To the Graduate Council:

I am submitting herewith a thesis written by Prashant Shanabhai Patel entitled "Elizabethton, TN - One Way Flow vs. Two Way Flow: A Case Study." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

Dr. F.J. Wegmann, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Prashant Patel

Date 7/6/93

# ONE WAY FLOW VERSUS TWO WAY FLOW IN DOWNTOWN ELIZABETHTON, TENNESSEE : A CASE STUDY

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Prashant Shanabhai Patel

August 1993

## DEDICATION

This thesis is dedicated to my parents, Shanabhai and Jayaben Patel, my family, and my friends. Their love, understanding, support, and unending patience enabled me to complete this work. Therefore, to celebrate the completion of this thesis, there could be nothing more fitting than to honor them with this dedication.

## ACKNOWLEDGEMENTS

In the course of this research, I was assisted, encouraged, and mildly harassed by several people whom I must acknowledge. For their assistance, constructive criticism, and encouragement, I thank Dr. Fred Wegmann, Dr. Arun Chatterjee, and Dr. Jack Humphreys who served as my major professor and committee, respectively. Particularly, I thank Dr. Wegmann for his persistent encouragement which at times seemed to border on harassment. Because of his time and effort, this research became not only more meaningful in terms of content and results but it became more meaningful to me as an individual achievement.

Finally, I would like to express my thanks to my parents, family, and friends for their love, support, and faith in me which helped me achieve more than I imagined. If it was not for their encouragement, the completion of this thesis would not be possible. Therefore, I deeply thank each and every one of you from the bottom of my heart.

## ABSTRACT

This research was conducted to determine the feasibility of replacing the existing one-way traffic pattern with a two-way traffic pattern along Elk Avenue and E Street and to identify an appropriate traffic operational plan for downtown Elizabethton, TN. The study also investigated the feasibility of using an on-street angle parking space arrangement instead of the current parallel parking space arrangement. In order to analyze the traffic conditions of downtown Elizabethton, field observations of traffic volumes and traffic flow patterns along Elk Avenue and E Street were conducted. An inventory of parking was also taken to investigate the parking situation.

It was concluded that Elizabethton should remain with the one-way street system instead of converting the two parallel roads of Elk Avenue and E Street to two-way operation. It was found that the parking supply is adequate and parallel parking is more appropriate for downtown Elizabethton than angle parking.

## TABLE OF CONTENTS


| CHAPTER | | PAGE |
|---|---|---|
| I. | INTRODUCTION | 1 |
| | Scope of Work | 1 |
| II. | LITERATURE REVIEW | 4 |
| | One-Way Street Systems | 4 |
| | Advantages of a One-Way Street System | 5 |
| | Disadvantages of a One-Way Street System | 7 |
| | Advantages of a Two-Way Street System | 9 |
| | Disadvantages of a Two-Way Street System | 9 |
| | Parking | 10 |
| | The Parking Issue | 10 |
| | Accidents Involving Parked Vehicles | 13 |
| | Parking Space Arrangements | 14 |
| | Economic Losses Due to Parking | 19 |
| III. | DESCRIPTION OF DOWNTOWN ELIZABETHTON | 20 |
| | Field Observations | 22 |
| | Problems - Merchants' Interviews | 29 |
| IV. | ANALYSIS OF EXISTING CONDITIONS | 34 |

Capacity and Level of Service of Intersections..... 34
Parking Analysis..... 41
Accident Analysis..... 51
Signal Warrant Analysis..... 54
V. ALTERNATIVE IMPROVEMENTS..... 65
Capacity and Level of Service Analysis..... 66
Signal Warrant Analysis..... 74
Parking..... 82
VI. CONCLUSIONS..... 87
LIST OF REFERENCES..... 91
VITA..... 94

## LIST OF TABLES


| TABLE | | PAGE |
|---|---|---|
| 1. | Suggested Criteria for Acceptable Walking Distances | 11 |
| 2. | Summaries of Before-After Studies Involving a Change from Angle to Parallel Parking | 17 |
| 3. | Merchant/Business Interviews | 31 |
| 4. | Existing Traffic Volumes of the AM Peak Time Period (in Veh./Hr.) | 36 |
| 5. | Existing Traffic Volumes of the Mid-day Peak Time Period (in Veh./Hr.) | 37 |
| 6. | Existing Traffic Volumes of the PM Peak Time Period (in Veh./Hr.) | 38 |
| 7. | Level of Service of Key Intersections (Existing Conditions) | 39 |
| 8. | Level of Service of Key Intersections (Existing Conditions with Signal Retiming) | 43 |
| 9. | Parking Accumulation | 46 |
| 10. | Volumes for the One-Way Street System | 56 |
| 11. | Volumes Required for Signal Installation Warrant Satisfaction | 57 |
| 12. | Summarization of Signal Warrant Analysis for the One-Way Street System | 63 |

13. Two-Way Flow Volumes of the Mid-day Peak Time Period (in Veh./Hr.)..... 75

14. Two-Way Flow Volumes of the PM Peak Time Period (in Veh./Hr.)..... 76

15. Level of Service of Key Intersections (Two-Way Flow)..... 78

16. Level of Service of Key Intersections (Unsignalized - Two-Way Flow)..... 79

17. Volumes for the Two-Way Street System..... 81

18. Summarization of Signal Warrant Analysis for the Two-Way Street System..... 83

19. Parking Space Arrangements on Elk Avenue..... 85

## LIST OF FIGURES


| FIGURE | | PAGE |
|---|---|---|
| 1. | Pedestrian Conflict Points | 6 |
| 2. | Curb Parking Geometry | 15 |
| 3. | Typical Flat-Angle Parking Layouts | 18 |
| 4. | Core Area | 21 |
| 5. | Phase Pattern For Existing One-Way System | 23 |
| 6. | Geometrics of Elk Avenue and Riverside Drive For The Existing One-Way System | 24 |
| 7. | Geometrics of E Street and Sycamore Street For The Existing One-Way System | 25 |
| 8. | Geometrics of Elk Avenue and Pine Street For The Existing One-Way System | 26 |
| 9. | Geometrics of Elk Avenue and Sycamore Street For The Existing One-Way System | 27 |
| 10. | Geometrics of Elk, Elm, and F Street For The Existing One-Way System | 28 |
| 11. | Intersections Analyzed | 35 |
| 12. | Phase Pattern of Retimed Signals | 42 |
| 13. | Off-Street Parking Lots | 45 |
| 14. | Parking Accumulation | 48 |
| 15. | Turnover Rate (Vehicles/Space) | 49 |
| 16. | Average Parking Duration (Hours/Vehicle) and | |

Average Occupancy (%)..... 50
17. Duration of Parking..... 52
18. Four Hour Volume Warrant..... 61
19. Peak Hour Volume Warrant..... 62
20. Two-Way With Angle Parking On Elk Avenue..... 67
21. Two-Way With Parallel Parking On Elk Avenue.... 68
22. Geometrics of Elk Avenue and Riverside Drive For The Proposed Two-Way System..... 69
23. Geometrics of E Street and Sycamore Street For The Proposed Two-Way System..... 70
24. Geometrics of Elk Avenue and Pine Street For The Proposed Two-Way System..... 71
25. Geometrics of Elk Avenue and Sycamore Street For The Proposed Two-Way System..... 72
26. Geometrics of Elk, Elm, and F Street For The Proposed Two-Way System..... 73
27. Phase Pattern For Two-Way System..... 77

# CHAPTER I

# INTRODUCTION

Transportation planners and engineers have traditionally focussed their attention on reducing traffic congestion and moving traffic on the roadway system in downtown areas. In many cases, traffic congestion has been treated successfully by the implementation of a one-way street system as opposed to the normal two-way street system.

The town of Elizabethton, TN, which has a population of approximately 11,900, converted two parallel roads -- Elk Avenue and E Street -- from a two-way to a one-way street system, but now some of the downtown merchants want to convert them back to a two-way street system. They argue that due to the one-way system a more circuitous route must be taken by patrons to visit their stores; and the businesses along Elk Avenue lack exposure to the motorists traveling westbound through the C.B.D., all which have led to a decline in business.

## Scope of Work

This study was conducted to determine the feasibility of developing a two-way traffic pattern as opposed to the one-way traffic pattern presently existing in downtown Elizabethton, TN. The objective of this study was to

define the most appropriate traffic operational plan which will provide the maximum safety and welfare to the citizens while encouraging and promoting the attractiveness of downtown Elizabethton. There are two key issues which standout. First, there is the controversy of a two-way versus a one-way flow pattern on Elk Avenue and E Street. Second, what is the most appropriate type of on-street parking for the downtown area, angle or parallel parking?

The analysis procedure was formulated and consisted of the following items:

1. Field observations
    a. Traffic volumes
    b. Flow patterns
2. Merchant/Business interviews
3. Accident analysis at key intersections
4. Parking analysis
    a. Inventory
    b. Accumulation
    c. Turn-over
    d. Long-term parkers
5. Computer analysis of capacity and Level of Service
    a. Existing one-way flow

b. Existing one-way flow with retimed signals

c. Two-way flow

6. Design

a. Two-way street system

b. Parking

Field data was collected through traffic volume counts and turning movement observation. In addition, merchant surveys and an analysis of traffic accident reports were conducted. From the traffic volume counts and turning movement data, a computer analysis using the Highway Capacity Manual software was conducted indicating the capacity and level of service for the key intersections. From these results, the Level of Service for the two-way flow was determined along with necessary traffic operation changes.

# CHAPTER II

# LITERATURE REVIEW

This research is concerned with defining traffic operational techniques of improving traffic flow on the streets of downtown Elizabethton. It is limited to those techniques that can be accomplished within existing rights-of-way and with minimum street reconstruction. Possible techniques include special lane designations, such as exclusive use lanes, or specific turning and storage lanes [5]. The main concerns of this research deal with defining the advantages and disadvantages of a one-way street system versus a two-way street system and various means of providing downtown on-street parking.

## One-Way Street Systems

There are many benefits to traffic flow of a properly planned one-way street system. There are three common classifications of one-way street operations:

* Class 1 -- a street on which vehicular traffic moves in one direction at all time.
* Class 2 -- a street on which vehicular traffic moves in one direction during all hours of the day and the flow is reversed at predetermined times.

* Class 3 -- a street on which vehicular traffic moves one-way during peak traffic periods and reverts to two-way operations at other times [9].

The one-way street system which is presently in operation in downtown Elizabethton falls into the Class 1 category. This is the most common type of one-way street operation.

## Advantages of a One-Way Street System

There are several advantages to having a one-way street system as opposed to a two-way street system. The one-way street system increases the capacity of a street from 20 to 50 percent [4]. This increase in capacity results from the fact that delays at intersections due to turning movements are minimized. A one-way system is advantageous on narrow streets because it reduces the meandering of vehicles.

A major concern for transportation planners and engineers is safety. The one-way street system generally increases safety. Pairs of one-way streets essentially provide a "divided highway." Pedestrians crossing an intersection of a one-way street have 50 percent fewer conflict points than in a two-way system (Figure 1) [9]. A reduction of intersection conflicts is conducive to a

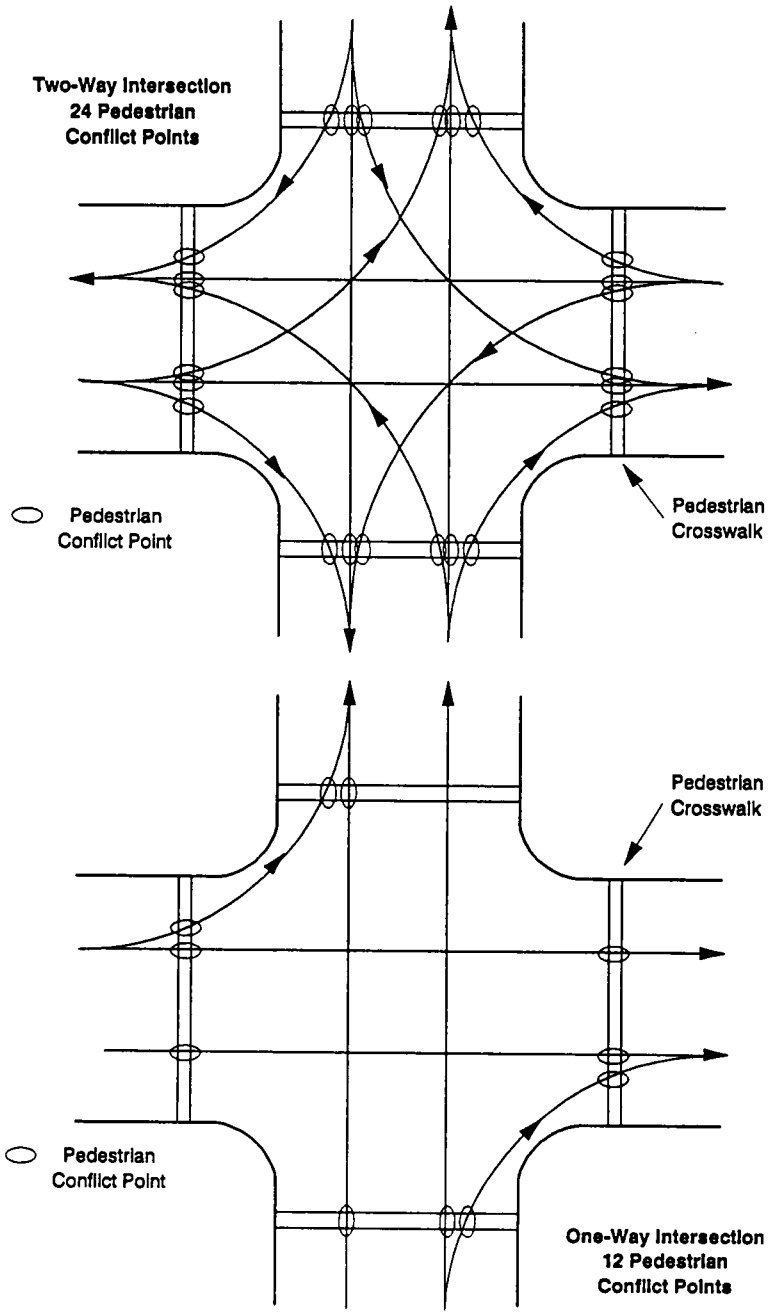



FIGURE 1. Pedestrian Conflict Points

reduced number of accidents. Headlight glare is eliminated due to unidirectional flow [4].

The operation of a street system can be greatly enhanced by one-way streets. Travel time is reduced due to improved signal progression and reduced congestion. Turning movements at intersections are unopposed in a one-way street system. Multi-lane turning movements may also be permitted. Traffic may be attracted to the one-way streets from heavily traveled adjacent two-way streets [4].

Not only is a one-way street system beneficial to traffic operations, but can also enhance economic conditions. The improved facilitation of traffic movement may bring economic benefits to adjacent land users and to the public. Improvements in capacity and a greater flexibility in meeting changing traffic patterns can be achieved with a minimum of physical changes. On-street parking prohibitions may be postponed or eliminated with this system [4].

## Disadvantages of a One-Way Street System

There are several disadvantages in the operation of a one-way street system. The possibility of wrong way turns made by unfamiliar drivers is increased [4]. Some motorists have to travel farther to reach their final

destinations. Some turning maneuvers are considered to be more difficult. For example, making a left turn onto a two-way street from the left lane of a one-way street is much more difficult than from a two-way street. The one-way street system may encourage double parking. Turning capacity is reduced as only 1/4 as many opportunities to turn are available in a grid system of one-way streets. More traffic signs are required such as one-way signs and other special signs to ensure that the motorists does not travel in the wrong direction on a one-way street.

Safety can also decrease in a one-way street system due to improper mid-block weaving by drivers positioning for an available parking space or to make a turn. Transition areas between one-way and two-way street systems are frequently more hazardous, therefore they require special traffic treatments [4].

Businesses catering to passing motoring public may be adversely affected because they depend on exposure and ease of accessibility. Businessmen usually oppose conversion to one-way movement in front of their places of business. However opposition usually disappears after a trial period. Adverse effects on businesses may especially be felt by convenient food stores, service stations, and drive-in establishments. The wider the street, the less advantage there is to be gained from one-

way movement because vehicles tend to speed due to the availability of extra maneuvering space and pedestrians have no refuge when crossing the street [12].

## Advantages of a Two-Way Street System

Two-way street systems provide the motorists with direct access to their destination. The two-way system also tends to have vehicles travelling at lowers speeds compared to the one-way system. The two-way street system may divert "through" traffic to other roads which helps reduce traffic congestion in the downtown area. Wrong way turns made by unfamiliar drivers are eliminated [6].

## Disadvantages of a Two-Way Street System

The two-way system has higher accident rates when compared to one-way system carrying similar traffic volumes. Possibilities of conflicts at intersections are greatly increased with the two-way system. There is also problems with headlight glare which are not present in the one-way system. Head-on and sideswipe accidents occur in the two-way street system. The two-way street system produces increased congestion which, in turn, lowers the level of service at which the street system operates. The number of pedestrian conflict points at intersections are increased in the two-way system [9].

## Parking

Increasingly congested traffic conditions and inadequate parking seriously threaten the economic health of communities. With increased activity and mobility, people go where and when they want, but most frequently where travel facilities best meet their requirements and convenience. On-street parking reduces traffic flow capacity and contributes to congestion. Parking will remain to be a problem to traffic flow as long as the public regards curb space as suitable and sufficient. This situation requires unusual methods to correct it.

## The Parking Issue

In many small communities, there is rarely a shortage of parking space. However, "some blocks, which show a net deficiency in space, may be adjacent or close to other blocks having a surplus of space" [11]. The extent to which the parking space deficiency of one block can be made up by the surplus of parking space of another block depends on the distance between the two blocks. There is no standard as to what constitutes a reasonable or acceptable walking distance, but the larger the city, the greater the walking distance that will be tolerated. However, Table 1 contains suggested criteria for

TABLE 1

SUGGESTED CRITERIA FOR ACCEPTABLE
WALKING DISTANCES

| Population Group (urbanized area) | Walking Distance (in feet) |
|---|---|
| Under 25,000 | 300 |
| 25,000-50,000 | 345 |
| 50,000-100,000 | 490 |
| 100,000-250,000 | 530 |
| 250,000-500,000 | 740 |
| Over 500,000 | 750 |

Source: Pignataro, Louis J. Traffic Engineering Theory and Practice. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1973.

acceptable walking distances [11]. If demand exceeds supply of parking spaces with an unacceptable walking distance - a situation detrimental to businesses occurs. Some physical factors make the downtown parking situation even more severe. Central business districts are limited in size, their boundaries often fixed by land use developed in a previous era, therefore streets cannot be widen.

To improve the economic health of downtown business by reducing traffic congestion, on-street parking will necessarily be gradually eliminated. Ultimately, whole blocks may have prohibited on-street parking to gain greater use of traffic lanes. Prohibited on-street parking may become the rule in most downtown areas [2].

Trade is the focal point of downtown parking - an important generator of traffic movement and parking demand. Merchants suffer first when parking and congestion are not relieved. Unfortunately, many merchants argue that their business is increased by having curb spaces available in front of their establishments. Curb parking prohibitions usually receive their first organized opposition from the merchants.

A study of curb-parked customers in Philadelphia, PA. gained the full support of merchants for a ban on curb parking from 8 A.M. to 6 P.M. on nearly all the downtown

one-way streets. The additional lane capacity eased the general traffic flow and improved customer-access to stores. After a year of operation, follow-up studies showed vehicle operating speeds increased by 42 to 51 percent. Operating speeds for trolleys and buses had increased by 27 to 40 percent [2]. Some merchants mistake traffic congestion as a sign of good business. They fail to foresee the consequences when access to an area is retarded by traffic and parking conditions.

## Accidents Involving Parked Vehicles

Cars in the process of parking and unparking at the curb create accident hazards. Studies show that accidents involving parking or parked cars account for approximately one-tenth of all accidents in the C.B.D. [2]. Of these accidents, the highest number of parking accidents involves cars moving away from the curb. Cars slowing to park, double-parked, and backing into curb spaces account for most other parking accidents.

The parked car also contributes to pedestrian accidents. Regularly, eight to ten percent of all pedestrian fatalities involve persons entering the roadway from behind or between parked cars. Approximately the same percentage of pedestrian injury-accidents occurs under those conditions.

Due to the various methods of keeping city accident records, it is difficult to compile data illustrating the full importance of parked car accidents. However, the available records indicate that parked cars cause enough accidents to justify careful study of parking improvements from the standpoint of accident hazard. Because of the public's concern, it is often possible to enlist support for parking proposals on the basis of accident facts.

## Parking Space Arrangements

There have been several studies performed in order to determine which type of parking space arrangement, angle or parallel, is safer. The various types of parking space layouts are shown in Figure 2. "An important and surprising fact is that parking configuration did not emerge as a variable that in itself was related to accident rate" [7]. Increased parking use was found to result in higher accident rates at the same location.

Studies in nine Utah cities showed that changing from angle parking to parallel parking reduced parking accidents by 57 percent. A similar study in Salem, Oregon revealed a 65 percent reduction in parking accidents [7]. Ten reports on angle parking were unanimous in finding extremely high frequencies of accidents compared with parallel parking.

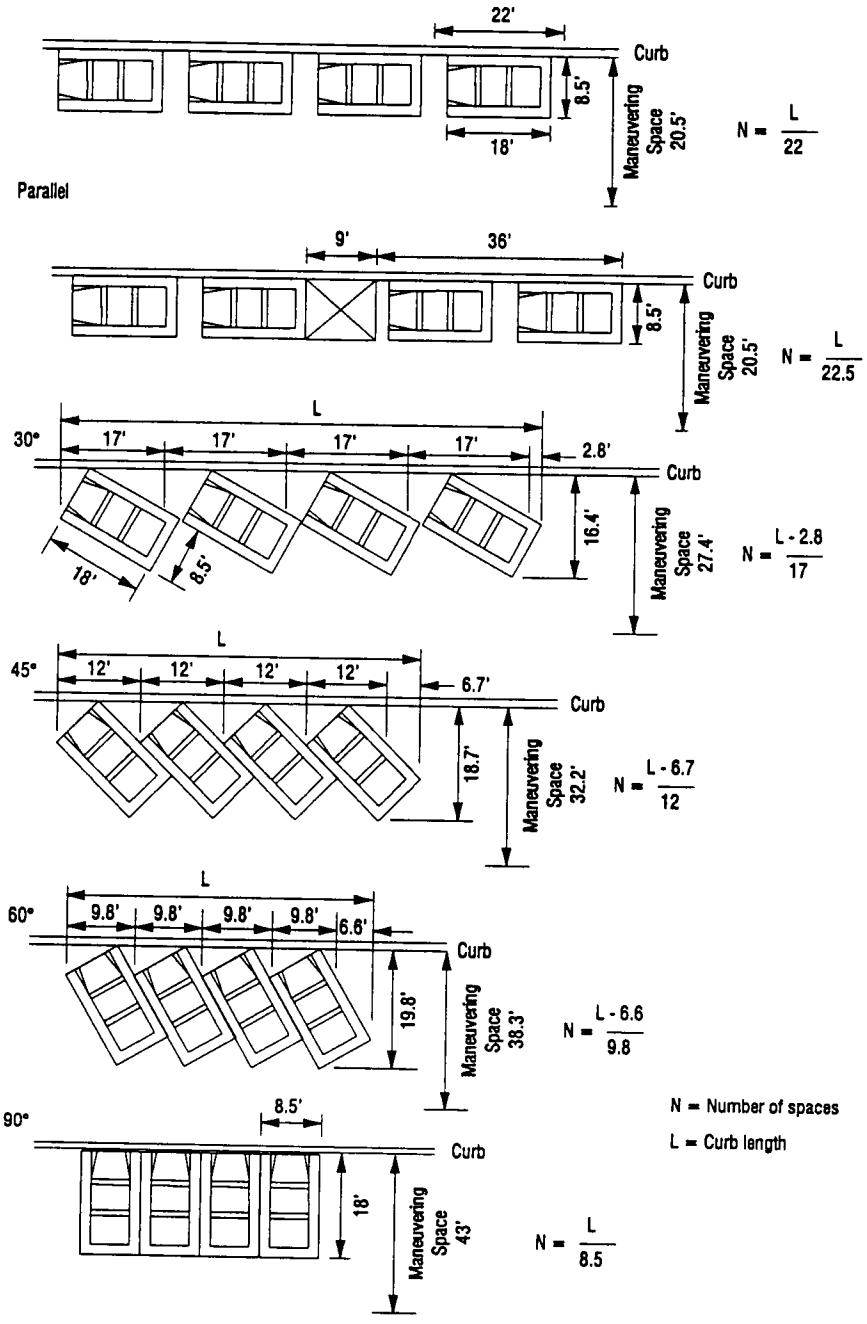



FIGURE 2. Curb Parking Geometry

Many studies have found that the removal of angle parking reduces accidents. The accident reduction rate varied from 19 to 63 percent for various study locations when angle parking was replaced with parallel parking [14]. Results of the before and after studies are summarized in Table 2. A study of 1,523 urban parking spaces in Maine found that parallel parking had an accident rate 12 percent lower than angle parking [14].

Flat angle parking may have benefits in aspects of safety and delay characteristics. This type of angle parking differs from the more conventional angle parking in that the spaces are laid out at an angle of 22.5 degrees to the curb. A diagram of the flat angle parking configuration is shown in Figure 3. The following are advantages to flat angle parking:

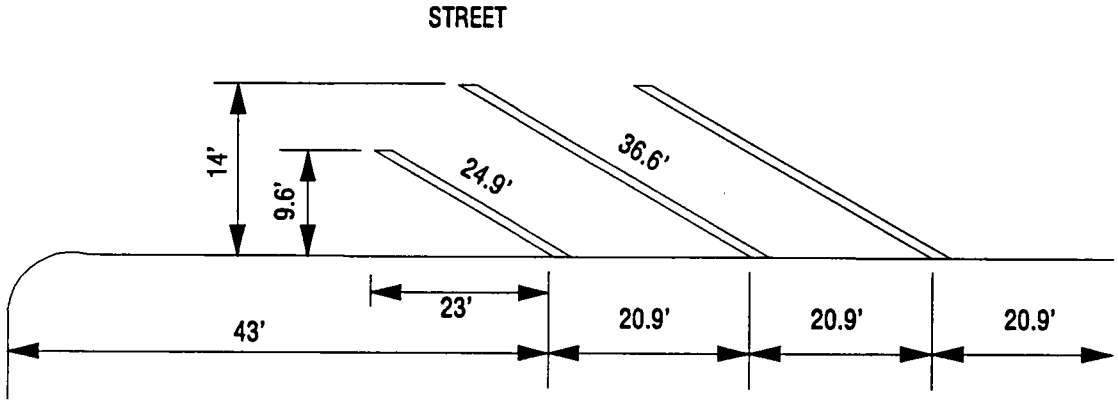
1. Flat angle parking does not adversely affect the safety or capacity of travel lanes when compared with parallel parking. This is true provided adequate widths for travel lanes are available.
2. Flat angle parking is safer for pedestrians entering or leaving parked vehicles.
3. Flat angle parking disrupts traffic flow less than parallel parking.

TABLE 2

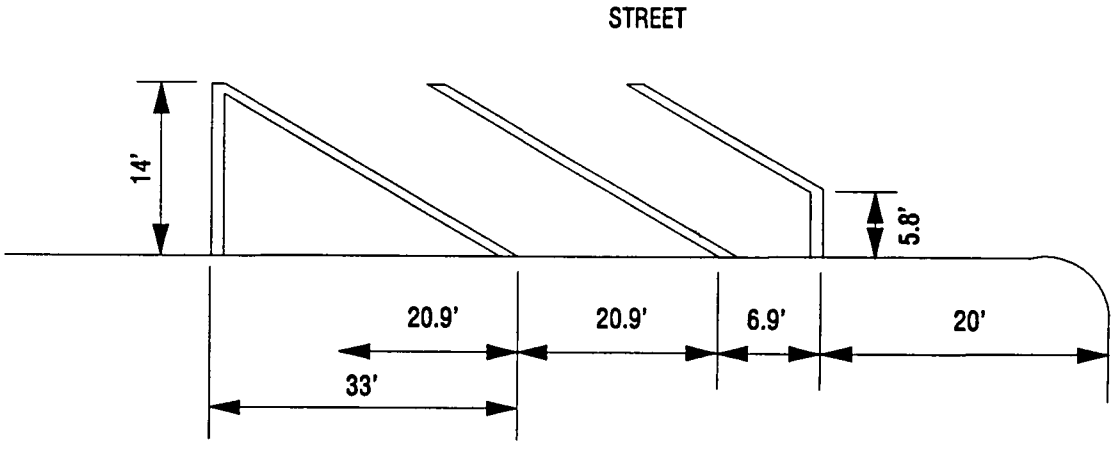
SUMMARIES OF BEFORE-AFTER STUDIES INVOLVING A CHANGE FROM ANGLE TO PARALLEL PARKING

| Study Location | Report Year | Accident Reduction |
|---|---|---|
| Minnesota City | 1947 | 47% |
| Wichita, KS | 1950 | 63% |
| Grand Rapids, MI | 1967 | 19% |
| Kansas City, MO | 1967 | 50% |

Source: Weant, Robert A., Herbert S. Levinson. Parking. The Eno Foundation for Transportation, Inc., Westport, Connecticut, 1990.




(A) 22.5° Angle Parking




(B) 22.5° Angle Parking

FIGURE 3. Typical Flat-Angle Parking Layouts

Angle parking requires greater street maneuvering and parked-vehicle space than parallel parking. Angle parking has higher accident rates than parallel parking at the same location. When there are major streets and minor streets in the downtown area, generally, angle parking is used on the minor streets carrying the slower moving traffic and parallel parking is used on the major streets. HCM and other traffic engineering manuals recommend parallel parking for any on-street parking adjacent to traveled lanes [7].

## Economic Losses Due to Parking

Parking shortages hamper a city. Failure to provide parking in business areas denies access to motor-vehicle users. Inadequate parking spaces result in excessive cruising and increased congestion. Delay forces drivers to park far from their destinations and, like traffic congestion, interferes with a desirable pattern of city development. Parking shortages and poor locations, combined with congestion, induce customers and business to drift away from central business districts and their long-established commercial facilities [2]. For example, many people are giving up the hectic chore of shopping in downtown for the more convenient shopping malls and plazas.

## CHAPTER III

## DESCRIPTION OF DOWNTOWN ELIZABETHTON

The study area is located in the central business district of Elizabethton, TN., which is a small town of approximately 11,900 people located in upper East Tennessee. Elizabethton's downtown comprises businesses such as small specialty retail shops, restaurants, and financial institutions. Everything in the downtown core area is within a few blocks walking distance.

Overall the streets of downtown Elizabethton follow the grid pattern. At the core of the downtown area (Figure 4) is a pair of one-way streets with the northern street, E (3 lanes), going westbound and the southern street, Elk (3 lanes), going eastbound. There are three streets and an alley way (Post Office Street) that run perpendicular to these two streets. These north-south streets are Sycamore (3 lanes), Pine (2 lanes), and Elm (2 lanes). Pine is a one-way street. Another alley runs east-west in between E Street and Elk Avenue. This alley provides rear door access to some of the downtown businesses. There are two major roads which by-pass the downtown. These are Broad Street (Highway 67-321-19-E) to the north and Main Street to the east.

There is on-street parking throughout the central business district with parking spaces on both sides of the

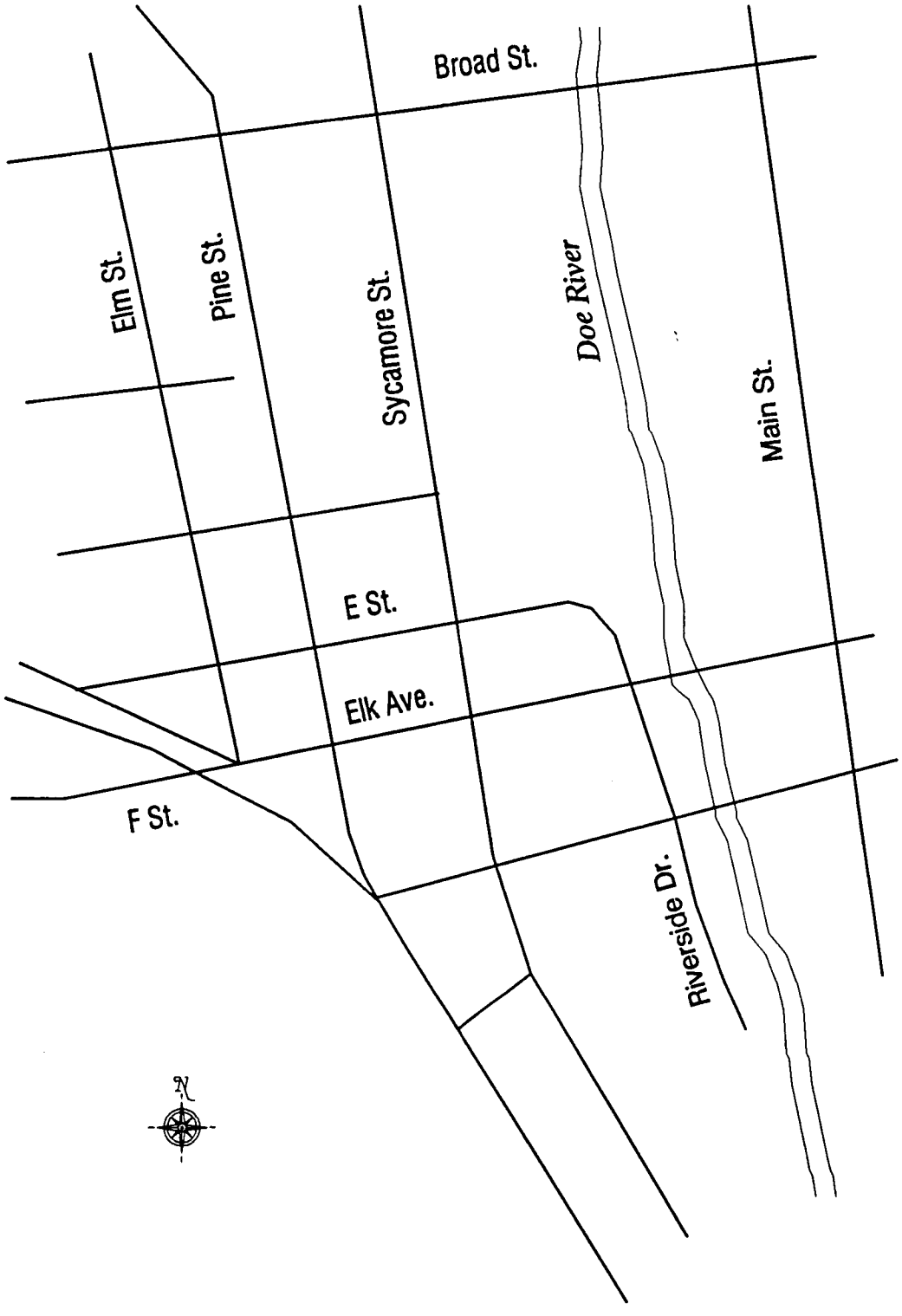


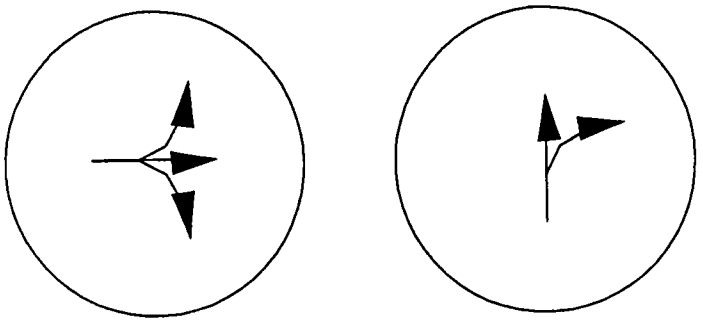

FIGURE 4. Core Area

street for most streets. Most of the on-street parking is parallel parking with some along E Street between Elk and Sycamore being angle parking. There are also four off-street parking lots adjacent to Elk Avenue and E Street. Additional off-street lots are available within a few blocks of the core area. Both, the on-street spaces and the off-street parking lots, are free to the general public with no time restrictions.

There are five key intersections which will be analyzed in detail. Three of these intersections are signalized, while the remaining two are controlled with stop and yield signs. The signalized intersections are E and Sycamore, Elk and Sycamore, and Elk and Pine and the existing phasing pattern for them is shown in Figure 5. The unsignalized intersections are Elk and Riverside and Elk, Elm, and F Street. The geometrics of all these intersections are shown in Figures 6 thru 10. The average daily traffic flows for E, Elk, and Sycamore were found to be 3380, 3850, and 4135 vehicles per day respectively.

## Field Observations

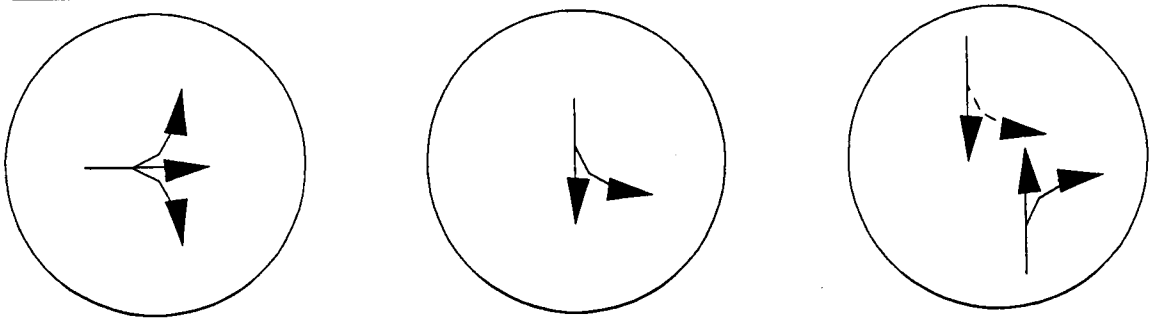
An important part of a traffic study is to conduct field observations to determine the cause and extent of traffic problems. Field observations revealed that the railroad tracks on Elk Avenue, near Pine, are very rough



PHASE A
Green = 32 sec.
Yellow = 4 sec.

PHASE B
Green = 27 sec.
Yellow = 24 sec.

ELK/PINE ST. Cycle Length = 87 sec.

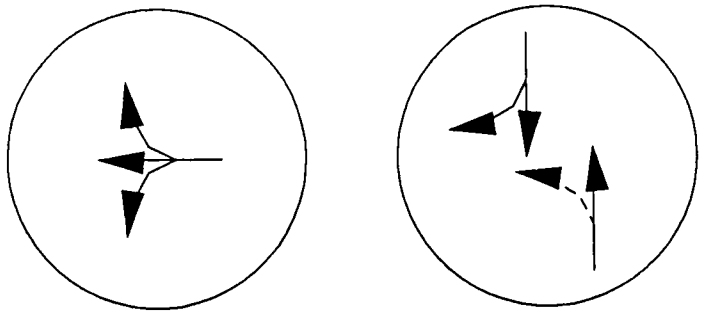


PHASE A
Green = 17 sec.
Yellow = 4 sec.

PHASE B
Green = 17 sec.
Yellow = 4 sec.

PHASE C
Green = 16 sec.
Yellow = 24 sec.

ELK/SYCAMORE ST. Cycle Length = 82 sec.



PHASE A
Green = 31 sec.
Yellow = 4 sec.

PHASE B
Green = 31 sec.
Yellow = 4 sec.

E/SYCAMORE ST Cycle Length = 70 sec.

FIGURE 5. Phase Pattern For Existing One-Way System

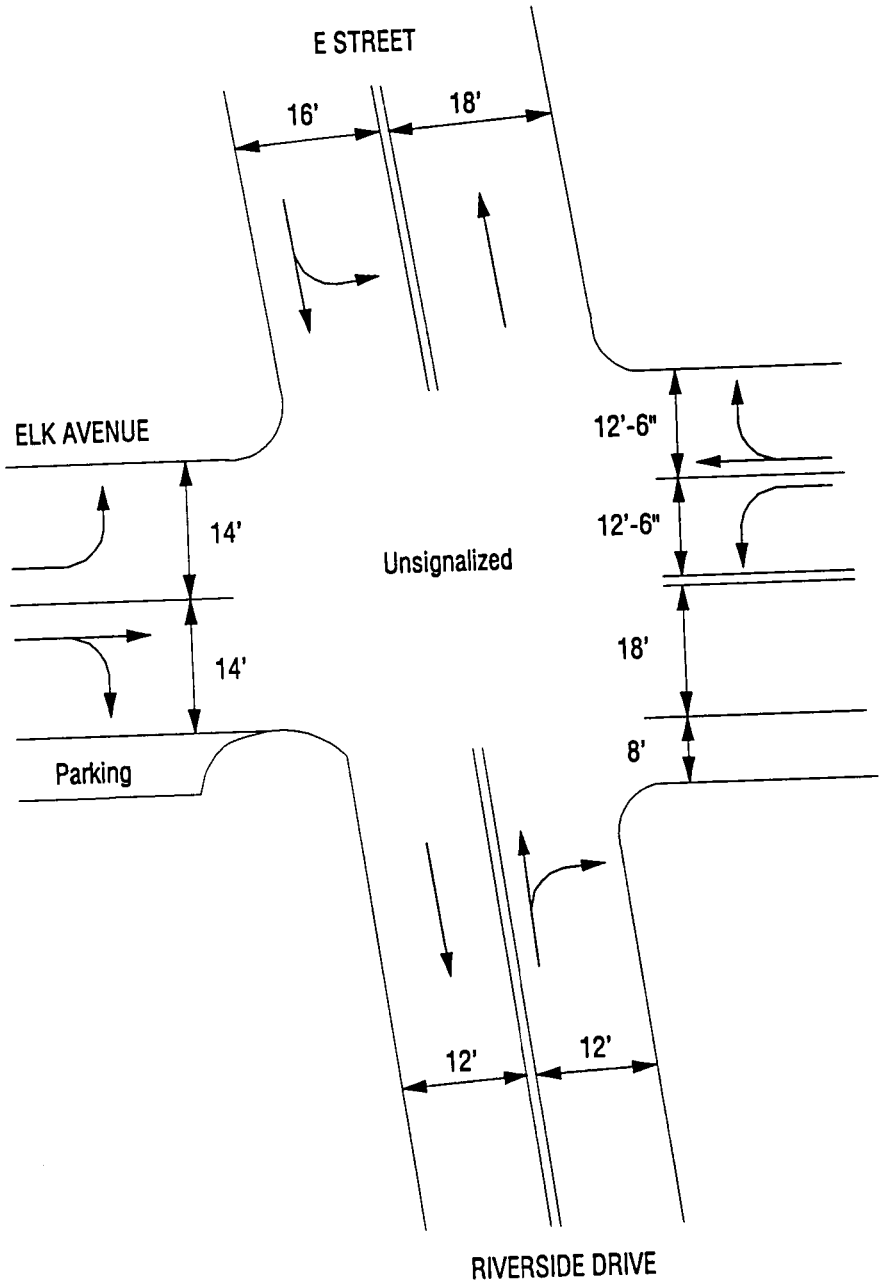



FIGURE 6. Geometrics of Elk Avenue and Riverside Drive For The Existing One-Way System

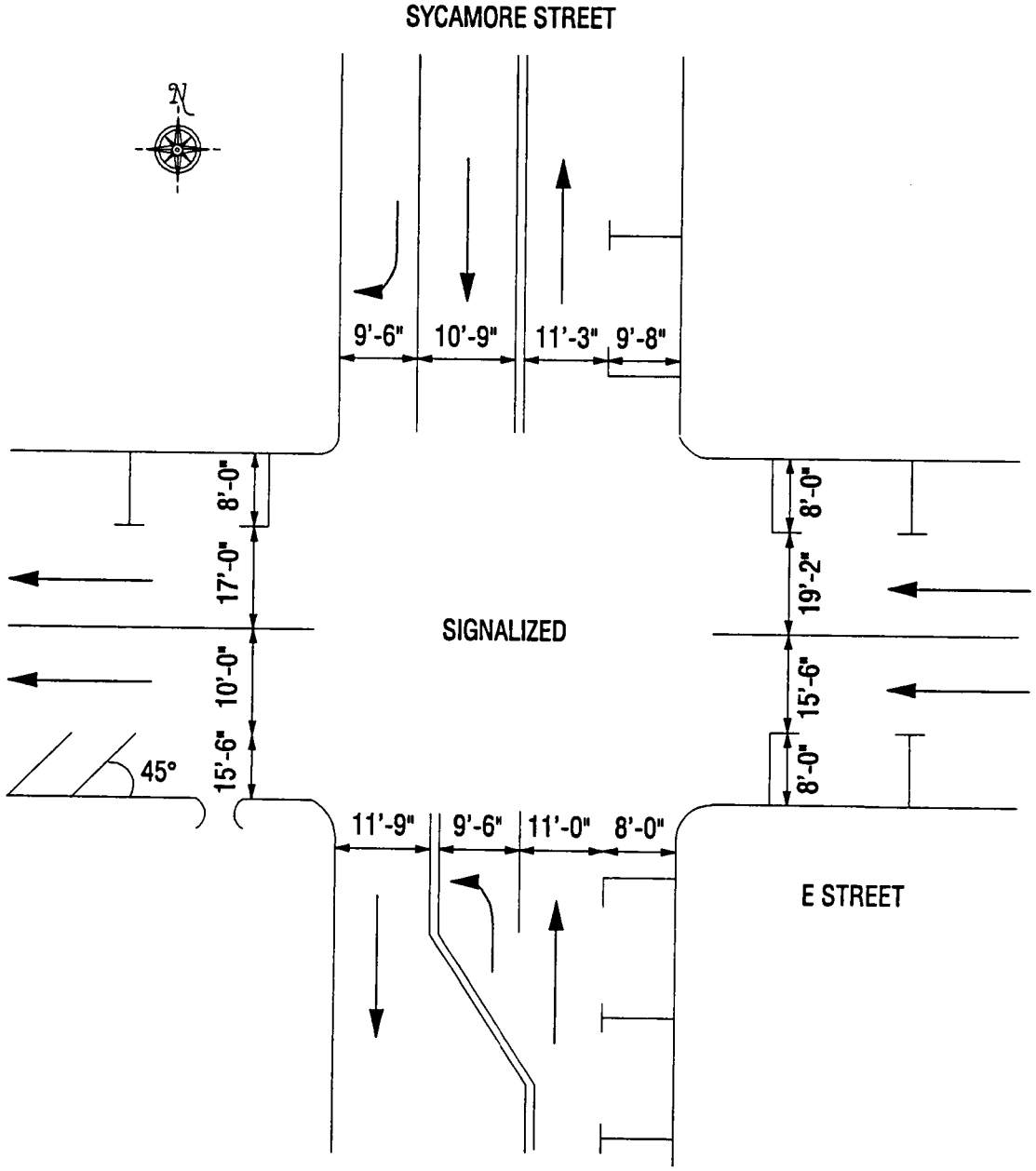



FIGURE 7. Geometrics of E Street and Sycamore Street For The Existing One-Way System

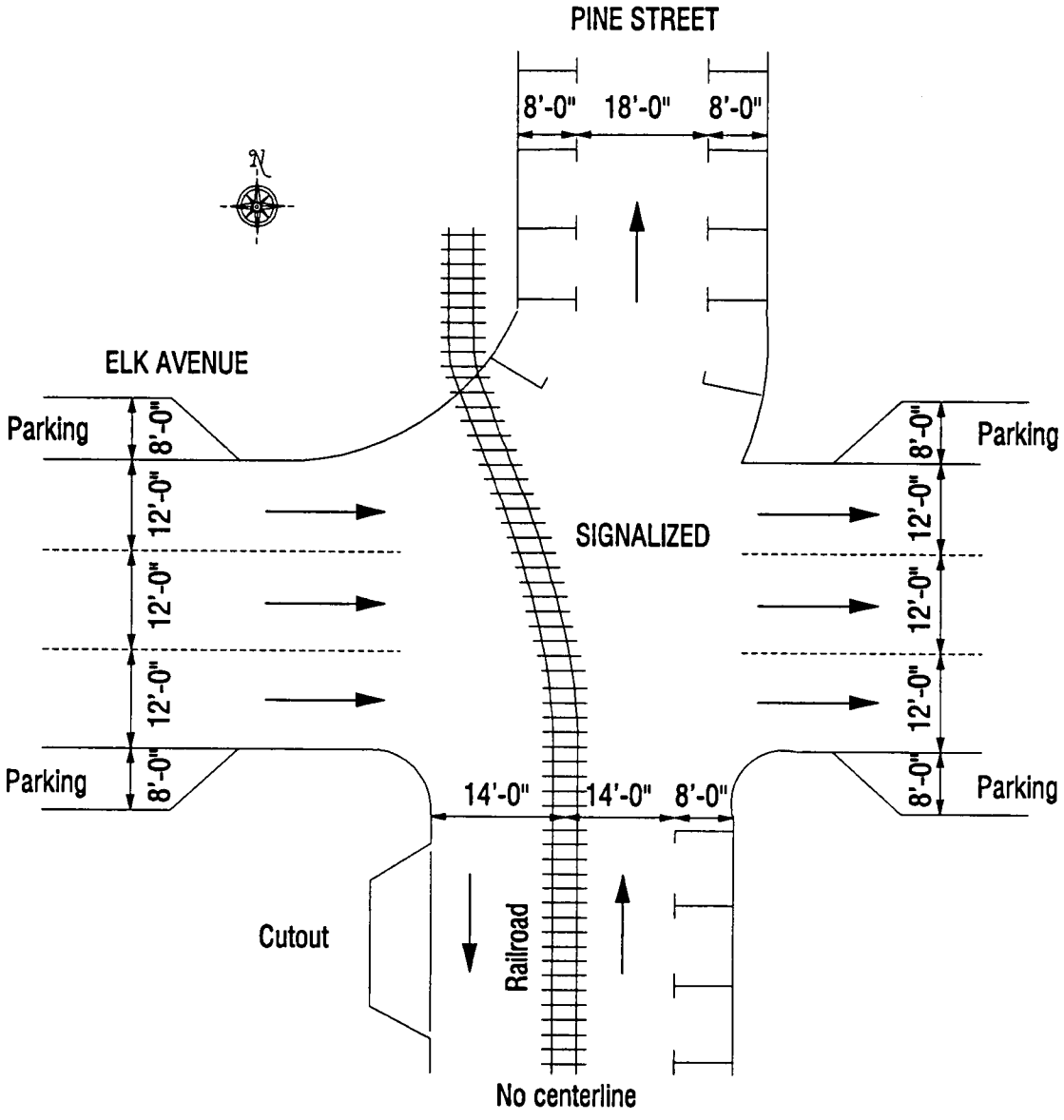



FIGURE 8. Geometrics of Elk Avenue and Pine Street For The Existing One-Way System

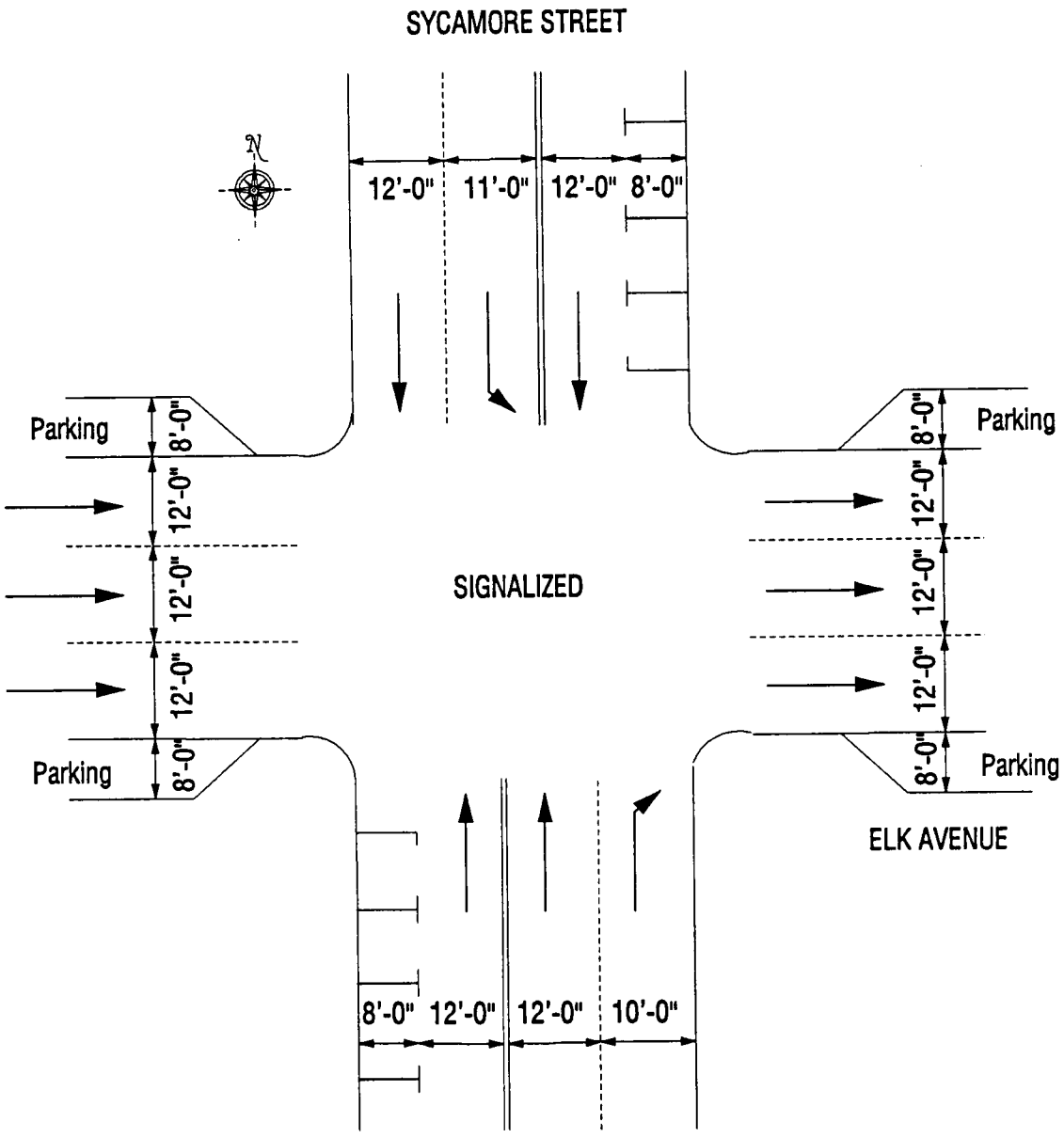



FIGURE 9. Geometrics of Elk Avenue and Sycamore Street For The Existing One-Way System

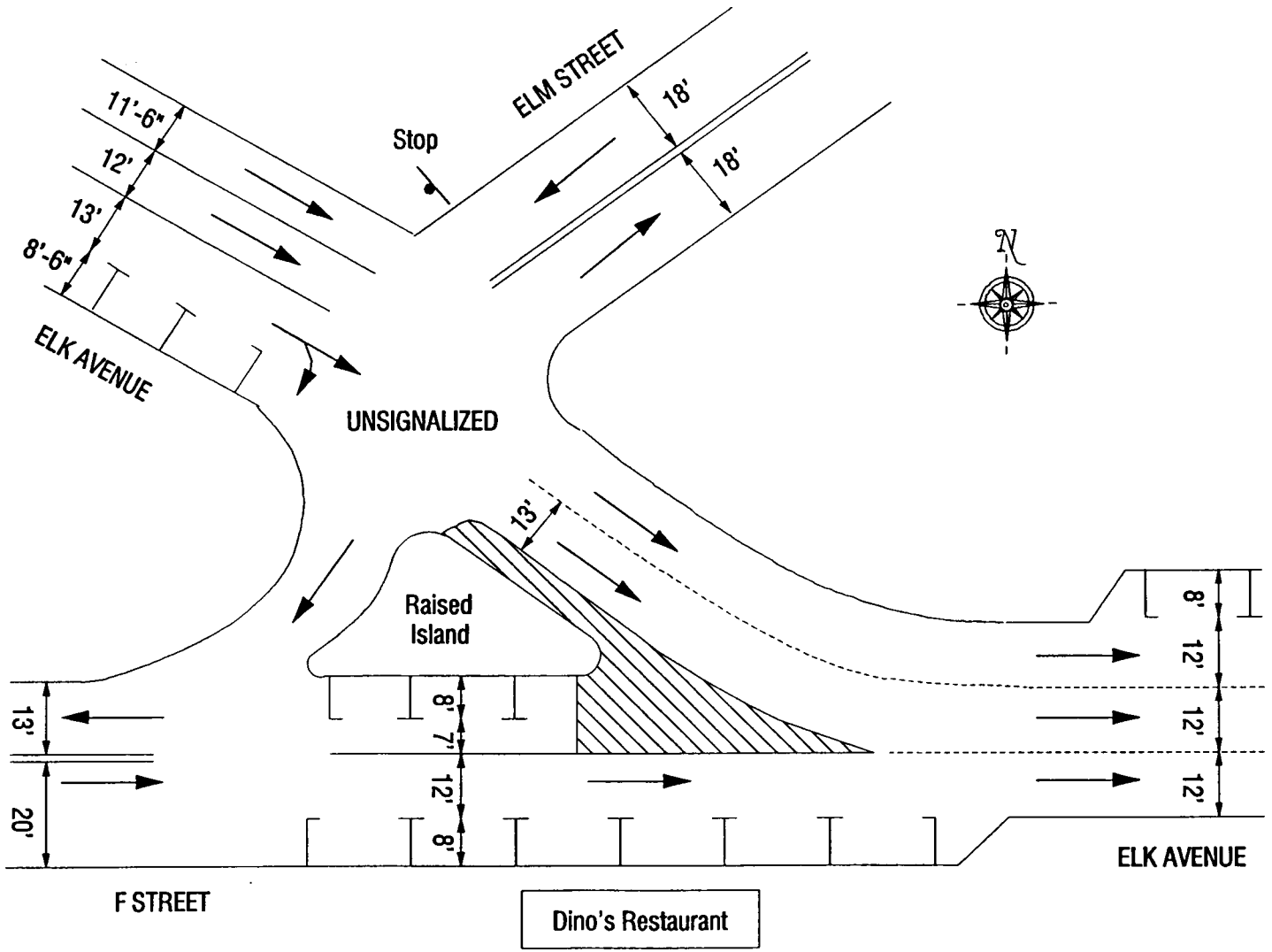



FIGURE 10. Geometrics of Elk, Elm, and F Street For The Existing One-Way System

and tend to slow down vehicles. A potential sight distance problem has also emerged for vehicles on Pine Street crossing E Street since the removal of the traffic signal at E and Pine Street. The one-way system is also confusing as merchants reported that at least one vehicle per week is observed traveling in the wrong direction on E Street.

There are no designated loading zones in the downtown area. One traffic lane gets blocked by on-street loading/unloading maneuvers performed by trucks. This practice of using a regular travel lane by freight vehicles for loading was frequently observed on Elk Avenue. In some cases a lane is blocked for 45 to 60 minutes. Loading is done via front doors of businesses instead of via rear doors. One of the reasons for this practice is that the alley way is difficult to use.

The 20 seconds - all red phase at the intersection of Pine and Elk and Sycamore and Elk is not being utilized by the pedestrians. Pedestrian movement was noticed to be very casual. Pedestrians do not observe the walk, don't walk indications at the crosswalks.

## Problems - Merchants' Interviews

In order to determine the general perception of traffic operations and parking issues in the downtown

area, 64 merchants were contacted. All the personal interviews were conducted at the business establishments and included the owner, resident manager, or individual clerk if this was the only representative available. Most interviews involved owners or business managers. The merchants interviewed all had business establishments located along E, Elk, or Pine Street. The merchants agree that downtown Elizabethton is a good place to do business. It is attractive, clean, and orderly. But, there are some issues which concern the merchants. Table 3 shows the primary problems/issues obtained from the merchants' interviews.

Insufficient parking spaces was identified as the major complaint of the downtown merchants of Elizabethton. Fifty-nine percent of the merchants' interviewed suggest that more parking is needed. It was felt that parking privileges are being abused because parking spaces do not turnover sufficiently. The merchants stated that their customers claim off-street parking lots are always full and it is difficult to find a space.

Another problem noted by 22 percent of the merchants is the lack of exposure the businesses on Elk Avenue are getting from the motorists traveling westbound on E Street. It is difficult for traffic from the east to get to Elk Avenue businesses, especially the 600 block, with

TABLE 3

MERCHANT/BUSINESS INTERVIEWS
(64 Interviewed)

| Problems/Issues | Percentage Mentioning As An Issue |
|---|---|
| Need more parking | 59 |
| Difficult access to CBD<br>Circulation<br>Access signing | 22 |
| On-street loading | 20 |
| Traffic signals | 14 |
| Speeding | 17 |

the one-way street pattern. This leads to excessive circulation in the downtown. Also the approach to the downtown is perceived as being negative because there is a "Do Not Enter" sign at the beginning of the one-way street pattern at the east and west entry points to downtown. It is also difficult to find the downtown due to the fact that the access to downtown is not well signed.

Traffic speeding through downtown is also a major concern as stated by 17 percent of the interviewed merchants. Vehicles travel at excessive speeds on Elk Avenue, especially during the afternoon. Fourteen percent think that improper operation of traffic signals may be a problem. The traffic signals are points of delay and the drivers get impatient by the all red phase. Twenty percent of the merchants stated that on-street loading is a problem. Trucks loading and unloading on the street disturbs traffic flow. Alleys are not generally used by patrons or goods delivery companies.

The merchants were also asked about their attitude towards establishing a two-way system on E Street and Elk Avenue. Forty-three percent stated they were in favor of changing E Street and Elk Avenue to a two-way system. Forty percent stated they prefer the system as it is and 17 percent were not sure as to whether or not to change to a two-way system. The next chapter discusses improving

existing conditions of the one-way system in downtown Elizabethton.

# CHAPTER IV

# ANALYSIS OF EXISTING CONDITIONS

## Capacity and Level of Service of Intersections

Capacity and level of service for key intersections in the downtown area were evaluated for the existing one-way street system. This was accomplished by using the 1985 Highway Capacity Software. There are five intersections which represent critical points for expediting the flow of traffic through the downtown area. These intersections are circled in Figure 11 and are as follow:

1. Elk/Riverside - unsignalized
2. Elk/Sycamore - signalized
3. E/Sycamore - signalized
4. Elk/Pine - signalized
5. Elk/Elm/F - unsignalized

Existing peak hour turning movements obtained on October 14, 1992 for the A.M., Mid-day, and P.M. time periods are presented for the existing one-way street system in Tables 4 through 6. These are the volumes which were used to evaluate the Level of Service of existing conditions. Table 7 shows the Level of Service of each of

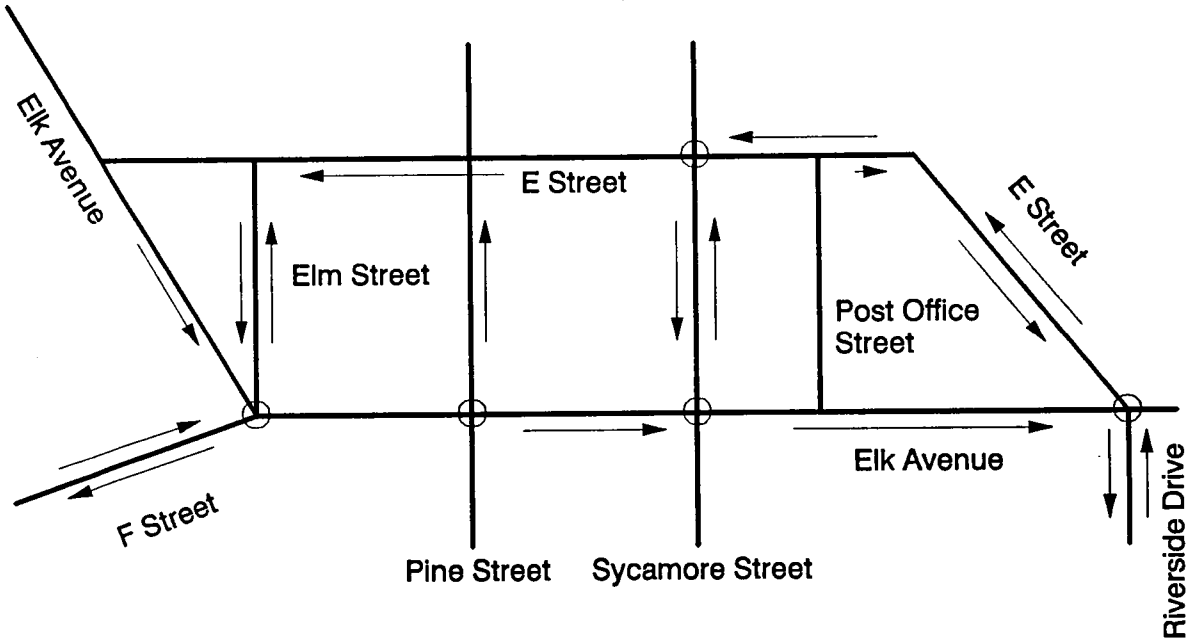



FIGURE 11. Intersections Analyzed

TABLE 4

EXISTING TRAFFIC VOLUMES OF
THE AM PEAK TIME PERIOD
(IN VEH./HR.)

| Intersection | Movement | EB | WB | NB | SB |
|---|---|---|---|---|---|
| Elk/Pine | LT | 27 | 0 | 0 | 0 |
| | TH | 196 | 0 | 10 | 0 |
| | RT | 45 | 0 | 18 | 0 |
| | RR | 0 | 0 | 2 | 0 |
| Elk/Sycamore | LT | 41 | 0 | 0 | 37 |
| | TH | 151 | 0 | 76 | 47 |
| | RT | 41 | 0 | 49 | 0 |
| | RR | 8 | 0 | 8 | 0 |
| ElK/Riverside | LT | 7 | 153 | 0 | 2 |
| | TH | 89 | 0 | 13 | 8 |
| | RT | 8 | 228 | 53 | 0 |
| Elk/Elm/F | LT | 25 | 0 | 0 | 37 |
| | TH | 172 | 0 | 0 | 29 |
| | RT | 8 | 0 | 82 | 0 |
| E/Sycamore | LT | 0 | 28 | 36 | 0 |
| | TH | 0 | 187 | 71 | 66 |
| | RT | 0 | 60 | 0 | 34 |
| | RR | 0 | 19 | 0 | 8 |

TABLE 5

EXISTING TRAFFIC VOLUMES OF
THE MID-DAY PEAK TIME PERIOD
(IN VEH./HR.)

| Intersection | Movement | EB | WB | NB | SB |
|---|---|---|---|---|---|
| Elk/Pine | LT | 66 | 0 | 0 | 0 |
| | TH | 364 | 0 | 27 | 0 |
| | RT | 78 | 0 | 26 | 0 |
| | RR | 4 | 0 | 0 | 0 |
| Elk/Sycamore | LT | 72 | 0 | 0 | 41 |
| | TH | 257 | 0 | 135 | 77 |
| | RT | 62 | 0 | 49 | 0 |
| | RR | 16 | 0 | 8 | 0 |
| ElK/Riverside | LT | 22 | 143 | 0 | 19 |
| | TH | 202 | 0 | 35 | 17 |
| | RT | 46 | 233 | 46 | 0 |
| Elk/Elm/F | LT | 25 | 0 | 0 | 67 |
| | TH | 278 | 0 | 0 | 52 |
| | RT | 23 | 0 | 126 | 0 |
| E/Sycamore | LT | 0 | 41 | 82 | 0 |
| | TH | 0 | 252 | 117 | 93 |
| | RT | 0 | 72 | 0 | 47 |
| | RR | 0 | 17 | 0 | 8 |

TABLE 6

EXISTING TRAFFIC VOLUMES OF
THE PM PEAK TIME PERIOD
(IN VEH./HR.)

| Intersection | Movement | EB | WB | NB | SB |
|---|---|---|---|---|---|
| Elk/Pine | LT | 89 | 0 | 0 | 0 |
| | TH | 441 | 0 | 30 | 0 |
| | RT | 89 | 0 | 29 | 0 |
| | RR | 0 | 0 | 0 | 0 |
| Elk/Sycamore | LT | 93 | 0 | 0 | 29 |
| | TH | 325 | 0 | 110 | 89 |
| | RT | 62 | 0 | 57 | 0 |
| | RR | 16 | 0 | 3 | 0 |
| ElK/Riverside | LT | 25 | 160 | 0 | 17 |
| | TH | 270 | 0 | 27 | 15 |
| | RT | 57 | 250 | 75 | 0 |
| Elk/Elm/F | LT | 23 | 0 | 0 | 82 |
| | TH | 353 | 0 | 0 | 61 |
| | RT | 13 | 0 | 160 | 0 |
| E/Sycamore | LT | 0 | 30 | 71 | 0 |
| | TH | 0 | 252 | 126 | 128 |
| | RT | 0 | 65 | 0 | 41 |
| | RR | 0 | 18 | 0 | 11 |

TABLE 7

LEVEL OF SERVICE OF KEY INTERSECTIONS
(Existing Conditions)

| Peak Time Period | Intersection | LOS | Delay/Veh.(sec.) |
|---|---|---|---|
| A.M. | Elk/Riverside | A | Unsignalized |
| | Elk/Sycamore | C | 15.7 |
| | Elk/Pine | B | 13.2 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 8.5 |
| MID-DAY | Elk/Riverside | A | Unsignalized |
| | Elk/Sycamore | C | 16.6 |
| | Elk/Pine | B | 14.3 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 8.8 |
| P.M. | Elk/Riverside | A | Unsignalized |
| | Elk/Sycamore | C | 17.7 |
| | Elk/Pine | B | 14.9 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 8.8 |

the five intersections. An average delay per vehicle value is also shown for each intersection for each peak time period. This represents the delay a vehicle might experience when traveling through a particular intersection during one of the peak time periods. The analysis of the existing situation revealed good traffic conditions. The worst Level of Service was found to be C at the intersection of Elk and Sycamore during all three peak time periods. For urban areas a Level of Service of C or better is considered acceptable.

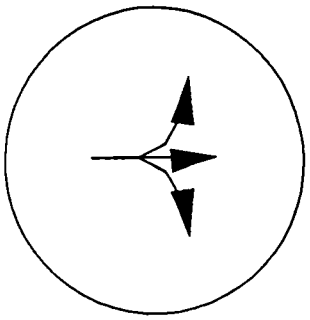
From field studies it became evident that the signal on Elk and Sycamore has an all red pedestrian phase (Chapter 3 - Figure 5) which was not well utilized by pedestrians and created excessive vehicle delay. For example, when driving a test vehicle through the downtown area, the time required to make a loop trip in downtown is 3 minutes and 24 seconds, and it was observed that 54 percent of the delay was at the signals. There was substantial traffic delays at the signalized intersections of Pine and Elk and Sycamore and Elk. It is difficult to travel through Elk Avenue without getting stopped at one of the traffic signals.

Thus, the next step was to explore opportunities to improve the level of service by retiming the signals at the three signalized intersections. A new phasing plan

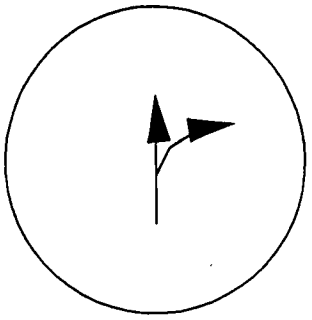
was developed and is shown in Figure 12 with the phase times and cycle lengths. The results of the analysis are shown in Table 8. Retiming the signals improved the level of service of two out of the three signalized intersections and decreased the amount of stopped delay per vehicle at all three intersections. Therefore, some of the delay problems currently experienced by vehicles can be solved by retiming the signals and eliminating the all red phase. After retiming the signals, all of the signalized intersections were operating at a level of service of B or higher. The unsignalized intersections of Elk, Elm, and F and Elk and Riverside are operating at a level of service of A.

## Parking Analysis

Some of the businesses stated that their customers claim there is an inadequate supply of parking in the downtown area. According to them, the existing parking lots are too far away and people do not want to walk long distances. Therefore, the merchants fear that if potential customers do not find a space they will just drive away. It was found that all of the off-street parking lots are within a reasonable walking distance of 300 feet or less to the downtown businesses. Also, it is argued that on-street parallel parking is difficult for people to use, especially the elderly people.

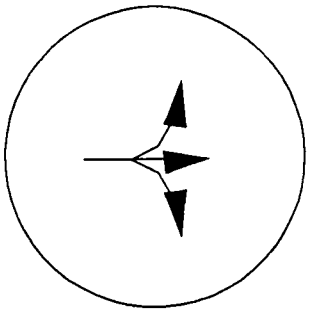


PHASE A
Green = 31 sec.
Yellow = 4 sec.

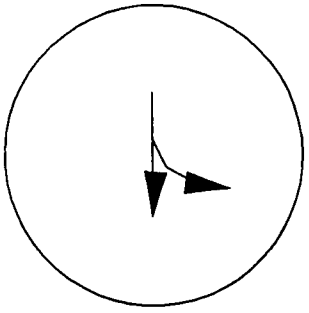


PHASE B
Green = 11 sec.
Yellow = 4 sec.

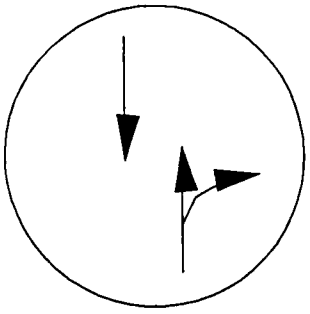
ELK/PINE ST. Cycle Length = 50 sec.



PHASE A
Green = 16 sec.
Yellow = 4 sec.

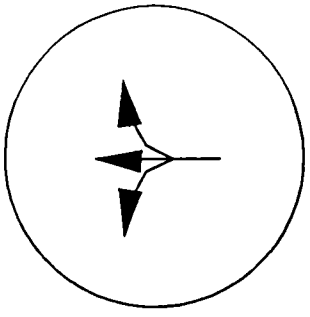


PHASE B
Green = 11 sec.
Yellow = 4 sec.

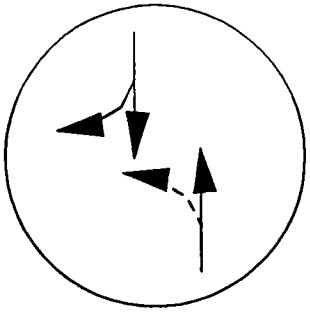


PHASE C
Green = 11 sec.
Yellow = 4 sec.

ELK/SYCAMORE ST. Cycle Length = 50 sec.



PHASE A
Green = 21 sec.
Yellow = 4 sec.



PHASE B
Green = 21 sec.
Yellow = 4 sec.

E/SYCAMORE ST Cycle Length = 50 sec.

FIGURE 12. Phase Pattern of Retimed Signals

TABLE 8

LEVEL OF SERVICE OF KEY INTERSECTIONS
(Existing Conditions with Signal Retiming)

| Peak Time Period | Intersection | LOS | Delay/Veh.(sec.) |
|---|---|---|---|
| A.M. | Elk/Riverside | A | Unsignalized |
| | Elk/Sycamore | B | 9.3 |
| | Elk/Pine | A | 3.4 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 6.5 |
| Mid-day | Elk/Riverside | A | Unsignalized |
| | Elk/Sycamore | B | 9.6 |
| | Elk/Pine | A | 3.6 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 6.7 |
| P.M. | Elk/Riverside | A | Unsignalized |
| | Elk/Sycamore | B | 9.6 |
| | Elk/Pine | A | 3.7 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 6.7 |

An inventory of the existing parking spaces was taken in order to determine the supply of parking available in the downtown area. On-street or curb-parking is available throughout the central business district. Throughout most of downtown, on-street parking can be found on both sides of the street. In the core area, the number of on-street parking available is 226 spaces, most of these are parallel parking with a few angle parking.

There are a total of four off-street parking lots with 103 spaces immediately adjacent to Elk Avenue and E Street available to the public (Figure 13). All downtown parking is free of charge and has no time restrictions. More off-street lots are available within a few blocks of the core area. A parking use survey was performed on October 15, 1992 from 9 A.M. to 5 P.M. The analysis of the survey data generated accumulation patterns, turn-over rates, occupancy, etc.

A parking accumulation analysis was performed for both the on-street and off-street parking. The analysis shows that for the most part the number of vehicles parked per 30 minute time period is relatively constant throughout the day. The values are given in Table 9 which notes the parking accumulation pattern. The parking accumulation peaks were found to be at the time periods of

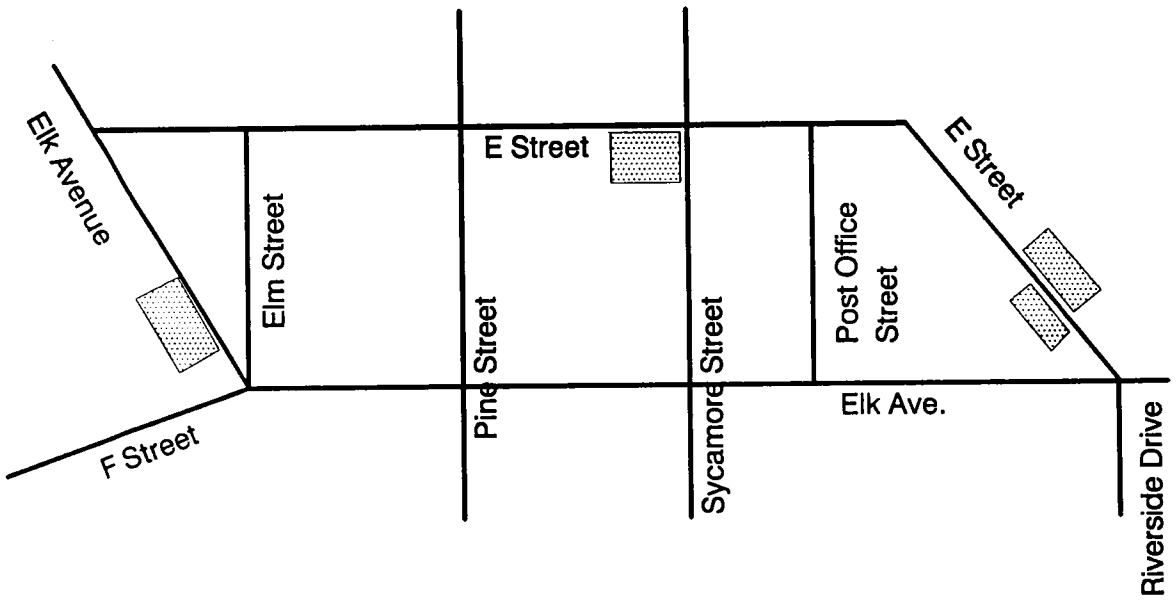



FIGURE 13. Off-Street Parking Lots

TABLE 9

PARKING ACCUMULATION

| Time | On-Street | Off-Street | Total | Occupancy (%) |
|---|---|---|---|---|
| 9:30 | 122 | 67 | 189 | 57.45 |
| 10:00 | 125 | 69 | 194 | 58.97 |
| 10:30 | 124 | 66 | 190 | 57.75 |
| 11:00 | 129 | 67 | 196 | 59.57 |
| 11:30 | 130 | 68 | 198 | 60.18 |
| 12:00 | 142 | 69 | 211 | 64.13 |
| 12:30 | 133 | 71 | 204 | 62.01 |
| 1:00 | 116 | 61 | 177 | 53.80 |
| 1:30 | 129 | 69 | 198 | 60.18 |
| 2:00 | 119 | 61 | 180 | 54.71 |
| 2:30 | 124 | 63 | 187 | 56.84 |
| 3:00 | 140 | 68 | 208 | 63.22 |
| 3:30 | 134 | 63 | 197 | 59.88 |
| 4:00 | 132 | 64 | 196 | 59.57 |
| 4:30 | 119 | 56 | 175 | 53.19 |
| Total Available = | 226 | 103 | | |

12:00-12:30 P.M. and 3:00-3:30 P.M. with an occupancy rate of 64 percent for both time periods (Figure 14).

Three statistics were calculated to characterize the nature of parking use in the downtown area. These are turn-over rates, average duration, and occupancy rates. Turnover refers to the average numbers of vehicles using each space during the main parking demand period. Results of the survey determined that 957 vehicles utilized the on-street parking spaces from the time period of 9 A.M. to 5 P.M. The turnover rate for the available on-street parking is 4.23 vehicles/space. The average duration that each vehicle spent in a space is 1.01 hours. The composite occupancy rate of 57 percent between 9 A.M. and 5 P.M. indicates that downtown parking spaces are not being utilized to the full extent possible. However, considering each block face the occupancy rates on Elk Avenue blocks were found to be higher than those on other blocks. The two blocks on Elk between Pine and Riverside have an occupancy of greater than 84 percent. By comparison the parking supply on E Street is adequate with occupancy rates being no higher than 56 percent. A break down of on-street parking statistics by block face is presented in Figures 15 and 16. One of the major problems with the downtown parking situation in Elizabethton is that the on-street parking spaces do not

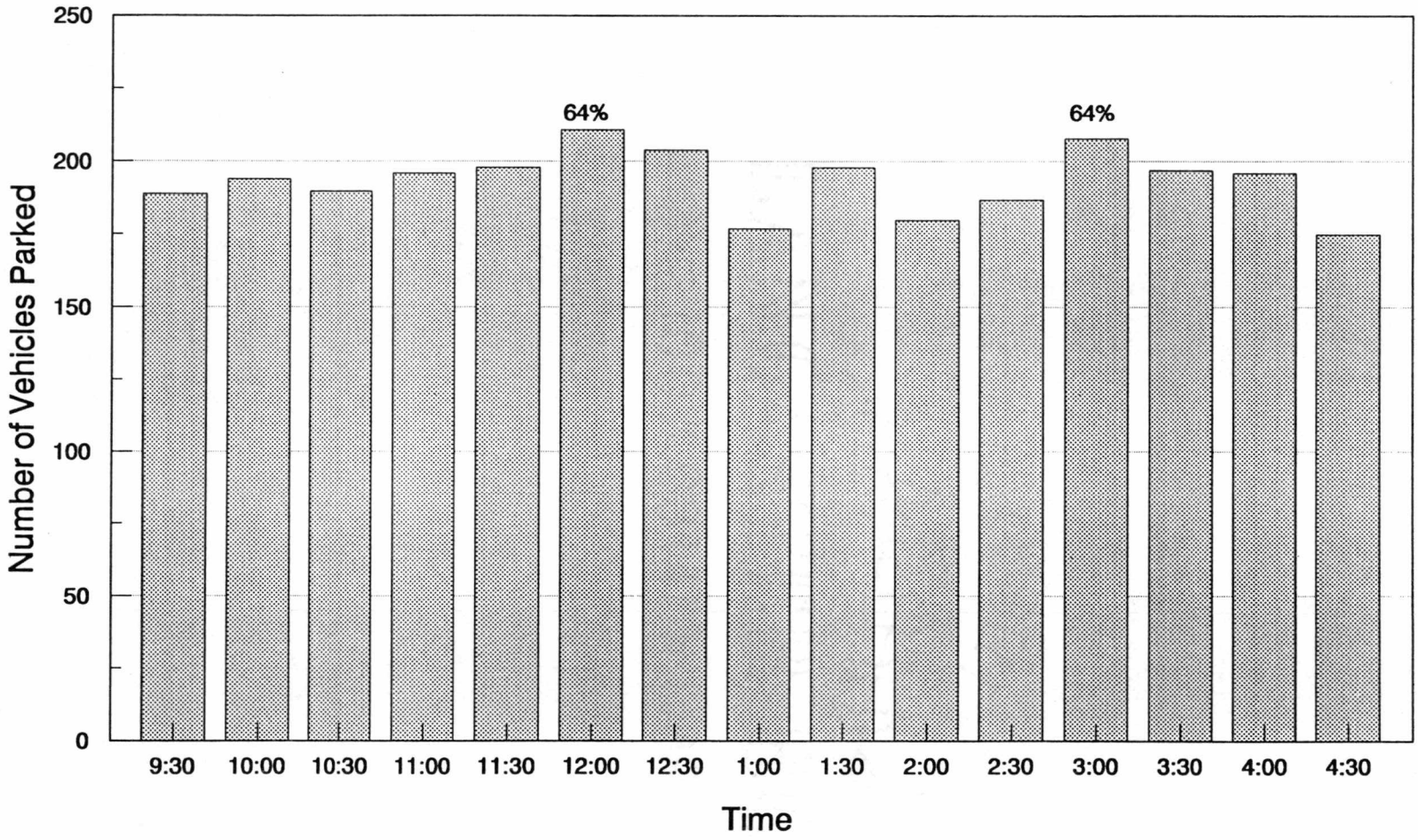



FIGURE 14. Parking Accumulation

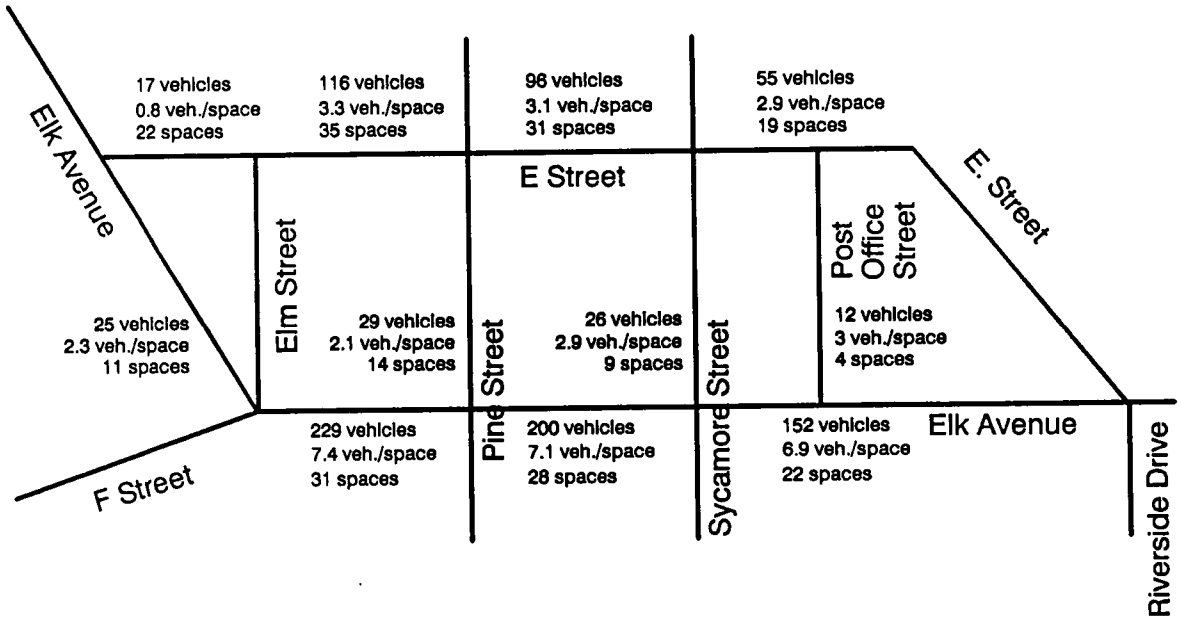



FIGURE 15. Turnover Rate (Vehicles/Space)

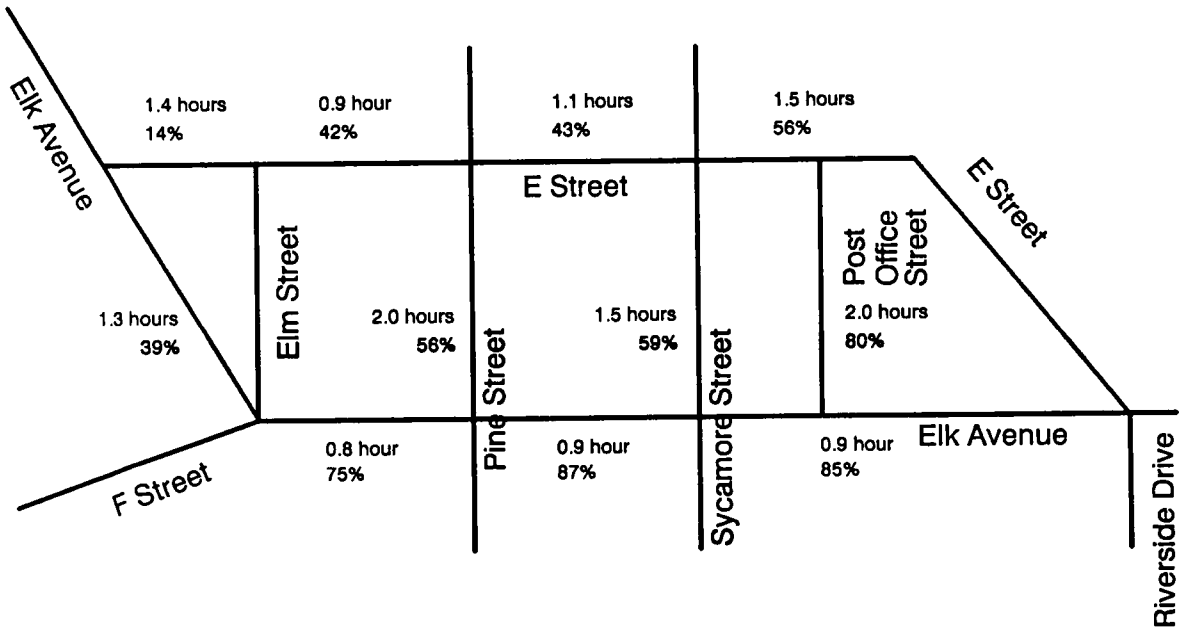


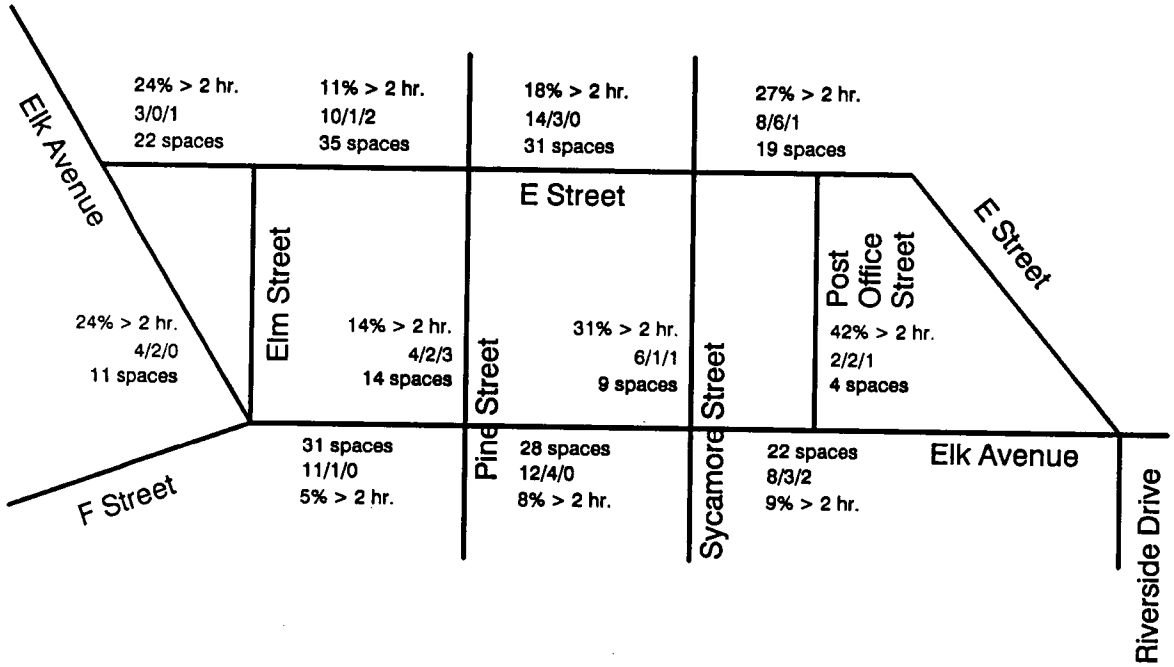

FIGURE 16. Average Parking Duration (Hours/Vehicle) and Average Occupancy (%)

turnover sufficiently. It was suggested by some merchants that turnover can be increased by imposing a two hour parking limit on the on-street parking spaces.

For the study day, it was determined that 82 vehicles parked from 2 to 4 hours, 25 parked from 4 to 6 hours, and 11 parked for 6 hours or more. When looking at individual block faces, the highest percent of 2 hours or more parkers was in the alley. Out of the 957 vehicles that utilized the on-street parking, 12.3 percent parked for a duration of 2 hours or more. If a 2 hour parking limit was imposed on on-street parking, an additional 65 space-hours (11 percent capacity) would become available. A breakdown of the duration of parking by block face is presented in Figure 17.

## Accident Analysis

An accident analysis was performed in order to determine the number and causes of accidents taking place in the downtown area over the past five years. Accident reports filed by police officers were examined, and the nature of accidents at each intersection was identified. Accidents were classified into categories such as right angle collisions, rear-end collisions, sideswipes, and parking maneuver accidents. With this information, the reasons as to why the accidents are occurring can be




Vehicles Parked a/b/c
a = More than 2 hours, but less than 4 hours
b = More than 4 hours, but less than 6 hours
c = More than 6 hours

FIGURE 17. Duration of Parking

established. Possible factors contributing to some of these accidents could be poor sight distance at intersections, excess speeding, poor street lighting, or inadequate gaps in traffic flow.

There were a total of 72 accidents reported within a span of 5 years (1988 - 1992). Most of the accidents occurred at an intersection and not in the mid-block area. Thirty-one percent of the accidents occurred at the intersection of E Street and Sycamore Street. This was the highest rate of all the intersections at 4.5 accidents per year. Sixty-five percent of all the downtown accidents that took place were right-angle accidents. Surprisingly, there were only two parking related accidents. This is very low considering the fact that there is on-street parking available throughout the downtown area. There was only one case of each of the following types of accidents : vehicle to pedestrian, vehicle to train, and vehicle to fixed object. All the other accidents involved were vehicle to vehicle accidents. A very low percent (11%) of the accidents resulted in a person being injured, while all the others resulted in only property damage. Fifty-seven percent of the accidents occurred during the P.M. hours, 20 percent during the A.M. hours, and 23 percent during the Mid-day hours. The results obtained from the accident analysis

are important in determining if there actually is a traffic safety problem. For example, too many right-angle accidents at the signalized intersection of E and Sycamore Street calls for the improvement of sight distance and visibility of the traffic control signal.

## Signal Warrant Analysis

The signal warrant analysis is used to determine whether a traffic signal will provide the greatest benefit to the safety of motorists and pedestrians, and, therefore, justified in its application. Traffic signals should neither be put into operation nor continued in operation (if already installed) unless one or more of the 11 signal warrants are met from the MUTCD (Manual on Uniform Traffic Control Devices). Certain conditions at an intersection such as inadequate sight distance, nearby employment sites, etc. may require traffic signal control even though none of the signal warrants were met [13]. Once a signal is warranted, it should improve the overall safety and/or operation of the intersection [8].

The signal warrants listed below were analyzed to determined whether or not signals are warranted for the five key intersections under the existing one-way street system.

**Warrants**

1 - Minimum Vehicle Volume - 8 hrs. of an avg. day

2 - Interruption of Continuous Traffic - 8 hrs. of an avg. day

6 - Accident Experience - 8 hrs. of an avg. day

8 - Combination of Warrants - 8 hrs. of an avg. day

9 - Four Hour Volumes

11 - Peak Hour Volume

The other warrants were not considered because they were not relevant to the situation in downtown Elizabethton. The volumes in Table 10 based on data collected for the one-way street system were used to determine whether or not they satisfied the requirement of the signal warrants during the A.M., Mid-day, and P.M. peak time period. The data represents average conditions. The first three intersections listed in Table 10 are signalized, while the last two intersections are unsignalized.

The Minimum Vehicular Volume warrant is used when the volume of intersecting traffic is the primary reason for installing a signal light. The warrant's requirements are met, if the traffic volumes in Table 11 are exceeded on the major street and on the higher-volume minor street approach to the intersection for 8 hours on an average

TABLE 10

VOLUMES FOR THE ONE-WAY STREET SYSTEM

| Intersection | VPH on Major St. (Total of Both Approaches) 2 lanes | VPH on Higher Volume Minor St. Approach (One Direction Only) 1 lane | 2 lanes |
|---|---|---|---|
| AM PEAK | | | |
| Elk/Pine | 268 | 30 | --- |
| Elk/Sycamore | 241 | --- | 125 |
| E/Sycamore | 294 | --- | 108 |
| Elm/F/Elk | 205 | 82 | --- |
| Elk/Riverside | 485 | 66 | --- |
| MID-DAY PEAK | | | |
| Elk/Pine | 512 | 53 | --- |
| Elk/Sycamore | 407 | --- | 192 |
| E/Sycamore | 382 | --- | 199 |
| Elm/F/Elk | 326 | 126 | --- |
| Elk/Riverside | 376 | 81 | --- |
| PM PEAK | | | |
| Elk/Pine | 619 | 59 | --- |
| Elk/Sycamore | 496 | --- | 170 |
| E/Sycamore | 365 | --- | 197 |
| Elm/F/Elk | 389 | 160 | --- |
| Elk/Riverside | 410 | 102 | --- |

TABLE 11

VOLUMES REQUIRED FOR SIGNAL INSTALLATION
WARRANT SATISFACTION

| # of lanes for moving traffic on each approach | | VPH on major street (total of both approaches) | VPH on higher volume minor street approach (one direction only) |
|---|---|---|---|
| major st. | minor st. | | |
| **WARRANT 1 : MINIMUM VEHICULAR VOLUME** | | | |
| 1 | 1 | 500 | 150 |
| 2 or more | 1 | 600 | 150 |
| 2 or more | 2 or more | 600 | 200 |
| 1 | 2 or more | 500 | 200 |
| **WARRANT 2 : INTERRUPTION OF CONTINUOUS TRAFFIC** | | | |
| 1 | 1 | 750 | 75 |
| 2 or more | 1 | 900 | 75 |
| 2 or more | 2 or more | 900 | 100 |
| 1 | 2 or more | 750 | 100 |

Source: Manual on Uniform Traffic Control Devices. Federal Highway Administration, Washington, D.C., 1988.

day. None of the intersections met the requirements of warrant 1 [8].

The Interruption of Continuous Traffic warrant is used in situations where traffic volume is so heavy on a major street that vehicles on the minor street experience delay in entering or crossing the major street. This warrant can be satisfied by exceeding the volumes (Table 11) on the major street and on the higher-volume minor street approach to an intersection for 8 hours of an average day. None of the five intersections met the requirements of this warrant.

The Accident Experience warrant is satisfied when:

1. "Five or more reported accidents have occurred within a 12 month period and could have been prevented by traffic signal control; and
2. Trial of less restrictive treatment to reduce accidents has been proven unsatisfactory; and
3. The volume of vehicular and pedestrian traffic is not less than 80 percent of the requirements stated in either the Minimum Vehicular Volume warrant, the Interruption of Continuous Traffic warrant, or the

Pedestrian Volume warrant; and

4. The installation of a signal will not seriously disrupt progressive traffic flow." [8]

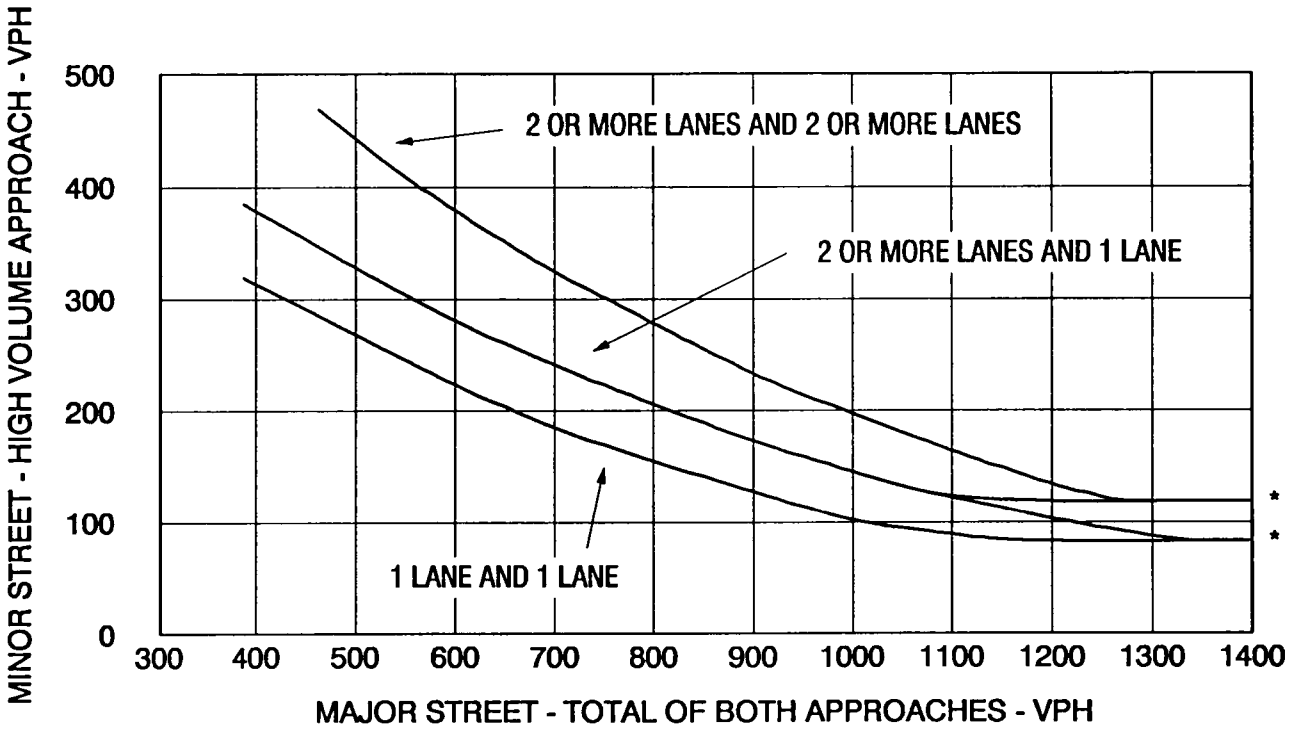
The intersections currently signalized are not expected to meet the above requirements because this warrant is only applied to unsignalized intersections. But, the two unsignalized intersections of Elk, Elm, and F and Elk and Riverside were tested to see if they met the requirements of the Accident Experience warrant. Neither one of the two unsignalized intersections met the requirements of this warrant.

The Combination of Warrants warrant may justify the installation of a signal if the Minimum Vehicular Volume warrant and the Interruption of Continuous Traffic warrant are satisfied to the extent of 80 percent or more of the stated values for 8 hours on an average day. The requirements of this warrant were not met by any of the intersections.

"The Four Hour Volume warrant is satisfied when each of any four hours of an average day the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher volume minor street approach (one

direction only) all fall above the curve" in Figure 18 "for the existing combination of approach lanes [8]." The Peak Hour Volume warrant is also used when conditions are such that for one hour of the day minor street vehicles suffer undue delay in entering or crossing the major street. This warrant can be satisfied when the plotted points representing the VPH on the major street (total of both approaches) and the corresponding VPH of the higher volume minor street approach for one hour (any four consecutive 15-minute periods) of an average day falls above the curve in Figure 19 for the existing combination of approach lanes [8]. None of the intersections satisfied the requirements of either the Four Hour Volume warrant or the Peak Hour Volume warrant.

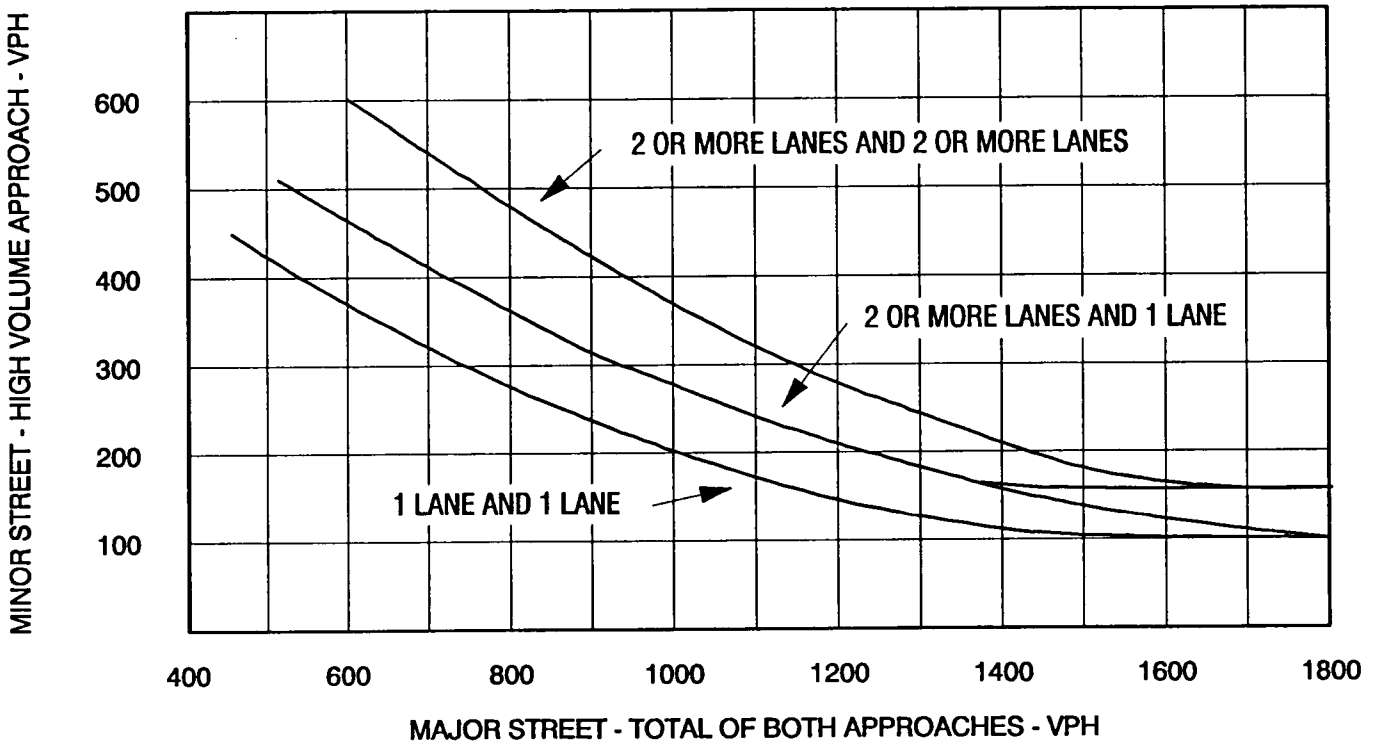
Overall, none of the five key intersections of downtown Elizabethton are warranted for traffic signal control under the existing one-way street system. Table 12 summarizes the results of the signal warrant analysis. Another analysis was performed using adjusted criteria recommended for small communities with a population of 10,000 or less. This analysis showed that the signal at Elk and Sycamore is warranted. The signal at E and Sycamore came close to meeting the adjusted warrants, but the signal at Elk and Pine did not meet these warrants. Further research needs to be conducted for the removal of




*NOTE: 115 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACH WITH TWO OR MORE LANES AND 80 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACHING WITH ONE LANE.

SOURCE: Manual on Uniform Traffic Control Devices. Federal Highway Administration, Washington, D.C., 1988.

FIGURE 18. Four Hour Volume Warrant




*NOTE: 150 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACH WITH TWO OR MORE LANES AND 100 VPH APPLIES AS THE LOWER THRESHOLD VOLUME FOR A MINOR STREET APPROACHING WITH ONE LANE.

SOURCE: Manual on Uniform Traffic Control Devices. Federal Highway Administration, Washington, D.C., 1988.

FIGURE 19. Peak Hour Volume Warrant

TABLE 12

SUMMARIZATION OF SIGNAL WARRANT ANALYSIS
FOR THE ONE-WAY STREET SYSTEM

| Time Period | Intersection | Satisfaction of Warrant 1 | 2 | 6 | 8 | 9 | 11 |
|---|---|---|---|---|---|---|---|
| AM | Elk/Pine | no | no | -- | no | no | no |
| | Elk/Sycamore | no | no | -- | no | no | no |
| | E/Sycamore | no | no | -- | no | no | no |
| | Elm/F/Elk | no | no | no | no | no | no |
| | Elk/Riverside | no | no | no | no | no | no |
| Mid-day | Elk/Pine | no | no | -- | no | no | no |
| | Elk/Sycamore | no | no | -- | no | no | no |
| | E/Sycamore | no | no | -- | no | no | no |
| | Elm/F/Elk | no | no | no | no | no | no |
| | Elk/Riverside | no | no | no | no | no | no |
| PM | Elk/Pine | no | no | -- | no | no | no |
| | Elk/Sycamore | no | no | -- | no | no | no |
| | E/Sycamore | no | no | -- | no | no | no |
| | Elm/F/Elk | no | no | no | no | no | no |
| | Elk/Riverside | no | no | no | no | no | no |

the signal at the intersection of Elk and Pine because it serves as an aid to pedestrians crossing the intersection.

From all the analyses performed on the one-way street system, only the Level of Service Analysis and Signal Warrant Analysis need to be confronted. There is plenty of parking available in downtown Elizabethton because none of the blocks exceeded 90 percent occupancy. The Level of Service Analysis revealed that the existing traffic signal controls are not operating efficiently because when the signals were retimed the level of service of each signalized intersection improved. All of the intersections can be operated at a level of service of B or better by retiming the signals. But, from the Signal Warrant Analysis, it was determined that none of the five key intersections are warranted for traffic signal control. Therefore, the signals which are already in operation need to be considered for removal. Another analysis using the adjusted criteria for small communities showed that the only signalized intersection which clearly failed to meet the warrants was Elk and Pine. The next chapter discusses the possibilities of converting the existing one-way street system into a two-way street system.

# CHAPTER V

## ALTERNATIVE IMPROVEMENTS

As suggested by merchants, a proposal has been made for an alternative traffic operations plan consisting of the two-way street system replacing the one-way street pair of Elk Avenue and E Street. Along with this alternative, the type of on-street parking (angle or parallel) was also evaluated. A two-way street system would increase the amount of exposure the businesses on Elk Avenue would receive from traffic traveling westbound. A two-way flow pattern might also tend to slow down traffic which the merchants on Elk Avenue would like to see. It may also divert through traffic to parallel streets and attract only those motorists whose destination is in the downtown area. The primary benefit of the two-way street system would be to reduce travel time and distance for the vehicles traveling westbound that are destined to the businesses located on Elk Avenue.

The disadvantage of the two-way system is that the capacity of the two streets would decrease because the multi-lane flexibility would be lost. With 3 lanes, there will be only one lane in each direction with a wide median and this could lead to more congestion especially at intersections with increased turn movements, along with

the increase of vehicular and vehicle-pedestrian conflicts at intersections. Further, in order to avoid the problem of blocking a moving traffic lane with loading/unloading functions, curb-side loading zones will be required for truck deliveries and pickups. Ultimately it would be desired to improve rear door access to businesses and increase use of the alley ways. Typical street layouts for the two-way system are shown for flat angle parking and parallel parking in Figures 20 and 21. The proposed geometrics for the 5 key intersections under the two-way system are shown in Figures 22 through 26.

## Capacity and Level of Service Analysis

A level of service analysis was performed for the five key intersections with the proposed two-way street system. In order to predict how traffic will travel in the two-way system, existing flow patterns were observed. Vehicle movements were traced through the downtown area by observation at key locations during the Mid-day and P.M. peak time periods. From these observations, new paths and probable volumes for the proposed two-way system were determined. The revised paths were developed by the following criteria : 1) Provide direct movement, 2) Avoid left turns, and 3) Stop where now desired. The revised Mid-day and P.M. peak time period volumes for the two-way

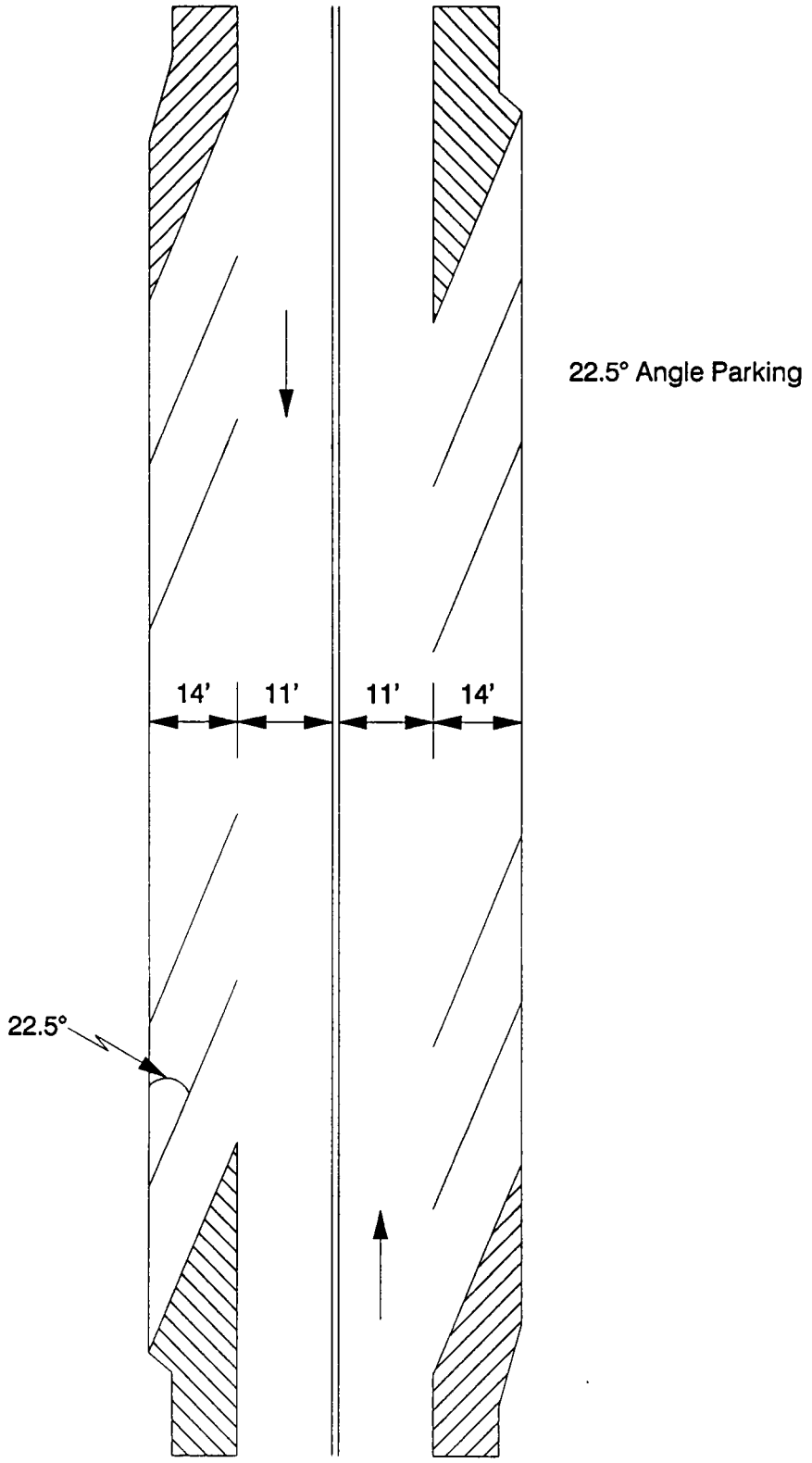



FIGURE 20. Two-Way With Angle Parking On Elk Avenue

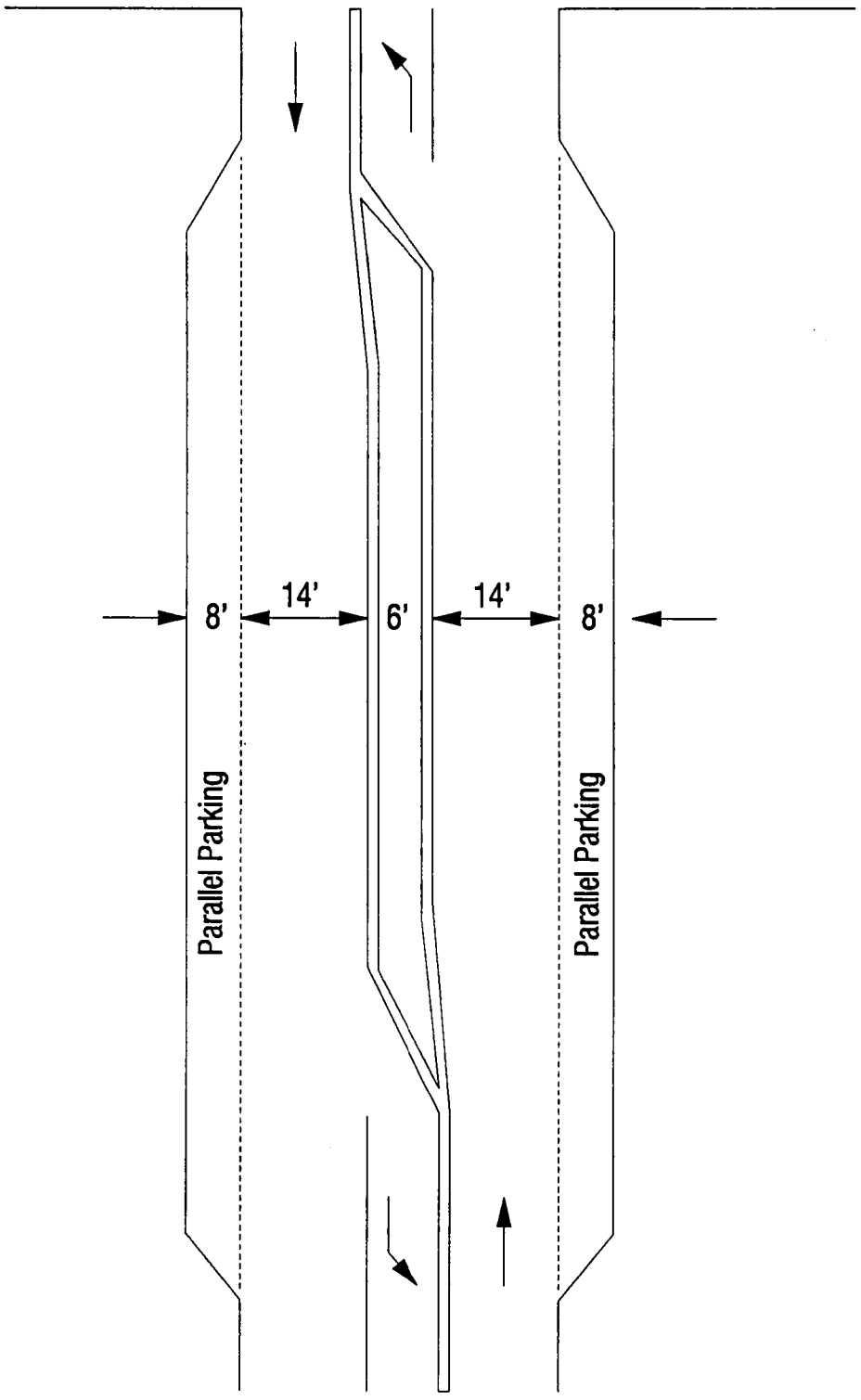



FIGURE 21. Two-Way With Parallel Parking On Elk Avenue

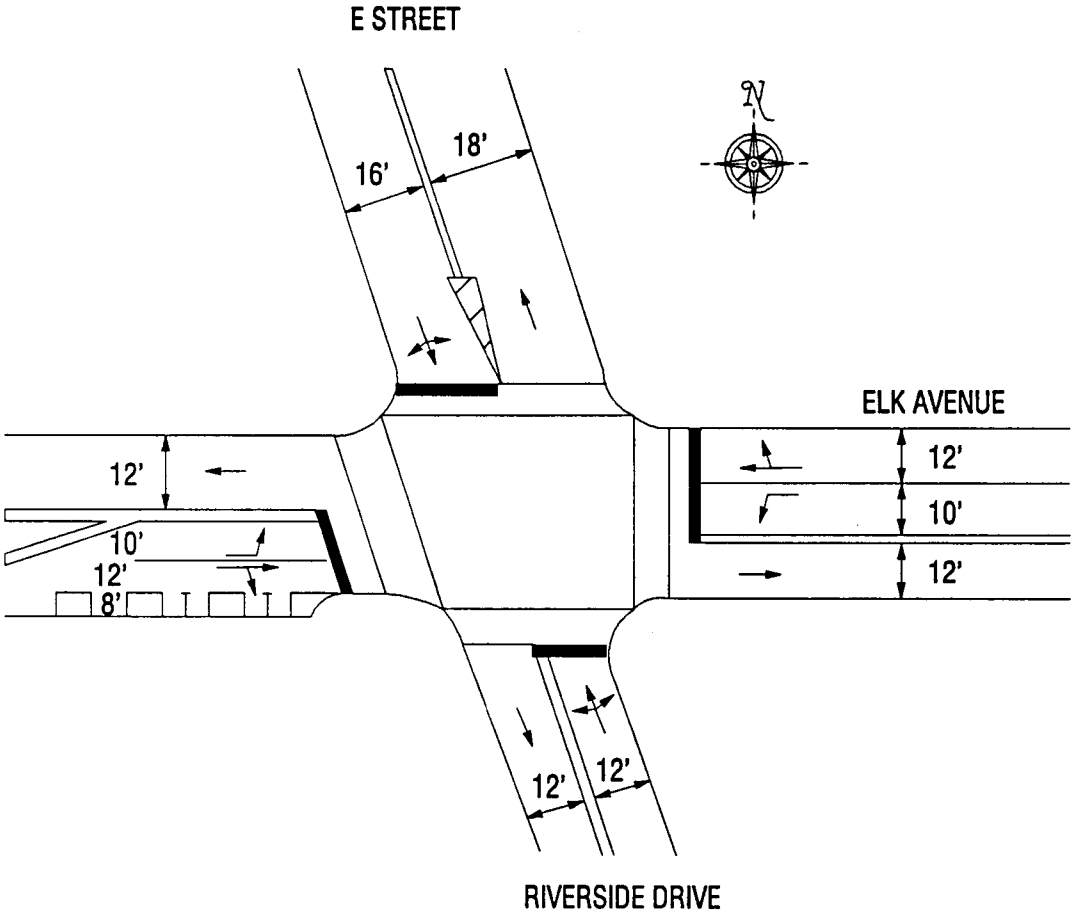



FIGURE 22. Geometrics of Elk Avenue and Riverside Drive For The Proposed Two-Way System

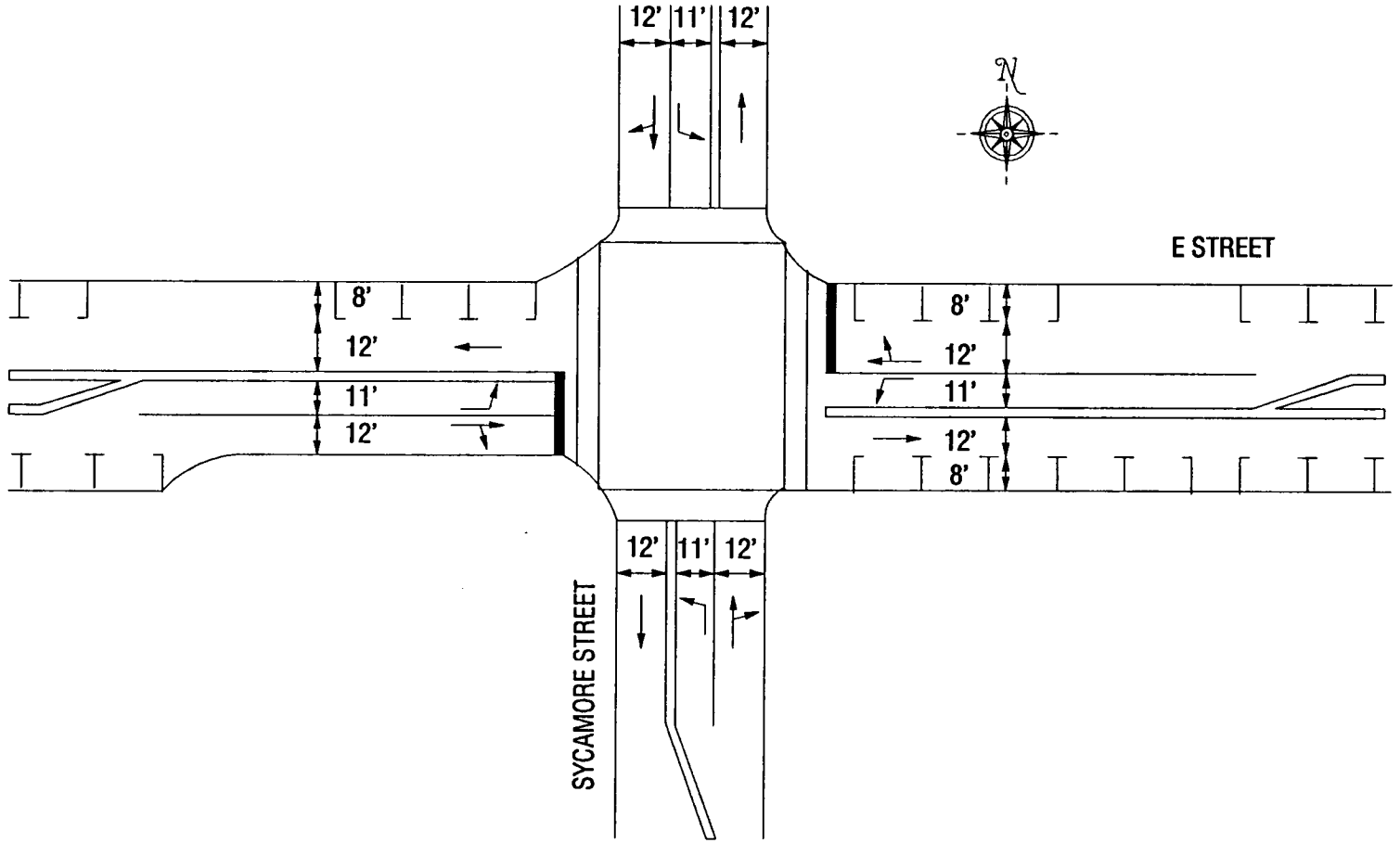



FIGURE 23. Geometrics of E Street and Sycamore Street For The Proposed Two-Way System

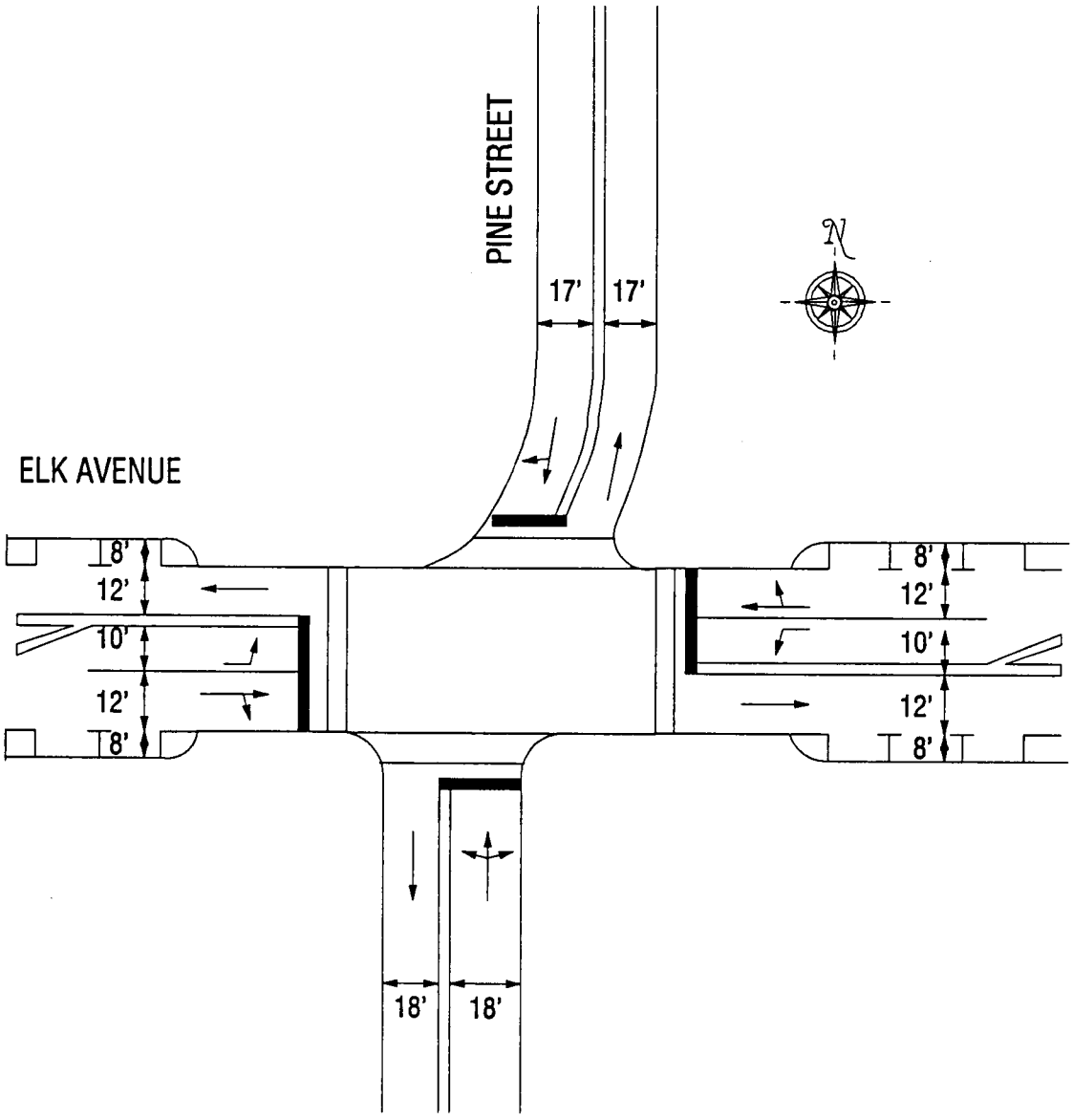



FIGURE 24. Geometrics of Elk Avenue and Pine Street For The Proposed Two-Way System

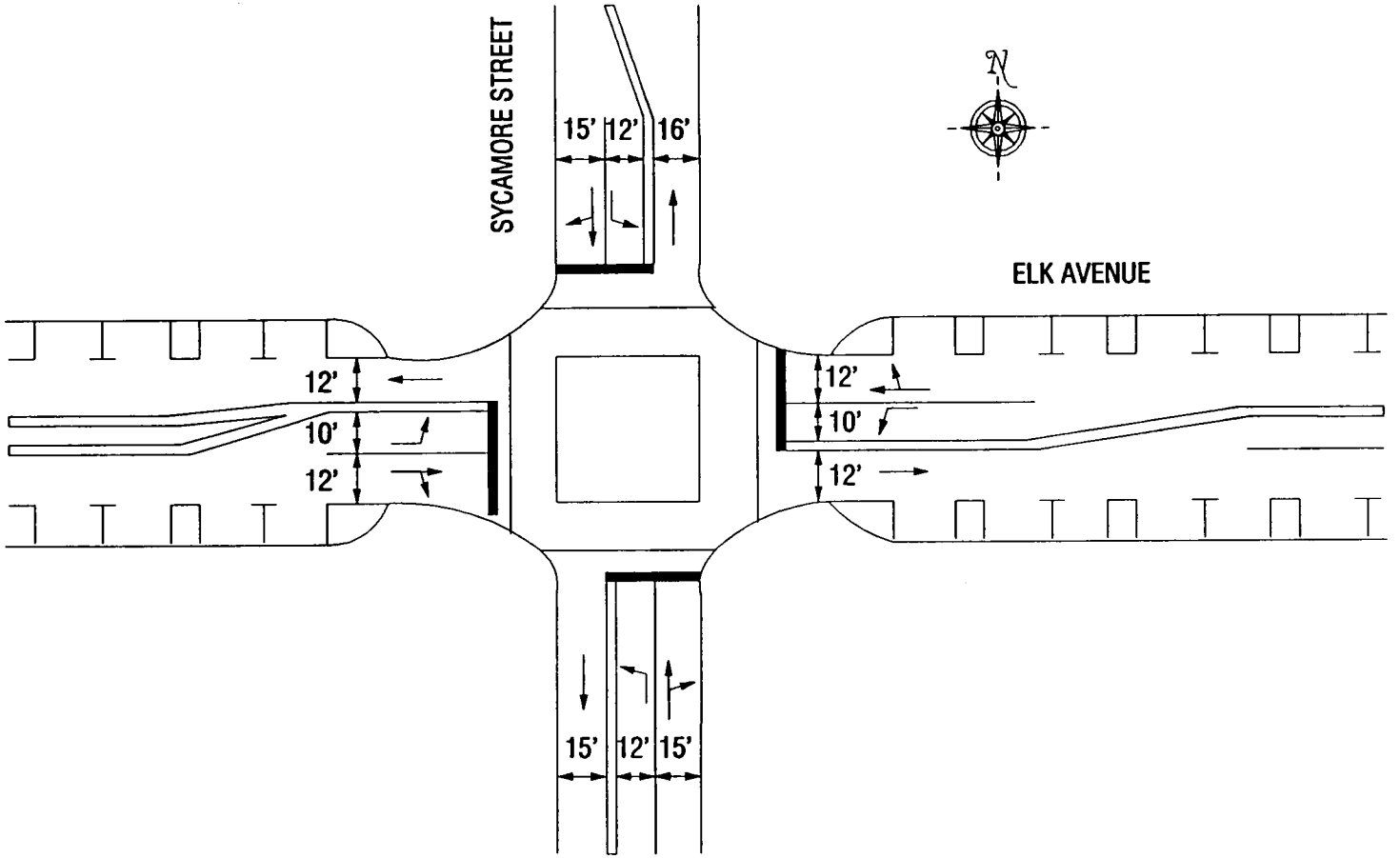



FIGURE 25. Geometrics of Elk Avenue and Sycamore Street For The Proposed Two-Way System

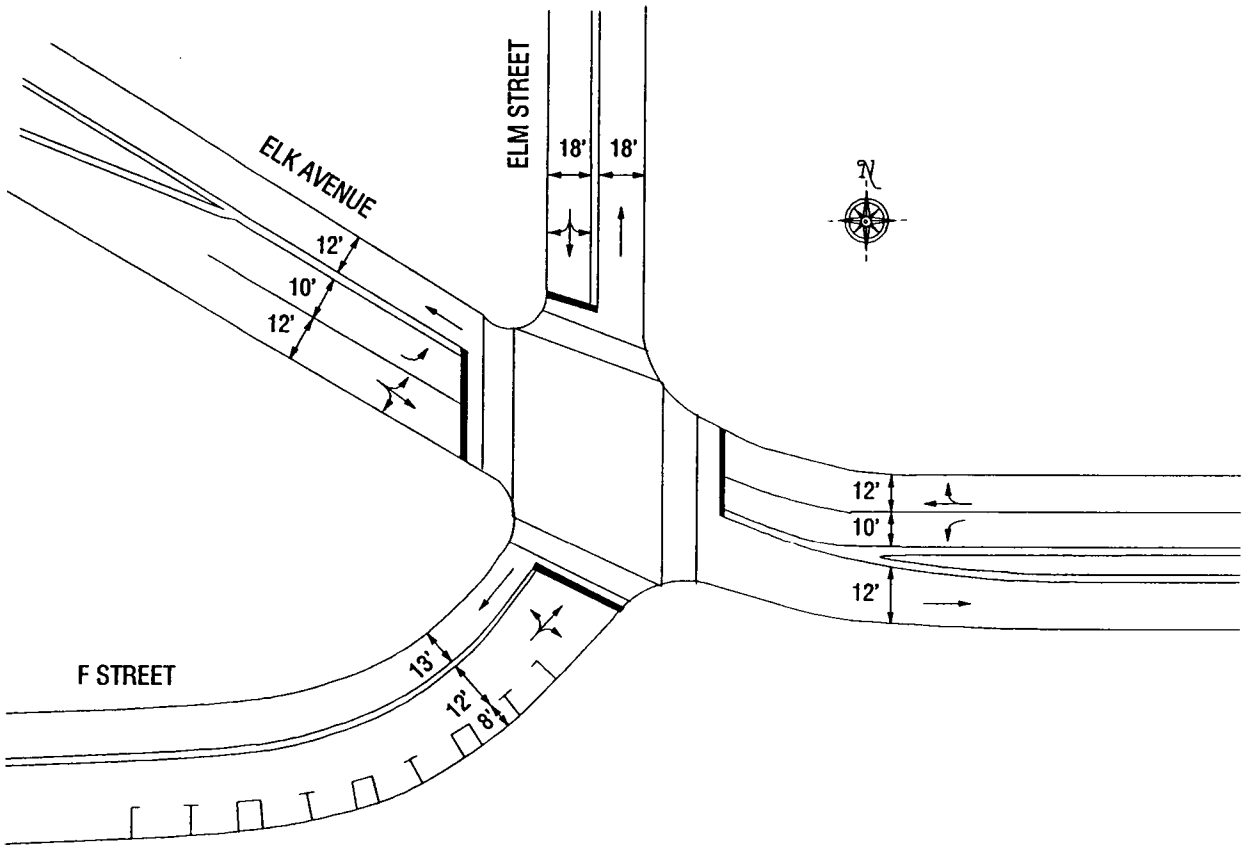



FIGURE 26. Geometrics of Elk, Elm, and F Street For The Proposed Two-Way System

street system are given in Tables 13 and 14. The phasing pattern for the two-way street system is shown in Figure 27. In the worst case scenario, 29 percent of the traffic from E Street was estimated to be diverted to Elk Avenue. This analysis considered only the Mid-day and P.M. peak time periods. Table 15 shows the results of the Level of Service analysis.

Another level of service analysis was performed for the three existing signalized intersections, but assuming signals were not present. Table 16 shows the level of services for these three intersections analyzed as non-signalized intersections. All three intersections provided a better level of service for the major streets without traffic signal control. For the intersections of E and Sycamore and Elk and Sycamore, the minor streets level of service was found to be C and D for the left turn movement. The signal light at the intersection of Elk Avenue and Pine Street can be removed without creating any problems.

## Signal Warrant Analysis

A signal warrant analysis was performed for the two-way street system to determine which intersections warrant a signal. The same signal warrants were tested as for the one-way street system with the exception of the Accident

TABLE 13

TWO-WAY FLOW VOLUMES OF
THE MID-DAY PEAK TIME PERIOD
(IN VEH./HR.)

| Intersection | Movement | EB | WB | NB | SB |
|---|---|---|---|---|---|
| Elk/Pine | LT | 18 | 10 | 10 | 0 |
| | TH | 207 | 167 | 27 | 0 |
| | RT | 82 | 10 | 26 | 0 |
| Elk/Sycamore | LT | 39 | 17 | 10 | 50 |
| | TH | 134 | 129 | 150 | 67 |
| | RT | 78 | 10 | 51 | 32 |
| Elk/Riverside | LT | 18 | 143 | 10 | 121 |
| | TH | 162 | 117 | 35 | 17 |
| | RT | 37 | 157 | 46 | 10 |
| Elk/Elm/F | LT | 23 | 10 | 10 | 10 |
| | TH | 125 | 167 | 10 | 17 |
| | RT | 25 | 10 | 126 | 10 |
| E/Sycamore | LT | 22 | 17 | 58 | 10 |
| | TH | 115 | 75 | 131 | 107 |
| | RT | 25 | 63 | 10 | 41 |

TABLE 14

TWO-WAY FLOW VOLUMES OF
THE PM PEAK TIME PERIOD
(IN VEH./HR.)

| Intersection | Movement | EB | WB | NB | SB |
|---|---|---|---|---|---|
| Elk/Pine | LT | 23 | 10 | 10 | 0 |
| | TH | 256 | 166 | 30 | 0 |
| | RT | 60 | 10 | 27 | 0 |
| Elk/Sycamore | LT | 49 | 19 | 10 | 59 |
| | TH | 167 | 122 | 133 | 79 |
| | RT | 78 | 10 | 60 | 40 |
| Elk/Riverside | LT | 25 | 160 | 10 | 142 |
| | TH | 250 | 110 | 27 | 15 |
| | RT | 57 | 170 | 75 | 10 |
| Elk/Elm/F | LT | 23 | 10 | 10 | 10 |
| | TH | 159 | 166 | 10 | 21 |
| | RT | 13 | 10 | 160 | 10 |
| E/Sycamore | LT | 28 | 19 | 60 | 10 |
| | TH | 148 | 102 | 144 | 130 |
| | RT | 29 | 70 | 10 | 50 |

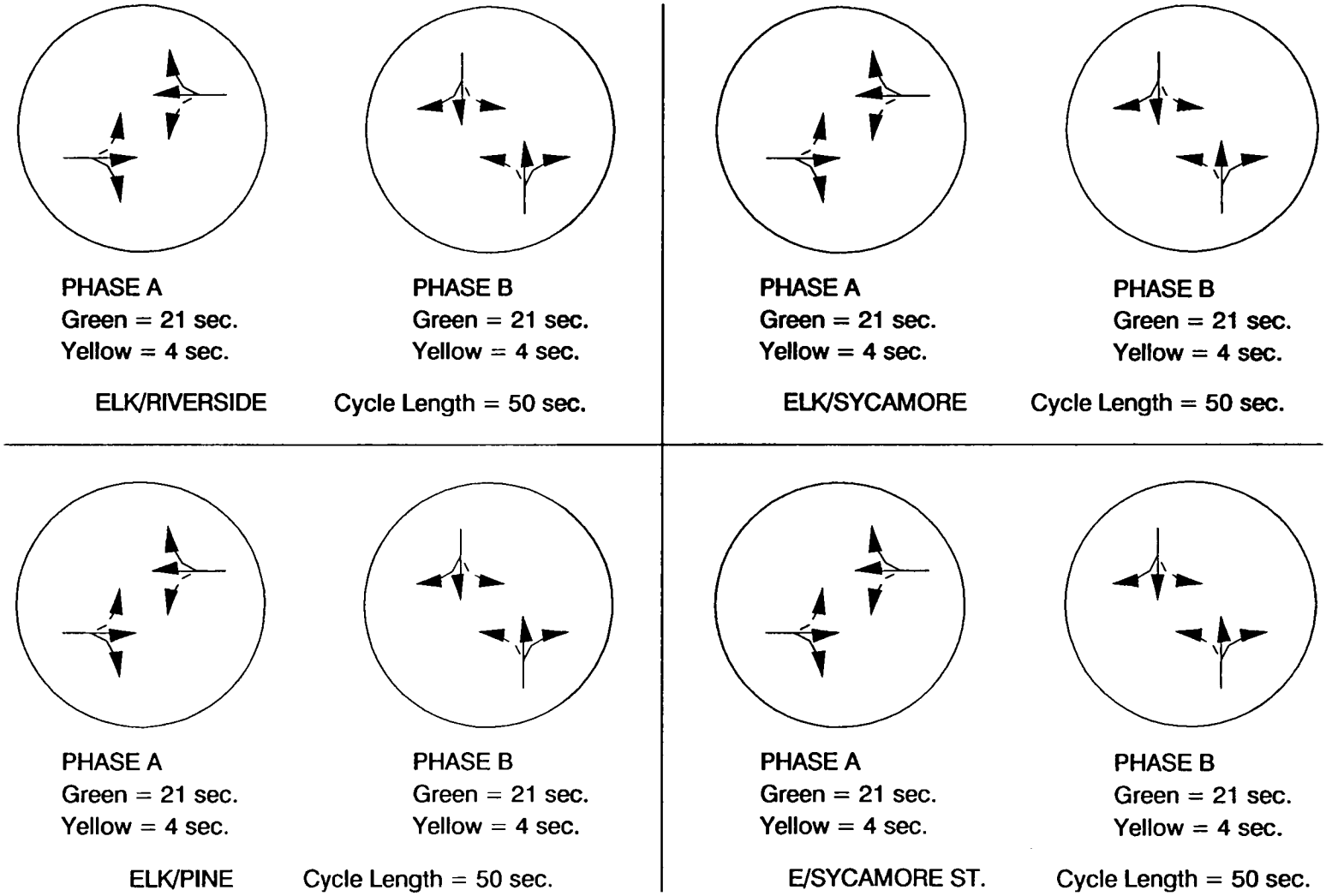



FIGURE 27. Phase Pattern For Two-Way System

TABLE 15

LEVEL OF SERVICE OF KEY INTERSECTIONS
(Two-Way Flow)

| Peak Time Period | Intersection | LOS | Delay/Veh.(sec.) |
|---|---|---|---|
| MID-DAY | Elk/Riverside* | B | 7.9 |
| | Elk/Sycamore | B | 7.2 |
| | Elk/Pine | B | 8.2 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 6.7 |
| P.M. | Elk/Riverside* | B | 8.7 |
| | Elk/Sycamore | B | 7.4 |
| | Elk/Pine | B | 8.6 |
| | Elk/Elm/F | A | Unsignalized |
| | E/Sycamore | B | 7.0 |

* Placed signal at previously unsignalized intersection.

TABLE 16

LEVEL OF SERVICE OF KEY INTERSECTIONS
(Unsignalized - Two-Way Flow)

| Intersection | Peak Time Period | |
|---|---|---|
| | Mid-day | P.M. |
| Elk/Sycamore | A | A |
| Elk/Pine | A | A |
| E/Sycamore | A | A |

Experience warrant. This warrant could not be tested because there was no accident history for the proposed two-way street system and is not appropriate for intersections that are already signalized.

The signal warrants listed below were analyzed to determined whether or not signals are warranted for the five key intersections under the proposed two-way street system.

**Warrants**

1 - Minimum Vehicle Volume - 8 hrs. of an avg. day

2 - Interruption of Continuous Traffic - 8 hrs. of an avg. day

8 - Combination of Warrants - 8 hrs. of an avg. day

9 - Four Hour Volumes

11 - Peak Hour Volume

The revised volumes for the two-way street system on Table 17 were used to determine whether or not they satisfied the requirements of the signal warrants. The same procedure was used to test the signal warrants as for the one-way street system (see Chapter 4).

The signal warrant analysis revealed that only the intersection of Elk and Riverside will need traffic signal control under the two-way system. The signals which are

TABLE 17

VOLUMES FOR THE TWO-WAY STREET SYSTEM

| Intersection | VPH on Major St. (Total of Both Approaches) 2 lanes | VPH on Higher Volume Minor St. Approach (One Direction Only) 1 lane | 2 lanes |
|---|---|---|---|
| MID-DAY PEAK | | | |
| Elk/Pine | 494 | 63 | --- |
| Elk/Sycamore | 407 | --- | 211 |
| E/Sycamore | 317 | --- | 199 |
| Elm/F/Elk | 360 | 146 | --- |
| Elk/Riverside | 634 | 148 | --- |
| PM PEAK | | | |
| Elk/Pine | 525 | 67 | --- |
| Elk/Sycamore | 445 | --- | 203 |
| E/Sycamore | 396 | --- | 214 |
| Elm/F/Elk | 381 | 180 | --- |
| Elk/Riverside | 772 | 167 | --- |

already in operation are unwarranted and need to be considered for removal. Table 18 summarizes the results of the signal warrant analysis. Another analysis using adjusted criteria for smaller communities showed that a signal may be needed at the intersection of E and Sycamore.

## Parking

Parking supply in the CBD is currently adequate. Occupancy rates did not exceed 90 percent on any blocks. Under two-way flow with one lane in each direction, on-street parking spaces can be increased by providing angle parking instead of parallel parking.

The arrangement of on-street parking spaces, whether it be parallel or angle, affects safety. Angle parking provides more parking per unit of curb length than parallel parking, but it requires more space for maneuvering thereby increasing exposure and hazard. "Visibility can be inadequate for drivers backing out into traffic; oncoming drivers must suddenly stop as cars unpark; and drivers must proceed slowly to find empty spaces" [14]. Consequently, there is a higher accident rate for angle parking than for parallel parking at the same location.

The current arrangement of parking spaces in downtown Elizabethton was observed to be safe. From the accident

TABLE 18

SUMMARIZATION OF SIGNAL WARRANT ANALYSIS
FOR THE TWO-WAY STREET SYSTEM

| Time Period | Intersection | Satisfaction of Warrant 1 | 2 | 8 | 9 | 11 |
|---|---|---|---|---|---|---|
| Mid-day | Elk/Pine | no | no | no | no | no |
| | Elk/Sycamore | no | no | no | no | no |
| | E/Sycamore | no | no | no | no | no |
| | Elm/F/Elk | no | no | no | no | no |
| | Elk/Riverside | yes* | no | no | no | no |
| PM | Elk/Pine | no | no | no | no | no |
| | Elk/Sycamore | no | no | no | no | no |
| | E/Sycamore | no | no | no | no | no |
| | Elm/F/Elk | no | no | no | no | no |
| | Elk/Riverside | yes* | no | yes | no | no |

* A preliminary analysis indicated it would also be warranted for the AM peak, thus spanning a total of 8 hours.

report analysis, only two accidents were parking related out of a total of 72 accidents in the entire downtown area over a period of five years. Therefore, despite the potential for gaining a few more parking spaces, there is no need to change the parking space arrangement because of the potential increase in parking related accidents. However, the addition of flat angle parking for the two-way system would provide an extra 8 parking spaces on Elk Avenue over parallel parking, of which 4 spaces may be needed to provide loading zones for trucks. The number of parking spaces provided by each type of parking space arrangement for the one-way and two-way system on Elk Avenue is given in Table 19. Flat angle parking (22.5 degrees) is the only feasible type of angle parking for both the one-way and two-way system because any larger angle (30 degrees or more) would reduce the traffic lanes to less than 11 feet. This would not allow enough space for two lanes of traffic and for parking/unparking maneuvers.

While the parking analysis proved that there is plenty of parking available in the downtown area because parking did not exceed 90 percent on any of the blocks. If need be, the number of parking spaces available can be increased by imposing a two hour parking limit for on-street parking on Elk Avenue. The signal warrant analysis

TABLE 19

PARKING SPACE ARRANGEMENTS
ON ELK AVENUE

| Parking Arrangement | No. of On-Street Spaces | Travel Lane Width (in ft) | Total No. of Travel Lanes | Adequate Maneuvering Space? |
|---|---|---|---|---|
| | | ONE-WAY SYSTEM | | |
| Parallel | 66 | 11 | 3 | Yes |
| Flat Angle (22.5°) | 74 | 11 | 2 | Yes |
| 30° Angle | 92 | 8.6 | 2 | No |
| | | TWO-WAY SYSTEM | | |
| Parallel | 62 | 11 | 2 | Yes |
| Flat Angle (22.5°) | 70 | 11 | 2 | Yes |
| 30° Angle | 87 | 8.6 | 2 | No |

revealed that only the intersection of Elk and Riverside required traffic signal control under the two-way system. Another analysis using adjusted criteria for smaller communities showed that a signal may also be needed at E and Sycamore. Further research needs to be conducted for the removal of the signal at the intersection of Elk and Pine because it serves as an aid to pedestrians crossing the intersection. Therefore, the only signal at the present time which may be considered for removal is at the intersection of Elk and Sycamore. The level of service analysis showed that when the previously signalized intersections were examined as unsignalized intersections, a level of service of A was achieved at the intersections for the Mid-day and P.M. peak time periods.

# CHAPTER VI

# CONCLUSIONS

The traffic and parking conditions of downtown Elizabethton on a relative basis are not as bad as the merchants perceive them to be. Strictly from the point of view of traffic flow, there is no need to change the existing one-way system. However, an alternative flow pattern was examined considering its potential impact on downtown businesses.

The alternative which was investigated in detail is the two-way street system replacing the one-way system. In this proposal, E Street and Elk Avenue are converted from one-way to two-way streets, while all others remain the same. The two-way street system would increase the amount of exposure the businesses on Elk Avenue would receive. On the negative side, under the two-way system, the delay experienced by motorists could increase because there will only be a single traffic lane in each direction. Trucks loading or unloading would become more disruptive to the traffic flow. Currently there are no on-street loading zones on either Elk Avenue or E Street and trucks usually double park and block one of the three lanes. With the two-way system, double parked trucks will interfere with traffic flow. The number of potential

traffic conflicts at the intersections will also increase under two-way flow. The primary benefit of the two-way street system would be the reduction of travel time and distance to the vehicles traveling westbound destined to the businesses on Elk Avenue.

The Level of Service Analysis reflected that under the one-way system, all of the intersections could operate at a level of service of B or better, if the signals were retimed. In the one-way and two-way system, the three previously signalized intersections operate at a level of service of A when controlled by stop signs. Therefore, the existing traffic signal controls should be considered for removal.

The signal warrant analysis revealed that none of the intersections require traffic signal control under the one-way street system. Another analysis using adjusted criteria for small communities showed that the signal at Elk and Sycamore is warranted. The signal at E and Sycamore came close to meeting the adjusted warrants, but the signal at Elk and Pine did not meet these warrants. But, further research needs to be conducted as to the removal of the signal at the intersection of Elk and Pine because this signal serves as an aid to pedestrians crossing the intersection. Under the two-way street system, only the intersection of Elk and Riverside is

warranted for traffic signal control. The analysis using adjusted criteria for small communities showed that a signal may be needed at E and Sycamore.

On an overall basis, parking supply in the downtown is adequate for now. Occupancy rates did not exceed 90 percent on any blocks. If business activities on Elk Avenue grow substantially in the future, parking on Elk Avenue may become inadequate unless other options are provided. At the present time, parallel parking should be the preferred arrangement. However, if need be, an additional 65 space-hours (11 percent capacity) could be gained on Elk Avenue, if a two hour parking time limit is imposed and enforced on the downtown on-street parking spaces.

In conclusion, the town of Elizabethton should remain with the one-way street system and on-street parallel parking as the parking space arrangement. If additional parking is needed in the future, then a two hour parking limit should be imposed and enforced on the on-street parking spaces on Elk Avenue. At the present time, the traffic signal controls at the intersections of Elk and Sycamore, E and Sycamore, and Elk and Pine should not be removed. These traffic signal controls need to be retimed in order for the intersections to operate more efficiently. Nothing needs to be done at the

intersections of Elk, Elm, and F; and Elk and Riverside because they are operating adequately.

# LIST OF REFERENCES

## LIST OF REFERENCES


1. Arlinghaus, Sandra L. "Street Geometry and Flows. "The Geographical Review, Volume 81, No. 2, April 1991, pp. 206-214.

2. Burrage, Robert H., Edward G. Mogren. Parking. The Eno Foundation for Highway Traffic Control, Saugatuck, Connecticut, 1957.

3. Carter, Everett C. and Wolfgang S. Homburger. Introduction to Transportation Engineering. Institute of Transportation Engineers, Reston Publishing Company, Inc., Reston, Virginia, 1978.

4. Downtown Circulation Study, Gatlinburg, TN. Gatlinburg Regional Planning Commission, Gatlinburg, TN, June 1975.

5. Highway Research Board. "Improved Street Utilization Through Traffic Engineering", Special Report No. 93. Washington, D. C.: Highway Research Board, National Academy of Sciences, 1953.

6. Homburger, Wolfgang S. and James H. Kell. Fundamentals of Traffic Engineering. Institute of Transportation Studies, University of California, Berkeley, 1988.

7. Humphreys, Jack B., Donald Wheeler, Paul Box, T. Darcy Sullivan. "Safety Considerations in the Use of On-Street Parking," Transportation Research Record 722, 1979, pp. 26-35.

8. Manual on Uniform Traffic Control Devices. Federal Highway Administration, Washington, D. C., 1988.

9. Matson, Theodore M., Wilbur S. Smith, and Frederick W. Hurd. One-Way Streets. Traffic Engineering, New York, 1955.

10. Parking in the City Center. Wilbur Smith and Assoc., New Haven, Connecticut, July 1966.

11. Pignataro, Louis J. Traffic Engineering Theory and Practice. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1973.

12. Pok, S. F. "One-way Streets and Unbalanced Flow." Northwestern University, Evanston, Ill., Spring 1967.

13. User Guide: For Removal of Not Needed Traffic Signals. Federal Highway Administration, Washington, D. C., November 1980.

14. Weant, Robert A., Herbert S. Levinson. Parking. The Eno Foundation for Transportation, Inc., Westport, Connecticut, 1990.

## VITA

Prashant Shanabhai Patel was born in India on November 5, 1969. He came over to the United States at the age of three with his parents. He went to several different elementary schools and graduated from McMinn County High School of Athens, TN. in May 1987. The following fall he attended the University of Tennessee, Knoxville and earned his Bachelor of Science degree in Civil Engineering in May 1991.

In September 1991, he accepted a teaching assistantship at the University of Tennessee, Knoxville and began study towards a Master's degree. He completed his graduate coursework within one year and then completed his thesis while working part-time for RPM & Associates in Brentwood, TN. He received the Master of Science degree in Civil Engineering in August 1993.