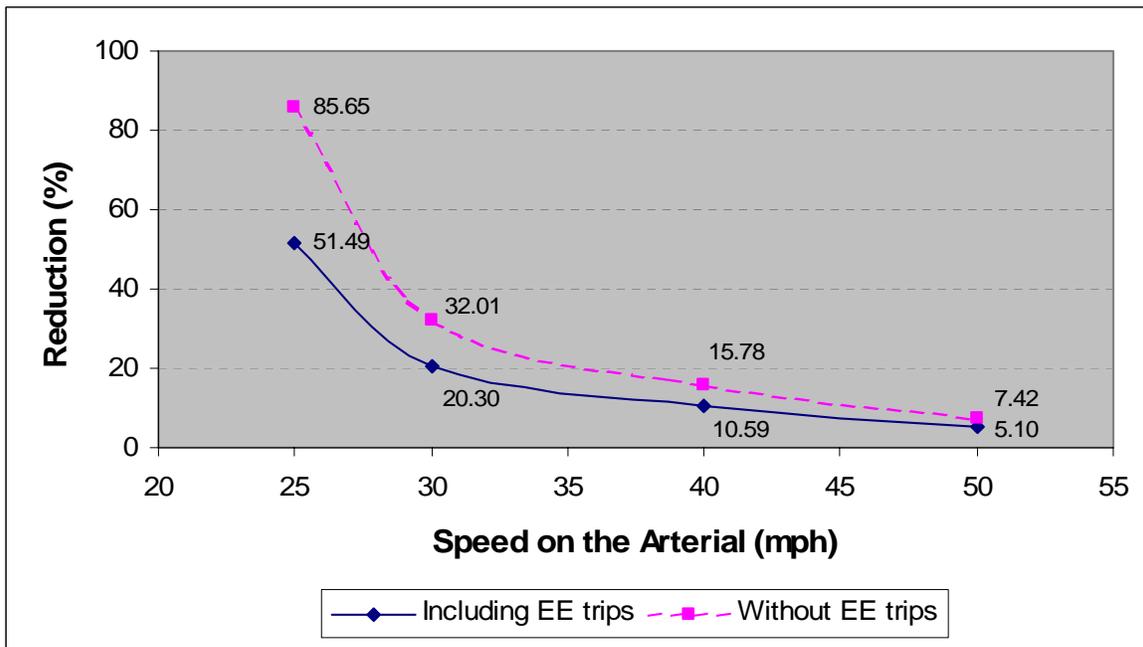


FIGURE 7 Percentage Reduction of Vehicles on the Arterial After Connectivity Improvements (Speed on Local Roads = 25 mph)