To the Graduate Council:

I am submitting herewith a thesis written by Thanh C. Duong entitled "A Synthesized Traffic Impact Analysis of Post-World's Fair Site Development." 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.

Arun Chatterjee, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

Thesis
D2

A SYNTHESIZED TRAFFIC IMPACT ANALYSIS OF POST-WORLD'S FAIR SITE DEVELOPMENT

A Thesis

Presented for the

Master of Science

Degree

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Thanh C. Duong

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ABSTRACT

Travel demand estimation is necessary to assess the traffic impact of a new development project on its surrounding streets. There are several different techniques currently available for the purpose of estimating future traffic volumes. The most widely used approach is the conventional four-step traffic estimation procedure. But a rigorous application of this comprehensive procedure is time consuming and expensive, and it requires considerable manpower and the use of a large computer. Thus the traditional procedure is not suitable for a quick response to local traffic issues. The objectives of the study were to explore simplified procedures and use a suitable approach in an actual case to quickly generate useful information for resolving a local traffic issue. The case chosen for this purpose involves the traffic impacts of the post-World's Fair site development on the surrounding streets in the Fort Sanders area in Knoxville, Tennessee.

The actual procedure used for this study is a simplified, manual-oriented technique that relies on synthesized trip generation and trip distribution models. Simplification is built on the basic structure of the conventional stepwise process. The primary means used in gathering the data for this study included manual traffic counts, small sample home interviews and business surveys, published materials from studies and reports, and data from local government agencies.

The local traffic issues involved two locations providing access to Fort Sanders area: (1) intersection of Forest Avenue and Summit Hill Drive, and (2) the Clinch Avenue viaduct. The questions raised were whether to close both access points or keep one of them open. Three alternative situations were examined by this study: (1) both locations closed; (2) both locations open; and (3) Forest Avenue and Summit Hill Drive intersection open and Clinch Avenue viaduct closed.

The findings of the study were that it was not desirable to close both access locations and virtually create a peninsula of the Fort Sanders area. The other two options did vary with respect to the generated traffic pattern. In both cases the traffic on the existing streets in the Fort Sanders area can be handled with improvements of certain key intersections. The quantifiable project costs for the two alternative options of reopening or closing permanently the Clinch Avenue viaduct did not differ significantly. The major differences of the two options lie in nonquantifiable factors including environmental impacts. As such the final decision on which option to adopt must be made by the decision maker, based on given objectives and his judgment.

The study demonstrated that the simplified technique can be used to estimate the future traffic volumes quickly and at a low cost. Consequently, this approach would enable policymakers to seek technical assistance from planners and traffic engineers and use factual information in decision making.

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CHAPTER I

INTRODUCTION

The 1982 World's Fair site was selected to be in the Lower Second Creek Valley in Knoxville, Tennessee. Immediate to the east of the Fair site is the City's Central Business District (CBD) and to the west is Fort Sanders Neighborhood, a small urban residential area.

The preparations for the World's Fair brought about considerable development activities both on-site and off-site. These activities included the demolition, rehabilitation and new construction of buildings; upgrading of local streets and sidewalks and a major reconstruction of the Interstate Highway system in and around the city of Knoxville.

Although the Fair lasted only for a six-month period, it has been a catalyst for a more permanent post-Fair redevelopment project for the Lower Second Creek area. To meet the requirements for such a development, the city has sponsored several task forces or teams to prepare a general post-Fair reuse plan for the Fair site, to develop criteria for the evaluation and selection of development proposals and to come up with a program for carrying out the plan. The most recent official report (1) outlined a mixed use development for the site consisting of three distinct areas. The east side of the Fair site is to be developed into a high density commercial area; the center of the area is reserved for public use; and for the west side,

between the railroad and Eleventh Street next to Fort Sanders area, is proposed a medium to high-density residential development including apartments and high-density high-rise condominiums.

Because of the Fair site's close proximity to the Fort Sanders area, even the preparations for the Fair have had substantial impact on the neighborhood. All houses along Tenth Street have been permanently displaced (2). Several major changes were made in the traffic flow pattern through the area. A portion of Clinch Avenue viaduct, which runs through the Fair site, was closed, and a one-way street system was implemented.

In anticipation of the post-Fair redevelopment activities which are now in the planning stages, the East Tennessee Community Design Center (ETCDC) has decided to conduct a supplemental study on the traffic impact of the new development on the Fort Sanders area. The Community Design Center provides consulting services to various community groups to analyze their problems and find solutions. In this case the Fort Sanders Neighborhood group has approached ETCDC to help them analyze the situation so the residents can voice their concern, if any, to appropriate authorities.

The Community Design Center discussed the study with Dr. Arun Chatterjee of the Civil Engineering Department at The University of Tennessee. Subsequently this student was assigned to this project.

The main task of the project was to help the Community Design Center resolve this question: What will be the traffic related impacts of the new development at the Fair site on the local streets

in the Fort Sanders area? In addition, the Center was particularly interested that the project address two current local traffic issues which have generated considerable public controversy: (1) whether it is desirable to cut off access to and from the northeast section of the Fort Sanders area by closing the Forest Avenue-Summit Hill Drive intersection, and (2) whether to close permanently Clinch Avenue viaduct to automobile traffic after the Fair, and restrict its use to pedestrians, bicycles and buses only.

In order to provide answers to these questions three alternative plans were considered and then evaluated relative to a same set of selective criteria. Plan "A" assumed the intersection of Eleventh Street and Summit Hill Drive to be open and the Clinch Avenue viaduct to be closed. Plan "B" assumed the Eleventh Street-Summit Hill Drive intersection to be open and the Clinch Avenue viaduct to be open also. Comparison between Plans "A" and "B" will enable the decision maker to evaluate the option of whether to close permanently the Clinch Avenue viaduct. Plan "C" assumed the closing of both the intersection and the viaduct. Examination of Plan "C" will aid the decision maker in the review of the desirability of creating a peninsula of the Fort Sanders area. A fourth alternative concept was also briefly considered and then eliminated because of its weakness. This alternative plan would assume the intersection of Eleventh Street and Summit Hill Drive to be closed and the Clinch Avenue viaduct open. Summit Hill Drive is a major arterial bordering the northern edge of the Fort Sanders area and the Fair site area. The closing of the intersection would eliminate the direct access from these areas to a major arterial thus making the

access to the regional Interstate highways more circuitous. Additionally, the closing of the intersection may be incompatible with the proposed high-density commercial and residential development at the Fair site. For these reasons, the fourth alternative plan was dropped from any further consideration.

This project was subject to a set of constraints, which are commonly encountered in the field of urban planning. There were not enough time and funds for sophisticated modeling requiring the use of computer. Also lacking were manpower and funds for large-scale surveys and data collection effort. The conventional four-step traffic estimation procedure, which is widely used in urban transportation planning (UTP) process, was found to be applicable to this project, but a rigorous use of this approach would have been too time-consuming and expensive. There was a need for a simplified process, within the framework of the stepwise traffic estimation procedure.

The objectives of the study were to explore simplified techniques which can provide quick estimates of future traffic volumes with minimum requirements for resources, and apply a suitable procedure to the case of the Fort Sanders area to generate useful information for resolving the questions regarding the local street system. This study is application oriented. Nevertheless, a search and study were made of alternative traffic estimation procedures prior to selecting a procedure. A discussion on alternative approaches of travel estimation and the state-of-the-art of simplified techniques is presented. Subsequently a detailed account is presented on the actual procedure used, the computations and the findings.

CHAPTER II

LITERATURE REVIEW OF TRAVEL DEMAND FORECASTING METHODOLOGY

The travel demand forecasting methodology has gone through an evolution of procedures, from the early method of factoring up the existing traffic volume based on the past trends to the techniques based on mathematical models. All various types of techniques have their usefulness for certain purposes. For urban travel demand analysis, mathematical models become essential. This chapter presents a review of various models used for travel forecasting.

A. ALTERNATIVE STRUCTURES FOR TRAVEL DEMAND MODELS[1]

Basically there are three alternative approaches for developing travel demand estimating models based on their structure and nature of outputs. The first approach, which may be called the one-step model or procedure, attempts to obtain a direct estimation of the number of trips on a specific facility by developing an equation which gives a causal relationship between a dependent variable and a number of independent variables. The general relationship can be expressed as:

$$V_r = f(x_1, x_2, \ldots, x_n)$$

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[1]Discussion in this section is based on the classnotes of the course CE5860: Urban Transportation Planning taught by Prof. Arun Chatterjee.

where

V_r = dependent variable, number of trips V on facility r;

x_1, x_2, ... x_n = independent variables.

The disadvantage of the one-step procedure is that it is difficult to develop such a model, since there are so many factors that influence traffic volume on a facility. And, most importantly, the model cannot easily reflect changes in either the road network or locations of major developments. It also does not generate any other information such as travel between zones and trips coming in and out of traffic zones.

The second approach, which may be called the two-step model or procedure, does not estimate traffic volume on a facility directly. It first estimates the trip movement between the zones, and then at the next step it finds appropriate routing for the trip interchanges. This approach adds more flexibility and resolves the difficulty of the one-step procedure of not being very sensitive to changes in the road network. Although the two-step procedure is able to reflect changes in road network adequately, it has difficulty in reflecting changes in growth pattern (i.e., land-use). It also does not generate any information on trips coming in and out of traffic zones.

The third approach is known as the three-step procedure or sequential travel estimation procedure. This procedure has an additional step of trip generation analysis in which trip productions and attractions are estimated. The purpose of the extra step is to add more flexibility to the procedure. The advantages of the approach

lie in its ability to reflect changes in both growth pattern and transportation network. It also generates useful information at the end of each step. The three-step procedure is expanded to four steps when mode-choice analysis is added to the process.

B. THE SEQUENTIAL TRAVEL ESTIMATION PROCEDURE

Because of its flexibility, the three-step (or four-step) procedure has become very popular in urban transportation studies. The following sections present a brief overview of the major elements of the standardized process. The relationships among the various steps of the procedure is shown in Figure 1.

Trip Generation

The purpose of the trip generation phase is to estimate the number of trip ends which consist of the amount of traffic produced by a zone and the amount of traffic attracted to a zone. The inputs of this step come from land use/socioeconomic data and detailed home-interview survey data. There are two basic techniques for estimating internal trip productions and attractions. One is an aggregate trip analysis at the traffic zone level and the other is a disaggregate trip analysis at the household level. A more popular approach is to use a combination of aggregate and disaggregate models in which trip productions may be forecast using cross classification models for household trip rates, and zonal trip attractions by using regression analysis (3).

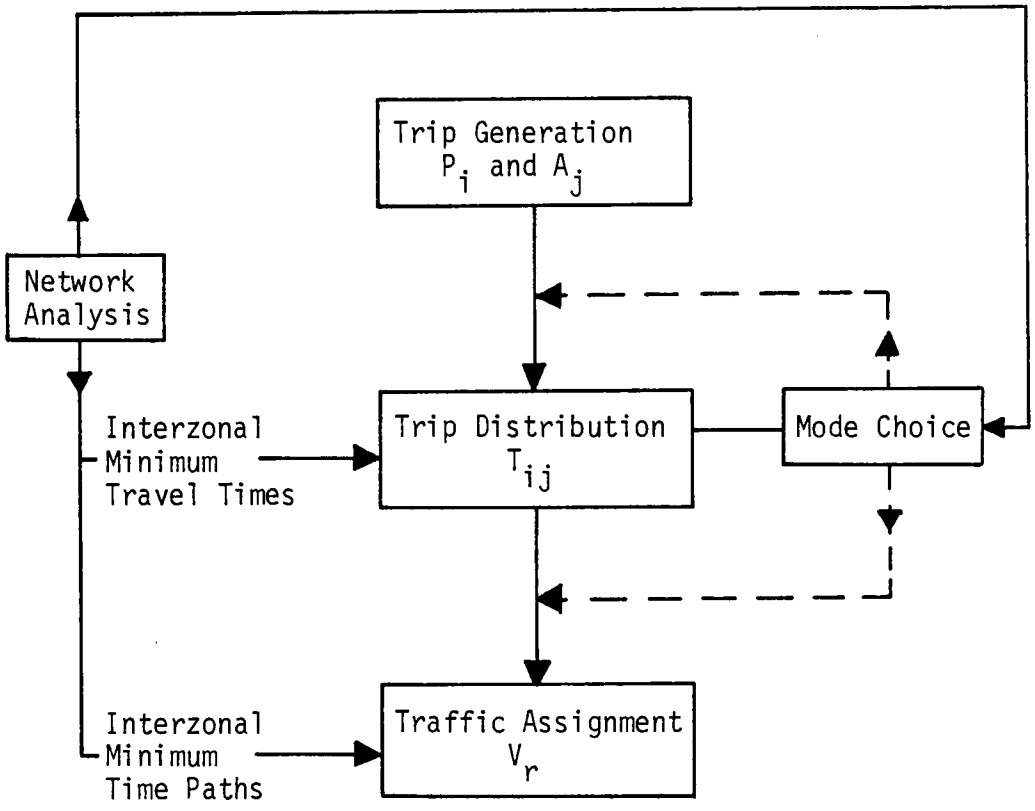


Figure 1. Flow diagram for the sequential travel estimation procedure.

Source: Classnotes of the course CE5860: Urban Transporation Planning taught by Prof. Arun Chatterjee.

Trip Distribution

The purpose of the trip distribution phase is to estimate the zone-to-zone movements, that is, the trip interchanges. There are several techniques that can be used for estimating trip interchanges. One is known as the Fratar Technique which utilizes growth factors for each traffic zone and uses an iterative balancing procedure to project a base year trip matrix to the future year. Another technique is the Intervening Opportunities Model which has been used in the Chicago Area Transportation Study. The most widely used technique is the gravity model. Mathematically the gravity model for trip distribution is expressed as follows:

$$T_{ij} = P_i \times \frac{A_j \times F_{ij}}{\sum_{j=1}^{n} A_j \times F_{ij}}$$

where

T_{ij} = number of trips produced in zone i and attracted to zone j;

P_i = total trip productions at zone i;

A_j = total trip attractions at zone j;

F_{ij} = friction factor or travel time factor, which is inversely proportional to a measure of travel impedance, usually the travel time

= $1/(\text{travel time between i and j})^X$.

The zonal trip productions and attractions are estimated in the trip generation phase, whereas the values of friction factors are derived by a trial and error procedure. When the values of the model

generated A_j's do not match closely with the original input values of A_j's, a balancing procedure is used to adjust the input values of A_j's (4).

Mode Choice

The purpose of the mode choice phase is to estimate the market share (i.e., mode split) for the auto and transit modes, respectively. The most commonly used mode choice model is known as the post-distribution model, and the major input to this step is the person-trip table consisting of trip interchanges between zones. Person-trip tables are developed from the trip-distribution phase. Other basic input information includes travel impedance measures for each zone pair, transit fare, auto operating cost, parking cost, etc. Two major outputs of the mode-choice analysis are transit person-trips and auto person-trips. The auto person-trips are then converted into vehicle-trips by using a vehicle occupancy model. A popular technique for mode-choice analysis is the Urban Mass Transportation Administration default model contained in the program UMODEL of the U.S. Department of Transportation, Urban Transportation Planning System (5).

Network Analysis

This is a supplementary phase which helps to generate input information necessary for other phases of the process. Two primary tasks of network analysis are to determine (1) the minimum time paths between zone pairs (for traffic assignment analysis), and (2) the minimum travel times between zone pairs (for trip distribution and

mode-choice analysis). Network coding is used for computer analysis. Intersections are represented by nodes, segments of a roadway by links, and traffic zones by centroids. The characteristics of each link, such as distance, speed, capacity, turn prohibition and functional classification, are also coded. The Moore's algorithm is usually used to determine the minimum time paths between zones.

Traffic Assignment

The purpose of the traffic assignment phase is to estimate traffic volumes on specific facilities. The two basic inputs to the process are the trip table (zonal trip interchanges) which comes from the trip distribution analysis and the minimum time paths which come from the network analysis. The trip interchange between each zone pair is loaded on each link of the minimum path, and its total is accumulated at the end of the process. There are several alternative techniques for highway assignment. The most commonly used technique is the "All or Nothing" procedure, which assigns all trips between a zone pair to its minimum time path. Other procedures include diversion techniques, the capacity restraint technique, and probabilistic multi-path assignment process (6).

The conventional travel estimation procedure based on the steps of trip generation, trip distribution, modal split, and traffic assignment discussed previously is extremely helpful for the analysis of transportation systems in urban areas. Its importance cannot be overemphasized. However, valuable as it is, the rigorous application of the procedure and model calibration are time consuming, expensive

and difficult. Available computer programs are complex, require large staff and considerable computer time. Therefore, there is a need for a simplified, noncomputer-oriented procedure applicable for small urban areas and localized transportation problems.

C. SIMPLIFIED TECHNIQUES

Recognizing the incompatibility of the conventional travel estimation procedure with the resources of many agencies with respect to manpower, time and funds, several authors have proposed simplifications of the travel estimation procedure (7,8). The proposed simplified procedure is a manual-oriented technique that relies on synthesized trip generation and trip distribution. Simplification is built on the basic structure of the conventional process. The simplified approach proposes to eliminate the costly and time-consuming internal home-interview O-D survey by borrowing trip-generation and trip-distribution models from other communities of similar characteristics with respect to population size, economic base and geographic form. A small sample, 1 or 2 percent, home-interview survey is recommended to derive trip rates for the internal household travel. Traffic counts at special major traffic generators are also recommended. Grecco et al. suggested that simplified techniques can be used for different types of analyses with varying scope and purpose: (a) network simulation, (b) small-area transit planning, (c) corridor analysis, and (d) localized traffic impact (7). Selection of a particular type of analysis depends on the nature of the problem to be analyzed.

Sosslau et al. also addressed the issue of a need for simplified travel estimation techniques to provide quick response to current urban policy questions (5). Simplified procedures were developed that can be used as alternatives to the more costly, computer-oriented conventional procedure. A "User's Guide" (9) was developed, describing transferable parameters, factors, manual techniques pertaining to a variety of models, most of which are basically similar to those of the conventional four-step procedure. The manual can be used by planners for quick-response travel estimation (9).

CHAPTER III

ESTABLISHING A SIMPLIFIED TECHNIQUE AND ITS APPLICATION

The analysis procedure used for this study is a simplified technique in which the basic structure of the conventional stepwise procedure is retained while simplification is applied to the procedure or model of its individual phases. The simplified procedure used in this study was established independently from the simplified and quick-response techniques reviewed previously. Figure 2 outlines the procedure used in this study for analyzing the traffic related impact of the post-Fair developments on the Fort Sanders area. Following are descriptions of each step.

A. STEP 1: DEFINE STUDY AREA

The study area is located in the Lower Second Creek Valley. The site lies west of the central business district of Knoxville, and east of the Fort Sanders neighborhood. It contains approximately 59 acres. The area has been the site of the 1982 World's Fair until October 31, 1982. Now it is proposed to be redeveloped into mixed land-use developments.

The official reuse plan (1) indicates three major use areas: a high density commercial along the east side, a medium- to high-density residential area on the west side, and a recreational area in the center. A general reuse plan is shown on Figure A-1, Appendix A.

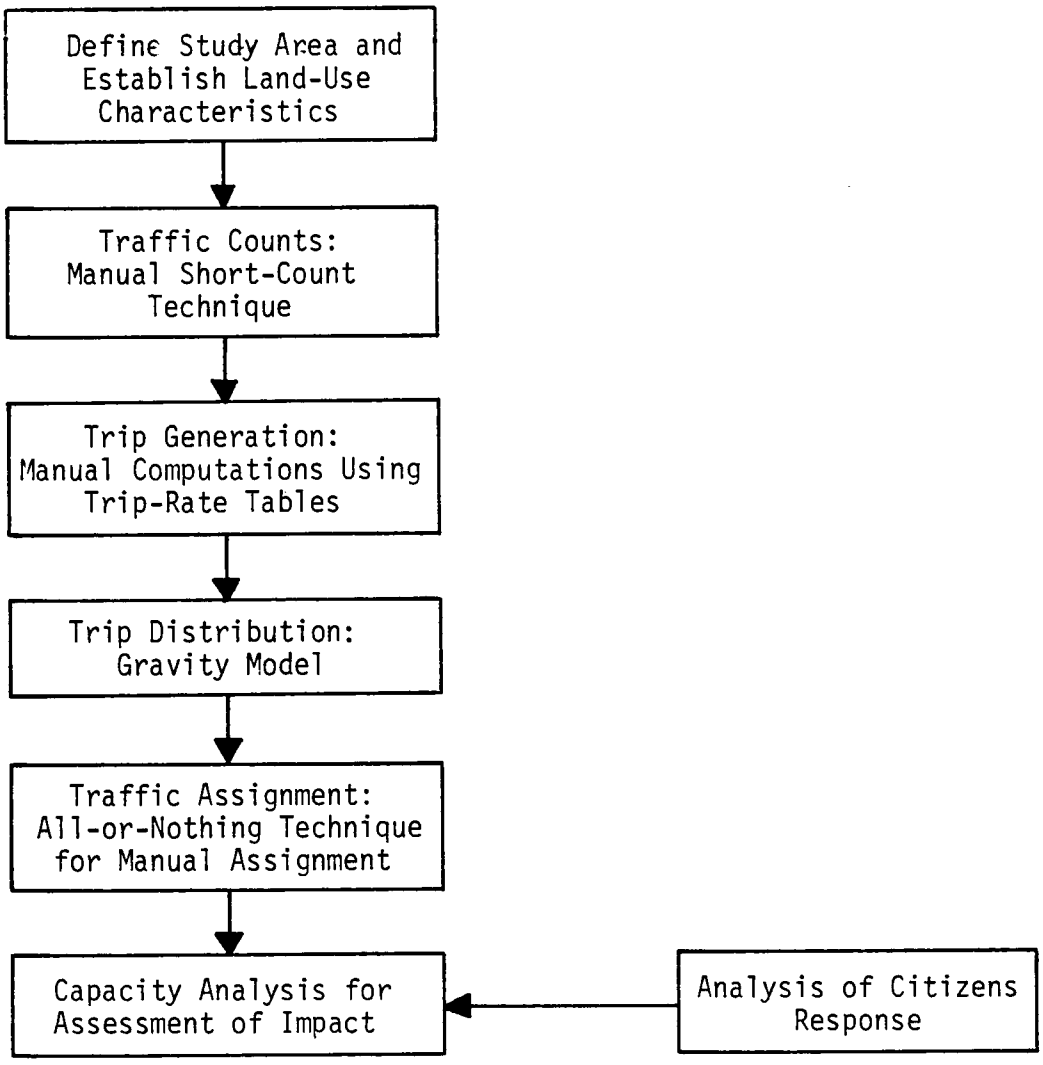


Figure 2. Flow diagram of the traffic impact analysis.

There are a total of 460,000 sq. ft. proposed for shopping area and office space, 17.1 acres for public recreation use, and 800 units for residential use. Figure 3 shows a proposed schematic housing plan for the study area. The distribution of land-uses proposed by the reuse plan is shown in Table C-1 of Appendix C.

The study area does not have direct access to the regional highway routes. It is connected via surrounding local and collector roads with the Interstate highways and other principal arterials. The surrounding roads include Henley Street, Summit Hill Drive, Eleventh Street, Clinch Avenue, Grand Avenue, and Cumberland Avenue. Access to the regional and local street systems is shown on Figure 4. Henley Street is currently proposed to be linked directly to the Interstate highways by a tunnel under Summit Hill Drive. In conjunction with this tunnel project, the Tennessee Department of Transportation (T.D.O.T.) also proposes widening of Summit Hill Drive west of Henley Street and closing the intersection of Forest Avenue and Summit Hill Drive, thus eliminating the access to and from the northeast sector of the Fort Sanders area.

The World's Fair brought about a number of changes in traffic-related activities. A section of Clinch Avenue which runs through the Fair site was closed to traffic. The intersection of Eleventh Street and Cumberland Avenue was signalized and its north leg was widened to three lanes. A system of one-way streets was implemented in the Fort Sanders area. To accommodate future travel demand and accessibility of the northeast sector of the Fort Sanders area, the reuse plan recommended that the connection of Summit Hill Drive with

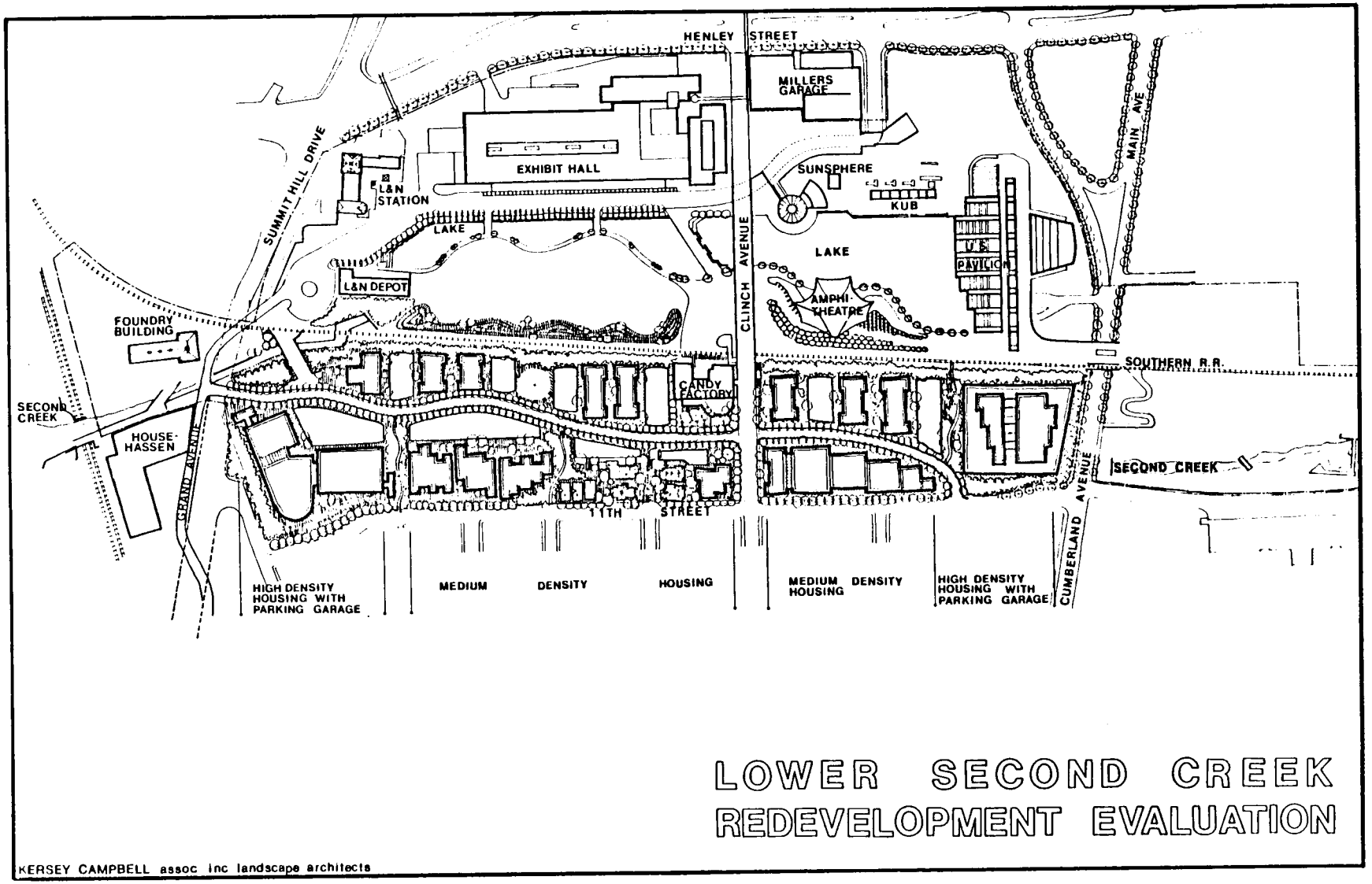


Figure 3. Proposed residential, commercial, and public use development for the World's Fair site.

Source: The Lower Second Creek Evaluation Project's Report, June 1981.

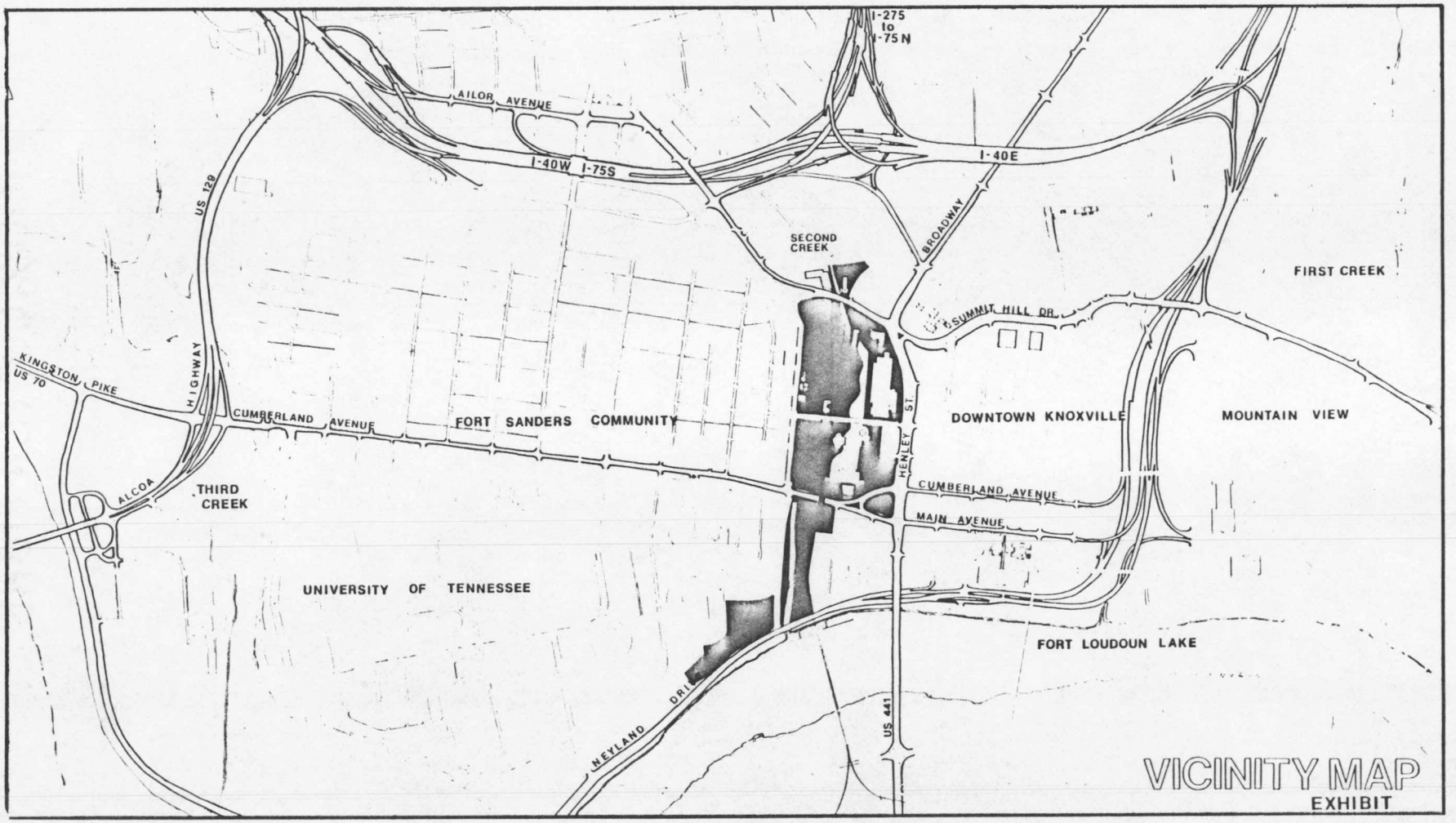


Figure 4. The study area and its surrounding local street system and the regional Interstate highways and arterials.

Source: The Lower Second Creek Evaluation Project's Report, June 1981.

Eleventh Street be maintained. The plan also proposed a new street to be built between the Convention Center and the concrete lake. The street is to connect Church Street and Grand Avenue, providing access to the residential section of the study area and at the same time serving the Convention Center. An extension of this new street from Church Street to Cumberland Avenue along the east face of the U.S. Pavillion also was proposed, together with a proposed tunnel connecting Tracts 9 and 11 (Figure 1-A, Appendix A). The proposed internal circulation plan is shown on Figure 2-A, Appendix A.

The analysis of this study was focused on the local street system of the Fort Sanders neighborhood adjacent to the Fair site. The key streets which are likely to be affected seriously by the new development are Eleventh Street, Clinch Avenue, and Cumberland Avenue. The key intersections of interest are those of Eleventh Street with Summit Hill Drive, Eleventh Street with Clinch Avenue, and Eleventh Street with Cumberland Avenue.

The study area was assumed to form one analysis area by itself. Inside this analysis area are two distinct areas: the residential area is on the west side and the commercial area is on the east side. Outside the focal analysis area are other surrounding analysis areas which were assumed to be defined by the census tracts. They went as far as the city limit. Figure 5 shows the study area in relation to the other analysis areas. Whenever feasible, two or more outlying census tracts were combined to form an analysis area. A total of 43 analysis areas were established for the study. All these areas were superimposed on a highway map of Knoxville to facilitate in the

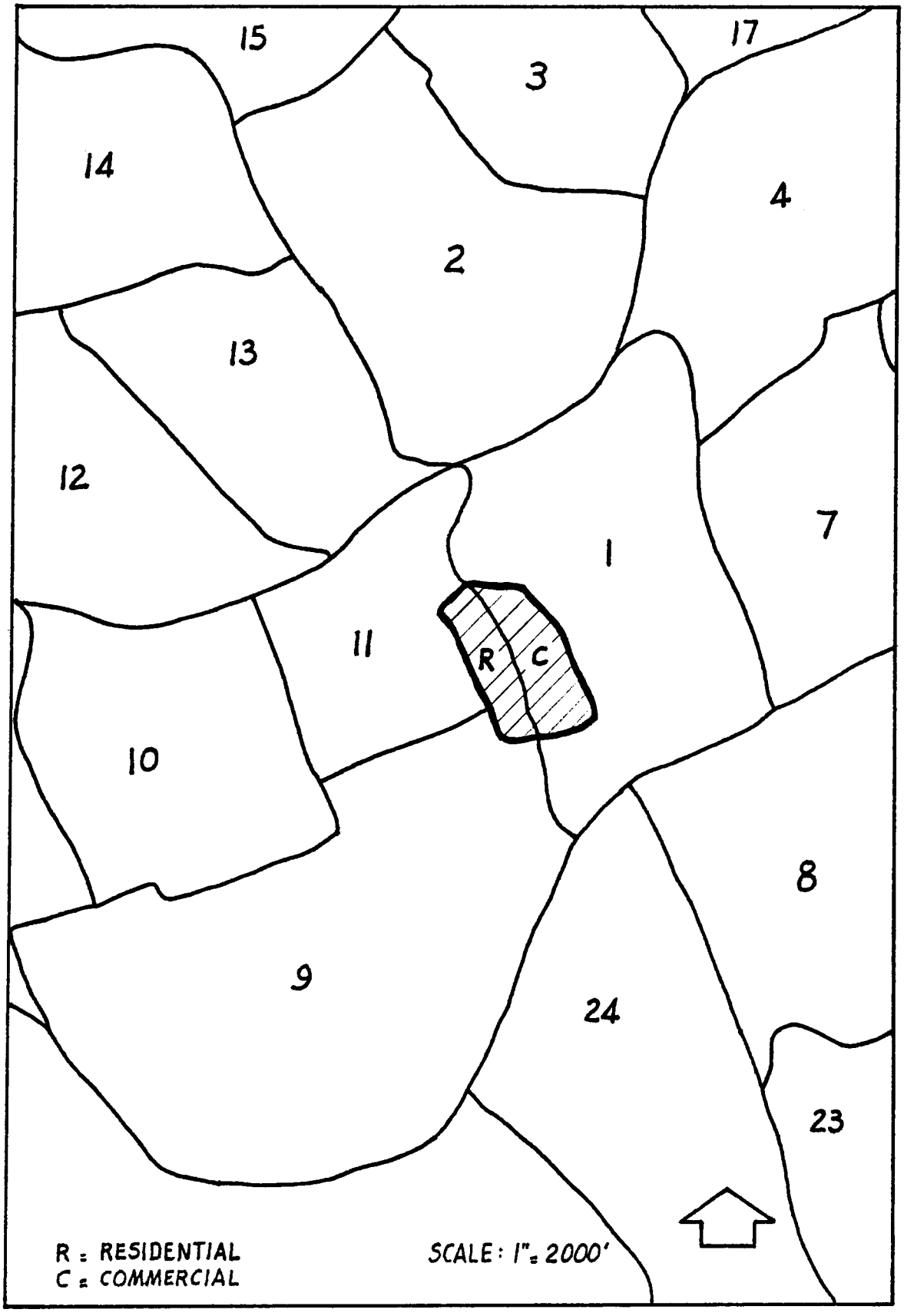


Figure 5. The study area and typical surrounding analysis areas.

manual trip distribution process. Figure D-1 of Appendix D shows the reduced map of traffic zones for Knoxville. Figure D-2 of Appendix D shows the city's reduced census tracts. In actual computations, a larger map of scale 1 inch to 2000 feet was used. The maps were obtained from the Knoxville-Knox County Metropolitan Planning Commission (MPC). Data regarding the socioeconomic characteristics such as population and employment for each traffic zone also were obtained from the MPC. The socioeconomic data are shown in Table D-1 of Appendix D.

B. STEP 2: TRAFFIC COUNT

Current traffic volumes and turning movements on a few key streets and one key intersection were determined by manually counting the traffic. Short-count technique was employed since it provides an economical means of obtaining existing annual average daily traffic (AADT). The AADT is the most common measure used in reporting the traffic on a roadway. Short counts of one-half hour duration were carried out at three locations on Eleventh Street, and at two locations each on Grand Avenue and Forest Avenue. The counts were made between 9:00 and 11:00 A.M. and between 2:00 and 4:00 P.M. on a weekday. The counts were confined to the off-peak hours on the premise that traffic volumes during these periods are generally more stable and subject to the least variation from day to day, thus providing more reliable samples (11). Assuming that the one-half hour volume is indicative of one-hour volume, the hourly volume at each count station was obtained by using a multiplicative factor of 2.

An hourly volume then can be expanded into daily volume, weekly volume, monthly volume, and annual volume by applying expansion factors. The expansion factors used in the study were obtained from the Traffic Engineering Department of the City of Knoxville. They are shown in Tables B-1 and B-2 of Appendix B. Turning movements at the intersection of Summit Hill Drive and Forest Avenue were determined by a one-hour manual count during the afternoon peak hour between 4:00 and 6:00 P.M. of a weekday. The results of the traffic counts and related computations are contained in Appendix B.

C. STEP 3: TRIP GENERATION

Instead of developing a new model, which would require extensive data collection, calculation of trips was performed using trip rates available from other sources. Data regarding land use characteristics of the site (office building, hotel, parking garage, etc.) and the corresponding number of units (square feet, rooms, parking spaces, etc.) were obtained from a published report (1). Three sources of trip generation rates were examined and these are reports by Gray (1), Grecco et al. (7), and Maricopa Association of Governments, Arizona (10). Most of the rates used in this study, however, were from the study by Grecco et al. (7). Trip-generation rates for different land uses are shown in Table C-1 of Appendix C. It is estimated that when the proposed post-Fair developments are completed, the area will generate approximately 28,000 vehicle trip-ends per day, of which 6,500 trip-ends came from residential use and 20,500 trip-ends came from commercial use.

D. STEP 4: TRIP DISTRIBUTION

The manual trip-distribution process used in this study was based on the Gravity Model, which is the most widely used technique for trip-distribution procedure. The model assumes that the trips from a given zone i are attracted to other zones j's in direct proportion to the attractiveness of zone j's and in inverse proportion to the spatial separation between i and j's. The spatial separation is usually measured in terms of the travel times. The Gravity Model can be expressed as follows:

$$T_{ij} = P_i \frac{A_j \times F_{ij}}{\sum_{j=1}^{n} A_j \times F_{ij}}$$

where

$A_j \times F_{ij}$ = the attractiveness of zone j with respect to zone i;

$\frac{A_j \times F_{ij}}{\sum_{j=1}^{n} A_j \times F_{ij}}$ = the relative attractiveness, which is the ratio of a zone's own attractiveness with respect to the total attractiveness;

F_{ij} = the friction factor.

The travel times between the study area and the census tracts were computed based on the distance measured on the city road map, the type of facility traversed, and the personal acquaintance with the local travel patterns. It was assumed, in general, that the operating speed on freeways was 50 mph and that on other arterials was 35 mph. Computed values of travel times were tabulated in

Table D-2, Appendix D. Friction factors were then derived by assuming that they are inversely proportional to the travel time square (i.e., $1/t_{ij}^2$, where t_{ij} is travel time between areas i and j).

The development plan for the study area proposed two separate activity areas. The residential area is to be on the west side and the commercial area on the east side. The trip distributions for these two areas were handled separately and in different manners. For the residential area of the World's Fair site, the trip ends were assumed to be home-based productions.

For the commercial area of the World's Fair site, the trip ends were assumed to be attractions. Since the productions at each census tract outside the Fair site were unknown, the distribution of the trips for the commercial area was performed with the Gravity Model concept applied in the reverse manner, that is, by assuming the trip ends in the commercial area to be the productions, and the combination of population and employment in each census tract to be the attraction. No adjustments for attraction totals was required for the study. The results of trip distribution for the residential area are shown in Table D-3 of Appendix D, and for the commercial area in Table D-4, Appendix D.

E. STEP 5: TRAFFIC ASSIGNMENT

Manual traffic assignment was performed for estimating the additional traffic loadings generated by the new development on existing streets in the study area. The manual traffic assignment procedure was based on the "All-or-Nothing" technique and no capacity

restraint was imposed. Further, a complete assignment on all road segments was not necessary, and assignments were made only on specific links of interest.

Figure A-2, Appendix A, shows a map of the new development area with its proposed internal streets and the adjacent streets in the Fort Sanders area. The vehicle trip ends were assigned based on this assumed internal circulation pattern. The figure indicates three access points onto Eleventh Street, one on Clinch Avenue viaduct and one on the Grand Avenue extension. For the purpose of the analysis, they were assumed to have the character of private driveways.

Because the objectives of the study were to investigate additional traffic impacts caused by the new development and to address the two local traffic issues stated previously, manual traffic assignments were applied to three alternative plans. Plan "A" assumed the intersection of Eleventh Street and Summit Hill Drive to be open and improved with separate left-turn lanes and signalization; but the Clinch Avenue viaduct was assumed to be closed to vehicular traffic. Plan "B" assumed both the Eleventh Street-Summit Hill intersection and the Clinch Avenue viaduct to be open, thus allowing direct access to the Fort Sanders area from all four sides. Plan "C" assumed the closing of both of these intersections, thus basically creating a peninsula of the neighborhood. On each specific route link of interest, two assignments were made. One was the loading of the residential area generated vehicle trips and the other was the loading of the commercial area generated vehicle trips. The

results of the traffic assignments for Plans A, B, and C are shown in Tables E-1, E-2, and E-3, respectively, in Appendix E. The column headings in the tables indicate the specific route links; and the first number in each cell corresponds to the residential loading and the second number corresponds to the commercial loading.

The manual traffic assignment used in this study consisted of three basic steps. The first step was to examine the available street system to decide the minimum paths or the most reasonable paths that the traffic is likely to follow to go from the Fair site (origin) to a particular analysis area (destination). The criterion used to select the most reasonable path was travel time and the goal was to minimize travel time between the origin and the destination. Additionally, when there were two competing routes within a corridor, such as an Interstate highway and a non-freeway arterial, the Interstate (or freeway) route was usually chosen because of higher speeds. Using a large road map of the City of Knoxville, this process was carried out by visual inspection and based on the personal knowledge of the local travel patterns.

The second step involved the assignment or loading of previously estimated trip interchanges, T_{ij}'s, on the various street segments (or network links) of interest. Since the new development at the Fair site would have the most profound impacts on the streets in the immediate vicinity of the development area, the street segments of interest were decided to be (a) Eleventh Street south of Clinch Avenue (for determining the traffic volume approaching Cumberland Avenue), (b) Eleventh Street between Clinch Avenue and Highland Avenue,

(c) Eleventh Street between Highland Avenue and Forest Avenue (for determining the traffic volume approaching Summit Hill Drive), (d) Clinch Avenue west of Eleventh Street, (e) Clinch Avenue east of Eleventh Street, (f) Forest Avenue, and (g) Highland Avenue. Because of the strategic location of the Clinch Avenue viaduct with respect to the development site, the Fair site was subdivided into two distinct subareas: (1) subarea north of the viaduct, occupying 62.5 percent of the development area, and (2) subarea south of the viaduct, occupying 37.5 percent of the main area. Subsequently, the total number of trips from the development site attracted to particular analysis areas, which were obtained from the previous trip-distribution phase, were split by subarea using these ratios for refining the traffic assignments. The access points from these subareas onto the peripheral roads were carefully chosen by examining the site plan.

The third step consisted primarily of recording the number of these assigned trips in a systematic manner. This was done by using tabular forms such as Table E-1, Table E-2, and Table E-3 in Appendix E. Finally, at the end of the process the assigned trips were summed to yield the total traffic volume on each street segment.

For example, let us consider the assigned volumes from the study area to "analysis area One" shown on Table E-1, "Traffic Assignment for Plan "A."" The previous trip-distribution step indicated that there were 2,074 daily vehicle trips going from the Fair site's residential area to analysis area One, which is located in the CBD area. Because the Clinch Avenue viaduct is closed, under Plan "A," the most reasonable paths that the traffic would follow to the CBD were via Cumberland

Avenue and Summit Hill Drive. Therefore, one-half of the traffic, or 1,037 trips, was assigned on Eleventh Street south of Clinch Avenue and one-half was assigned on the opposite direction. Let us consider another example. There were 78 trips that are predicted to travel to "analysis area Two," which is located in the north direction, off Broadway Street. Under Plan "A" with Clinch Avenue viaduct closed, it was assumed that the trips from residential subarea north of Clinch Avenue (62.5 percent) would take Eleventh Street, Summit Hill Drive and then Broadway Street; and that the trips from development's residential subarea south of Clinch Avenue (37.5 percent) would take Eleventh Street, then Cumberland Avenue, then Henley Street, and finally on to Broadway Street. Thus 62.5 percent of the trips, or 49 trips, were assigned on Eleventh Street north of Clinch Avenue. A further stratification of these trips were made recognizing different points of access from the northern subarea to Eleventh Street. Actually one-half of these trips, or 25 trips, were assigned to Eleventh Street between Clinch and Highland Avenues, and 49 trips were assigned on Eleventh Street between Highland and Forest Avenues and further on. The trips from the southern subarea was 37.5 percent of total trips from the site, or 29 trips. These were assigned on the Eleventh Street segment south of Clinch Avenue.

Future traffic volumes consist of existing traffic and its normal growth plus the traffic increase expected due to the development when it is completed. Existing traffic was determined from manual traffic counts discussed previously. For estimating the normal traffic growth, data were obtained from MPC on the growth in auto

ownership in the Fort Sanders area was used. Furthermore, it was assumed that full development at the study area was to be completed in five years, in 1988. The normal traffic growth factor was found to be 4.57 percent of the current ADT volumes for five years. The future traffic volumes were obtained by adding existing volumes and normal growth volumes and development traffic volumes.

F. STEP 6: INTERSECTION CAPACITY ANALYSES

One of the important elements limiting the flow of traffic on a street in an urban area is the intersection at grade (12). Since intersections in this case control the capability of streets to accommodate the flow of vehicles, capacity analyses were carried out at key intersections for estimating intersection capacity in terms of service volume at specific desired level of service. The resultant values served as a basis for evaluating alternative plans. The computational procedures for capacity analysis for this study followed the procedures contained in the 1965 Highway Capacity Manual (12). Turning movements at intersections were derived by using the results obtained from the spatial trip distribution from Step 3. The peak-hour volumes were assumed to be about 12 percent of the ADT volumes. Details of intersection capacity analysis computations are included in Appendix F. The key results are recapitulated in Table 1.

G. STEP 7: ANALYSIS OF CITIZENS' RESPONSE

Opinion surveys were conducted in the Fort Sanders neighborhood in an effort to seek local residents' opinions and attitudes toward

TABLE 1

COMPARISON OF ALTERNATIVE PLANS BASED ON INTERSECTION CAPACITY

Intersection	Plan "A"	Plan "B"	Plan "C"
(1) Eleventh Street and (2) Summit Hill Drive	(1) 9,560 ADT L.O.S. "C" or Better (2) ADT Not Available	(1) <9,560 ADT L.O.S. "C" or Better (2) ADT Not Available	Intersection Closed
(1) Eleventh Street and (2) Clinch Avenue	Intersection Closed	(1) 2,800 ADT L.O.S. "C" (2) 16,500 ADT L.O.S. "C" Approaching "D"	Intersection Closed
(1) Eleventh Street and (2) Cumberland Avenue	(1) 5,800 ADT L.O.S. "C" (2) 32,800 ADT L.O.S. "C" Approaching "D"	(1) <5,800 ADT L.O.S. "C" or Better (2) <32,800 ADT L.O.S. "C.	(1) 7,600 ADT L.O.S. "D" (2) 37,500 ADT L.O.S. "E" At Capacity

Explanation of abbreviations: ADT = Annual Average Daily Traffic on each street both directions; L.O.S. = Level of Service.

the local traffic-related issue of whether to close Clinch Avenue permanently to vehicular traffic and it be kept as a pedestrian pathway and bikeway after the World's Fair.

One hundred and one home interviews and 49 business interviews were conducted in the neighborhood by the staff of the Community Design Center. The response return rate was 100 percent since all the interviews were done in person. Appendix G contains tabulations of results. Table G-1, Appendix G, gives a percentage breakdown of responses according to different resident groups; Table G-2, Appendix G, is a percentage breakdown of responses from the business group; Table G-3, Appendix G, summarizes the results. Following are the findings:

In general, one-quarter of all respondents registered no opinion concerning the closing of Clinch Avenue viaduct. The remaining three-fourths of the respondents were equally divided; one-half disagreed with the closing and one-half agreed. It appeared there was no clear cut consensus among the interviewed residents on the issue of whether to close or open Clinch Avenue viaduct.

However, there were differences in attitudes among the survey groups. Students and professionals seemed to favor the closing of Clinch Avenue viaduct as a means of preserving the residential characteristics of the Fort Sanders neighborhood. Almost 50 percent of the students said yes to the closing and only 22 percent said they disagreed; one-third gave no opinion.

On the other hand, housewives and retirees did not feel that the viaduct should be closed. Eighty percent of the housewives and

77 percent of the retirees favored the reopening of the viaduct. There were only 15 percent retirees and 0 percent housewives who felt the viaduct should be closed. In fact, 23 percent of retired persons said they strongly disagreed with the closing of the viaduct.

The result of the business survey indicated that the business group which includes both employees and business owners was strongly in favor of reopening Clinch Avenue viaduct. Over three-fourths of the respondents disagreed with the proposal to close the viaduct while only 10 percent were in favor of closing it. Fourteen percent expressed no opinion.

In conclusion, business, housewives, and retirees appeared to be unsupportive of the proposal to close Clinch Avenue viaduct to automobile traffic after the World's Fair is over. They were in favor of reopening the viaduct. However, the student group seemed to be favorable toward the proposal and the professional group showed no clear cut consensus on the issue.

CHAPTER IV

EVALUATION OF ALTERNATIVE PLANS

The objective of the evaluation process is to select the best plan among the alternative plans according to the given set of objectives and criteria.

There are several approaches to evaluation and decision making. In the past, the traditional approach has focused on obtaining a single number or index such as the present worth value or a ratio such as the benefit cost ratio, and use the number as a basis for comparison and selection among alternatives. The advantage of this approach is its appearance of neutrality, since the comparison of numbers can be unbiased by emotional factors. The major disadvantage of the technique is that it usually fails to provide the decision maker with many abstract or qualitative criteria for comparison of alternatives. New approaches in recent times attempt to overcome the deficiency of the traditional approach by considering a wide range of evaluation criteria: monetary, quantifiable, and qualitative criteria. Several new techniques exist, such as the cost-effectiveness technique developed originally to aid the military in making their decisions (13), the multidimensional evaluation process (14), and the benefits matrix model (15). These new approaches have a great deal in common and all of these emphasize the need to consider noncostable factors in the decision making process, particularly criteria reflecting

public goals and objectives. This is perhaps the greatest advantage of the new techniques. Another advantage of the new techniques is that all forms of information are admissible in the framework (13). However, if given too much information the decision makers will have difficulty in making decisions. Therefore, it is important to include only relevant criteria by narrowing down to key information and then presenting it to the decision makers in a disaggregate manner so that the decision makers can work out trade-offs and compromises based on their own value judgment.

A. EVALUATION PROCESS

The evaluation process for this study consists of the following steps.

Step 1: Identification of Criteria for Evaluation

The following criteria and their data have been generated for the purpose of evaluation of the three alternative plans discussed in the previous chapter. The alternative plans are: plan "A," plan "B," and plan "C." Plan "A' assumed that the intersection of Eleventh Street and Summit Hill Drive to be open and the Clinch Avenue viaduct to be closed to vehicular traffic. Plan "B" assumed that the intersection of Eleventh Street and Summit Hill Drive to be open and the Clinch Avenue viaduct also to be open, thus allowing direct access to the Fort Sanders areas from all four sides. On the other hand, plan "C" assumed that both intersections to be closed, essentially creating a peninsula of the neighborhood. The generated

information was tabulated as the preliminary evaluation matrix as shown in Table 2. It should be pointed out that additional criteria beyond those shown can be used, if desired.

Right-of-way (R.O.W.) costs were based on rough estimates of the current market value of the land bordering Eleventh Street and Cumberland Avenue. No R.O.W. requirements were needed for plan "A" and plan "B" since the proposed improvements can be constructed within the existing R.O.W. But plan "C" requires new R.O.W. acquisition estimated at about $781,000 because of the additional traffic lanes on Eleventh Street and on a section of Cumberland Avenue, which would be needed to accommodate the projected ADT volumes.

Estimated construction costs were based on the average cost of similar construction in Knoxville. The cost was estimated to be $150,000 for plan "A," $200,000 for plan "B," and $620,000 for plan "C."

Road user costs (R.U.C.) are vehicular operating costs, usually expressed in cents per vehicle mile. These costs are influenced by the roadway classification and the running speed. It was assumed that the operating cost was 20 cents per vehicle mile for plans "A" and "B," and 23 cents per vehicle mile for plan "C," since the average operating speed for plan "C" was somewhat lower than that for plans "A" and "B." Annual R.U.C. is computed as follows:

TABLE 2

PRELIMINARY EVALUATION MATRIX

	Criteria	Plan A[1]	Plan B[2]	Plan C[3]
1.	Right-of-way cost	0	0	$781,000
2.	Construction cost	$150,000	$200,000	$620,000
3.	Annual road user cost[4]	160,400	132,200	241,700
4.	Annual road user benefits	81,300	109,500	Base plan
5.	Benefit cost ratio[5]	5.6	5.6	Base plan
6.	Traffic volume (in ADT) and level of service on Eleventh Street[6]	5800 C	4780 C or better	7600 D → E
7.	Air pollution	3	4	3
8.	Noise level	3	4	3
9.	Displacement of dwellings	0	0	18
10.	Potential for disruption of Fort Sanders neighborhood's traditional residential scale and character	3	4	3
11.	Opportunity for employment and economic development	3	5	2
12.	Convenience of access to CBD area	4	5	3
13.	Accessibility for police and fire protection, hospital and ambulance services	4	5	3

[1]Plan "A" assumed the Eleventh Street-Summit Hill Drive intersection open and the Clinch Avenue viaduct closed.

[2]Plan "B" assumed the Eleventh Street-Summit Hill Drive intersection open and the Clinch Avenue viaduct open.

[3]Plan "C" assumed the Eleventh Street-Summit Hill Drive intersection closed and the Clinch Avenue viaduct closed.

[4]Based on Eleventh Street only. It is not the total systemwise road user cost. It is noted here that the RUC difference between Plans "A" and "B" is not sufficiently large that one plan would be more preferable than the other.

[5]This is based on road user benefits and highway costs only.

[6]Estimated using procedure described in the previous chapter.

Annual R.U.C. = ADT x 365 x L x C

where

ADT = annual average daily traffic in the design year;

L = length of roadway in miles;

C = operating cost in dollars per mile.

Since the alternative plans will have more profound effect on Eleventh Street than on any other local streets in the Fort Sanders area, it was decided that computations be made for Eleventh Street only.

Based on the future ADT volumes estimated for Eleventh Street, the annual R.U.C. for plans "A," "B," and "C" were computed to be $160,400, $132,200, and $241,700, respectively.

Road user benefits (R.U.B.) are the savings to drivers through the use of one alternative as compared with another. Benefits are measured in terms of the decrease or savings in road user costs. Plan "C" was chosen to be the base plan for the purpose of comparison. The annual road user benefits for plans "A" and "B" were computed to be $81,300 and $109,500, respectively.

The benefit-cost ratios were derived by dividing the annual road user cost savings by the annual project costs based on an amortization period of 30 years and an interest rate of 9 percent. Using plan "C" as a base plan, the benefit-cost ratio for plan "A" was 5.6, and for plan "B" the ratio was also 5.6.

Traffic volume criterion was measured in terms of the projected annual average daily traffic volumes which were 5800, 4780, and 7600

for plans "A," "B," and "C," respectively, and in terms of the level of service. Plan "A" had level of service C, plan "B" had level C or better, and plan "C" had level D, approaching E.

Increase in the traffic volumes causes an increase in congestion and a decrease in travel speeds, and consequently an increase in air pollution with carbon monoxide and other hydrocarbon pollutants as well as an increase in noise level above the existing conditions. The scope of the study did not allow for the examination of the environmental problems in detail. Therefore, the environmental factors such as air pollution and noise level had to be dealt with in general terms. Table 3 was used as a guide for estimating relative values.

TABLE 3

SCALING GUIDE FOR QUALITATIVE EVALUATION

Scale	Evaluation
1	Negligible
2	Some
3	Fair, medium, good
4	High, very good
5	Highest, excellent

On a scale of 5, the air pollution and noise level for plan "A" were estimated to be at 3 (medium), for plan "B" at 4 (high), and for plan "C" at 3 (medium).

The implementation of plans "A" and "B" results in no displacement of dwellings. However, plan "C" requires 18 dwellings to be permanently relocated. The dwellings are all located on Eleventh Street.

On a scale of 5 from Table 3, the disruption of the Fort Sanders neighborhood's traditional residential scale and character for plans "A" and "C" were estimated at 3 (fair), and plan "B" at 4 (high).

The new development at the Fair site will undoubtedly stimulate economic development and employment in the immediate area of the site. As in the case of criteria 6, 7, and 10, the estimate of this opportunity is a subjective evaluation. Plan "A" was rated 3 (good) and plan "B" was rated 5 (excellent). Plan "C" was rated only 2 (some) because if the access from Summit Hill Drive to the Fort Sanders area is prohibited, it would be very difficult for the new development to take place at its present proposed intensity.

Convenience of access to the CBD area was measured in terms of the direct accessibility from the Fort Sanders area to the CBD. Plan A was rated 4 (very good), plan "B" was 5 (excellent), and plan "C" was 3 (good).

Regarding the criteria on accessibility to Fort Sanders for police and fire protection, hospital and ambulance services, plan "A" was rated 4 (very good), plan "B" was 5 (excellent), and plan "C" was 3 (good).

Step 2: Reduction of the Evaluation Matrix

To avoid inundating the decision maker with information, it was necessary to reduce the evaluation matrix to a more manageable form. This was done by eliminating equal criteria or combining criteria and also by eliminating inferior plans.

The preliminary evaluation matrix developed in step 1 above shows three plans ("A," "B," and "C") to be evaluated against 13 criteria. First, plan "C" was eliminated because it was inferior to both plans "A" and "B." The plan was substantially more expensive and offered very little in return for this additional expense. Although it caused almost the same environmental impacts as the other plans, plan "C" did not adequately serve the traffic demands. It displaced 18 houses in the Fort Sanders neighborhood, and it offered poor employment and economic development opportunity stimulated by the new development at the Fair site. Next, criteria 1, 5, and 9 can be eliminated because they are equal. Criteria 3 and 4 can also be eliminated because they were used to derive criterion 5. Criteria 7 and 8 can be combined since they all measure the environmental impacts. Criteria 12 and 13 can also be combined because they are measures of public service and are proportional to each other. Table 4 shows the final evaluation matrix.

Step 3: Defining Trade-Offs

Trade-offs reveal the increments in costs (or loss) against increments in gains (or benefits). Trade-offs aid the decision makers in the evaluation of the cost effectiveness of the alternative plans. The trade-offs between plan "A" and plan "B" were developed as follows:

Plans	Trade-Offs	
B vs. A	Gains:	Reduction of traffic congestion by 1020 vehicles per day and improvement of level of service above level C; increase in opportunity for employment

TABLE 4

FINAL EVALUATION MATRIX

	Criteria	Plan A	Plan B
1.	Traffic volume (in ADT) and level of service on 11th Street	5800 C	4780 C or better
2.	Potential for adverse environmental impacts on the Fort Sanders neighborhood	3[a]	4[a]
3.	Potential for disruption of neighborhood's traditional residential scale and character	3[a]	4[a]
4.	Opportunity for employment and economic development	3	5
5.	Public service	4	5

[a]In these cases a higher score implies a worse situation.

and economic development by two units; improvement of level of public service by one unit.

Costs: Additional disruption caused by the environmental factors by one unit; further disruption of neighborhood residential scale and character by one unit.

B. CONCLUSIONS

The objectives of the study were to resolve three local traffic-related issues: (1) what will be the traffic impacts of the new development at the Fair site on the local streets in the Fort Sanders area; (2) whether it is desirable to create a peninsula of the Fort Sanders area by closing both the intersection of Forest Avenue and Summit Hill Drive and Clinch Avenue viaduct; and (3) whether to close permanently Clinch Avenue viaduct to automobile traffic after the Fair, and restrict its use to pedestrians and bicycles only. The information generated by this study was organized to address these questions individually and is presented in the following sections.

What Will be the Traffic Impacts on Local Streets from the New Development?

To analyze the traffic-related impacts of the new development at the Fair site on the local streets in the Fort Sanders area three alternative plans (Plans "A," "B," and "C") were developed and examined. The nature and magnitude of impacts depend on the respective plans. The details of the impacts will be discussed in the following sections with reference to specific plans. In general, the

traffic-related impacts of this kind of new development on the adjacent areas may be expected to include the following: an increase in traffic volumes creating traffic congestion and delays; displacement of dwellings and businesses necessitated by widening of roads to accommodate the increased traffic; an increase in adverse environmental impacts such as noise and air pollution; disruption of the neighborhood traditional residential scale and character; a change in public services such as police and fire protection, hospital and ambulance services; and a change in the potential for employment opportunity and economic development. The status of these items are examined under each of the three alternative plans in the following sections.

Is it Desirable to Create a Peninsula of the Fort Sanders Area?

The issue of creating a peninsula is related to the alternative Plan C. Thus an examination of the impacts of Plan C would help resolve this question. Closing both the intersection of Forest Avenue and Summit Hill Drive and Clinch Avenue viaduct will cut off the continuity of northbound and eastbound movements. The local traffic volume from the Fair site's residential area and the Fort Sanders area's adjacent sector will be forced to use the intersection of Eleventh Street and Cumberland Avenue whether it is destined for the north, south, east, or west. This will result in disorientation of traffic flows, and unnecessary concentration of traffic on Eleventh Street and Cumberland Avenue. The future traffic volume on Cumberland Avenue at Eleventh STreet was estimated at 37,500 vehicles per day which is substantially over the desirable volume of 25,000 ADT for a five-lane

arterial road. The additional traffic on Eleventh Street was estimated at 4,511 ADT for the segment between Cumberland Avenue and Clinch Avenue, and slightly less on its remaining segments. Similarly, the analyses indicated that Clinch Avenue, Highland Avenue, and Forest Avenue are expected to have additional traffic of 1,480 ADT, 1067 ADT, and 659 ADT, respectively. Although Clinch Avenue, Highland Avenue, and Forest Avenue can handle the additional traffic, it is anticipated that intolerable traffic congestion may occur on Eleventh Street and Cumberland Avenue at Eleventh Street. The results of the capacity analysis carried out for this key intersection indicated that Eleventh Street can handle the future demand volume only at level of service "D," and Cumberland Avenue at level "E." A minimum of level of service "C" is recommended for city streets. Level "D" indicates increasing restrictions of traffic flow approaching instability and substantial delays and back-ups; and level "E" indicates that the street would be operating at its capacity, with unstable flow, heavy congestion and intolerable delays during a.m. and p.m. peak hours.

In order to provide an adequate level of service, two additional lanes, one in each direction, would be needed on the section of Cumberland Avenue at Eleventh Street, and one additional lane would be required on Eleventh Street, resulting in new R.O.W. acquisition together with a permanent displacement of 18 dwellings located on Eleventh Street. The R.O.W. cost and construction cost for Plan "C" were estimated roughly at $1,401,000.

While it is extremely difficult to assess precisely many qualitative factors such as public service, potential for disruption

of the neighborhood's traditional residential scale and character, and opportunity for employment and economic development, it can be observed that, relative to Plans "A," and "B," the implementation of Plan "C" would bring about a less favorable opportunity for employment and economic development for the Fort Sanders area and a decrease in public service due to a less direct access to the CBD and a more circuitous access to the Interstate highways.

Based on these considerations, it may be concluded that it would not be desirable to isolate the Fort Sanders area by closing both the intersection of Forest Avenue and Summit Hill Drive and Clinch Avenue viaduct. It may be pointed out that the concept behind the plan of eliminating both access locations is to reduce traffic. However, it appears that ironically the plan would result in an undesirable traffic situation with adverse impact on the neighborhood.

Whether to Close Permanently Clinch Avenue Viaduct

To evaluate this option it is necessary to make a comparison of the impacts of Plan "A" and Plan "B," one of which allows the closing and the other allows the opening of the viaduct. Plan "A" assumed the intersection of Eleventh Street and Summit Hill Drive to be open, and Clinch Avenue viaduct to be closed, whereas Plan "B" assumed both the intersection and the viaduct to be open.

Under Plan "A" Cumberland Avenue at Eleventh Street was estimated to carry a future traffic volume of 32,800 ADT; and Eleventh Street to carry 5,800 ADT on its segment between Cumberland and Clinch Avenues and smaller volumes on its remaining segments; and Forest

Avenue to carry 5,000 ADT. Additionally, Clinch Avenue west of Eleventh Street, Highland Avenue, and Forest Avenue were estimated to have additional development traffic volumes of 1,140 ADT, 260 ADT, and 1,140 ADT, respectively. The capacity analyses showed that all these existing streets are capable of handling the projected travel demand at an adequate level of service without substantial reconstruction. However, a realignment of Eleventh Street at Summit Hill Drive to provide one separate northbound left-turn lane and one separate northbound right-turn lane, together with the signalization of the intersection will be required. The intersection capacity analysis carried out for Cumberland Avenue at Eleventh Street indicated that Cumberland Avenue will be heavily utilized and the street is expected to operate at level of service "C," approaching level "D," thus resulting in substantial delays during the morning and afternoon peak periods.

Under Plan "B," with the opening of Clinch Avenue viaduct the east-west movements will be more effectively served. A portion of the traffic volumes, which would have been on Eleventh Street, Cumberland Avenue and Forest Avenue had the viaduct been closed, will now be diverted to Clinch Avenue. The traffic will spread out more evenly over the local street network, and the traffic congestion expected at the intersection of Eleventh Street and Cumberland Avenue under Plan "A" will now be shifted to Eleventh Street at Clinch Avenue. Eleventh Street was estimated to carry an additional development traffic of only 700 ADT, and Forest Avenue to carry an additional traffic of 775 ADT. Meanwhile, Clinch Avenue was estimated to carry a total future volume of 15,347 ADT.

Like Plan "A," the capacity analyses indicated that all the existing streets are expected to handle the future travel demand at an adequate level of service without substantial reconstruction. However, the realignment of Eleventh Street at Summit Hill Drive together with its signalization there, and the provision for separate left-turn lanes on Clinch Avenue at Eleventh Street together with the signalization of the intersection are to be required. Additionally, the intersection capacity analysis indicated that the Clinch Avenue at Eleventh Street will be heavily utilized and the street is expected to operate at level of service "C," approaching "D," resulting in substantial delays during the morning and afternoon peak periods. It should be noted here that although the analysis showed that Eleventh Street can handle the demand volume at level of service "C," the mid-block driveways which connect the Fair site's residential area to Eleventh Street might pose as serious spot interferences.

Both Plan "A" and Plan "B" would not require any widening of the existing streets, nor any additional R.O.W. acquisition and no additional displacement of dwellings. The difference in costs between the two alternative plans is not significant enough for one plan to be chosen over the other based on economic consideration. Nevertheless, the differences between the two plans lie in the many noncostable factors as shown on the two evaluation matrices, Table 3 and Table 4, pages 38 and 41. Again, while it is very difficult to quantify the qualitative factors, it can be concluded in a general sense that Plan "A" would create less adverse environmental impacts on the Fort Sanders area and would minimize the potential for disruption of the

Fort Sanders neighborhood's traditional residential scale and character. But, on the other hand, Plan "B" would bring about a more favorable opportunity for employment and economic development for the Fort Sanders area and a better access for public service.

In addition, the decision makers should be aware of the opinions and concerns held by the local residents who are affected by the new development. The result of the home interview survey showed that the student group is strongly in favor of the closing of Clinch Avenue viaduct to vehicular traffic; the professional group showed no clear-cut consensus on the issue; and the housewife and retiree groups appeared to be in favor of reopening the viaduct. The result of the business survey indicated that the business group, which includes both employees and business owners, is strongly in favor of reopening Clinch Avenue viaduct.

The final decision on what alternative plan to adopt will have to be made by the decision maker. He must make his choice of a plan based on his objectives and judgment with proper consideration of the trade-offs among the alternatives and other implications of the choice.

LIST OF REFERENCES

LIST OF REFERENCES

1. Gray, Aelred J., Reshaping Knoxville's Center City; A Reuse and Development Plan for Lower Second Creek, Final Report, Submitted to the Knoxville City Council, June 1981.

2. East Tennessee Community Design Center, Fort Sanders: Neighborhood Design Plan; Interim Report Phase One: Problems and Goals, September 1981.

3. Chatterjee, A., Martinson, D. R., and Sinha, K. C., "Trip Generation Analysis for Regional Studies," Transportation Engineering Journal, American Society of Civil Engineers, Vol. 103, No. TE6, November 1977, pp. 825-841.

4. Urban Transportation Planning and General Information, Federal Highway Administration, U.S. Department of Transportation, March 1972.

5. Sosslau, A. B., Hassam, A. B., Carter, M. M., and Wickstrom, G. V., Comsis Corporation, Travel Estimation Procedures for Quick Response to Urban Policy Issues, National Cooperative Highway Research Program Report 186, Transporation Research Board, 1978.

6. Traffic Assignment, Federal Highway Administration, U.S. Department of Transportation, 1973.

7. Grecco, W. L., Wegmann, F. J., Spencer, J. A., and Chatterjee, A., Transportation Planning for Small Urban Areas, National Cooperative Highway Research Program Report 167, Transportation Research Board, 1976.

8. Khasnabis, S., and Poole, M. R., "Synthesizing Travel Patterns for a Small Urban Area," Traffic Engineering, August 1975, pp. 28-30.

9. Sosslau, A. B., Hassam, A. B., Carter, M. M., and Wickstrom, G. V., Quick-Response Urban Travel Estimation Techniques and Transferable Parameters—User's Guide, National Cooperative Highway Research Program Report 187, Transporation Research Board, 1978.

10. Maricopa Association of Governments, Trip Generation by Land Use—Part I, Maricopa County, Arizona, 1974.

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

12. Highway Research Board, Special Report 87, Highway Capacity Manual 1965, National Academy of Sciences, National Research Council, Washington, DC, 1965.

13. Dickey, John W., Metropolitan Transportation Planning, Scripta Book Company, Washington, DC, 1975.

14. Beimborn, Edward A., "Structural Approach to the Evaluation and Comparison of Alternative Transportation Plans," Transportation Research Record 619, Transportation Research Board, National Academy of Sciences, Washington, DC, 1976, pp. 22-26.

15. Poole, Marion R., and Cribbins, Paul D., Benefits Matrix Model for Transportation Project Evaluation, Paper presented to the 1983 Annual Meeting, Transportation Research Board.

APPENDICES

APPENDIX A

SITE PLANS

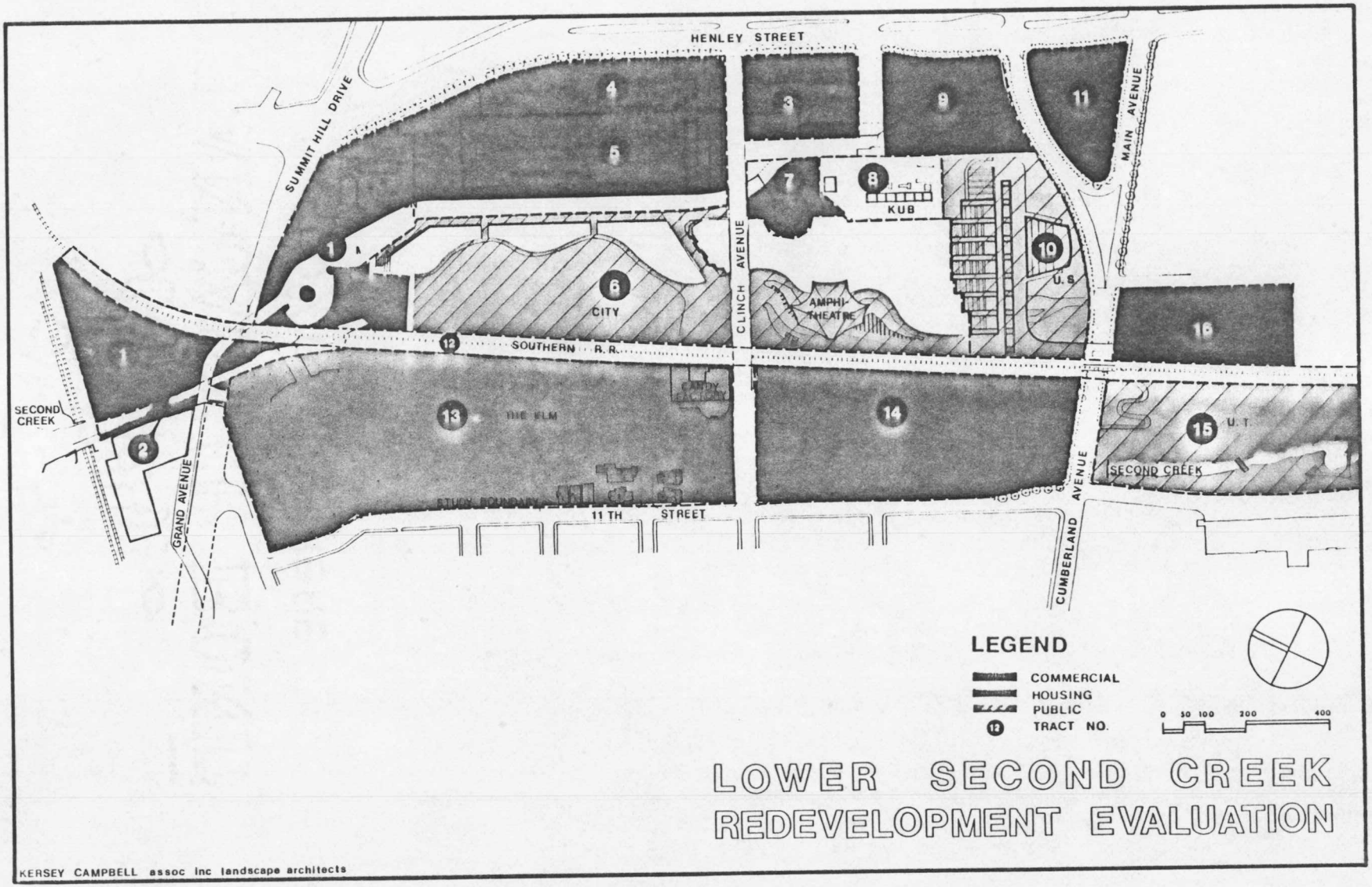


Figure A-1. A proposed general reuse plan for the World's Fair site.

Source: The Lower Second Creek Evaluation Project's Report, June 1981.

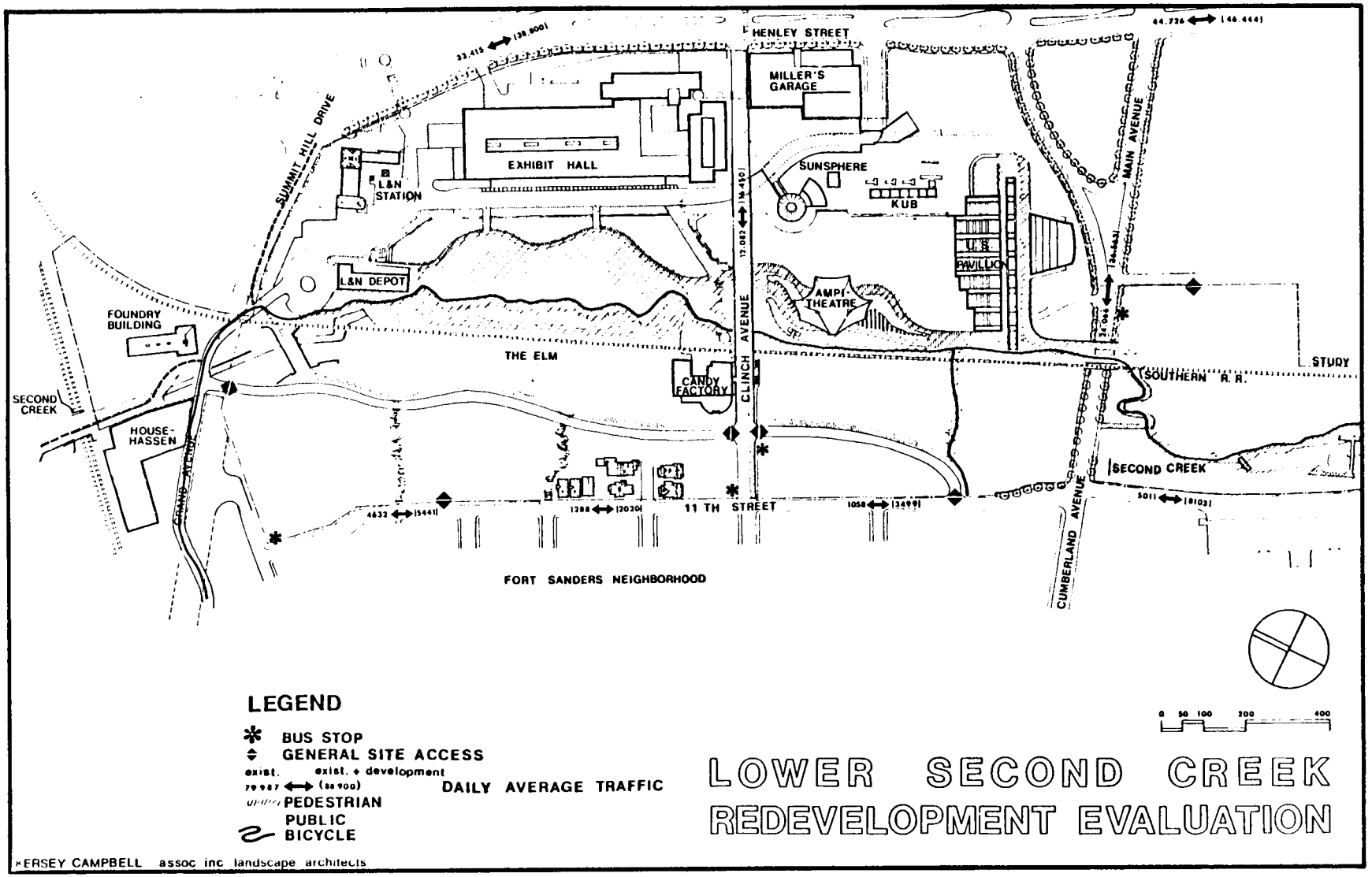


Figure A-2. Proposed internal circulation plan for the redevelopment of the World's Fair site.

Source: The Lower Second Creek Evaluation Project's Report, June 1981.

APPENDIX B

TRAFFIC COUNT

TABLE B-1

HOURLY STREET TRAFFIC VOLUMES AS PERCENT OF DAILY TRAFFIC[1]

Hour Beginning	Chicago	Columbus	Phoenix	Knoxville			
				Arterial	Collector	M Collector	Residential
12 Midnight	1.3	1.2	1.3	1.1	0.9	0.9	0.5
1 A.M.	0.7	0.7	0.8	0.7	0.4	0.4	0.2
2	0.5	0.5	0.4	0.5	0.2	0.2	0.1
3	0.3	0.4	0.3	0.3	0.1	0.2	0.2
4	0.2	0.4	0.3	0.4	0.2	0.2	0.0
5	0.6	1.1	0.7	1.1	0.8	0.9	0.4
6	1.7	3.3	2.3	3.8	2.6	3.0	1.7
7	5.2	7.5	6.8	6.4	6.1	7.6	4.8
8	6.0	6.6	6.4	5.5	6.6	8.4	6.5
9	5.0	5.4	5.2	5.1	4.1	3.3	5.0
10	5.5	5.5	5.6	5.3	4.2	4.1	4.8
11	6.2	5.8	5.8	6.0	5.2	4.2	5.5
12 Noon	6.8	5.7	6.2	6.3	5.7	5.0	5.4
1 P.M.	6.7	6.2	6.1	6.2	5.5	5.8	5.7
2	6.7	6.2	6.3	6.5	6.3	6.8	6.1
3	7.2	7.0	6.8	7.3	7.9	7.9	8.6
4	8.0	9.0	8.1	8.0	8.1	8.4	8.9
5	8.0	7.9	8.6	7.4	9.2	8.2	9.7
6	5.9	4.4	5.3	5.8	7.2	6.6	6.9
7	5.0	4.2	4.7	5.0	5.8	5.6	6.0
8	3.8	3.2	3.9	4.3	4.8	4.4	4.7
9	3.6	3.1	3.4	3.5	3.8	3.5	3.3
10	2.9	2.5	2.6	2.8	2.6	2.2	2.1
11	2.2	2.2	2.1	1.9	1.5	1.4	1.4

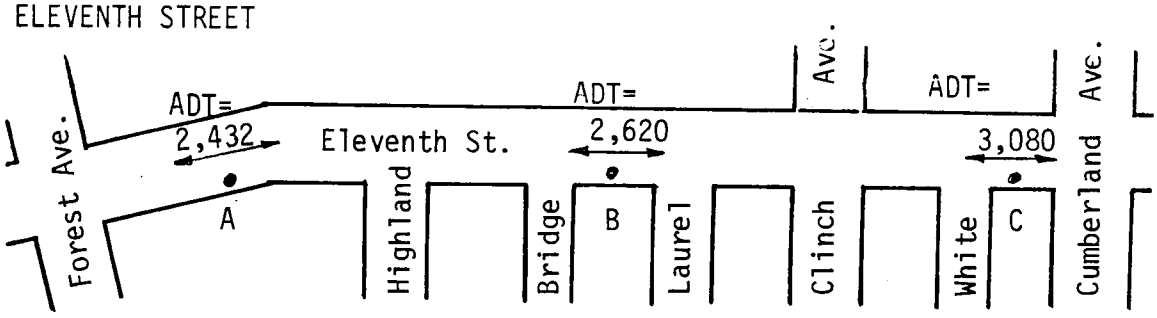
[1]Source: The Traffic Engineering Department, City of Knoxville (1982 data).

TABLE B-2

DAILY AND MONTHLY FACTORS[1]

	Arterial	Collector	Residential
Month			
January	1.087	1.165	1.064
February	1.044	1.026	1.002
March	1.000	0.966	0.928
April	0.961	0.962	0.963
May	0.955	0.971	0.949
June	0.982	0.972	1.104
July	0.976	0.980	1.049
August	0.998	0.975	1.014
September	1.037	0.997	0.970
October	0.982	0.996	0.953
November	0.947	0.973	0.959
December	1.033	1.036	1.082
Day			
Sunday	1.492	1.493	1.343
Monday	0.955	0.956	0.966
Tuesday	0.930	0.930	0.054
Wednesday	0.922	0.922	0.962
Thursday	0.921	0.921	0.948
Friday	0.863	0.864	0.851
Saturday	1.134	1.135	1.106

[1]Source: The Traffic Engineering Department, City of Knoxville (1982 data).



Not to Scale

LOCATION A

10:00 A.M.-11:00 A.M.
Tuesday, April 13, 1982
Minor Collector

Hourly volume = 102 x 2 = 204 veh.

24-Hour volume = 204 x 12.66 = 2,583 veh.

Adjusted for Tuesday = 2,583 x 0.93 = 2,402 veh.

24-Hour vol. adjusted for April = 2,402 x 0.962 = 2,311 veh.
(or annual average daily traffic - ADT)

2:00 P.M.-3:00 P.M.
Tuesday, April 13, 1982
Minor Collector

Hourly volume = 97 x 2 = 194 veh.

24-Hour volume = $194 \times \frac{1}{.068} = 194 \times 14.71 = 2,854$ veh.

24-Hour vol. adjusted for Tuesday = 2,854 x 0.93 = 2,654 veh.

24-Hour vol. adjusted for April (or ADT) = 2,654 x 0.962 = 2,553 veh.

AVERAGE: $ADT = \frac{2,311 + 2,553}{2} = 2,432$

LOCATION B

10:00 A.M.-11:00 A.M.
Tuesday, April 13, 1982

Hourly volume = 107 x 2 = 214 veh.

24-Hour volume = 124 x 12.66 = 2,709 veh.

24-Hour volume adjusted for Tuesday = 2,709 x 0.93 = 2,519

24-Hour volume adjusted for April (ADT) = 2,519 x 0.962 = 2,423

2:00 P.M.-3:00 P.M.
Tuesday, April 13, 1982

Hourly volume = 107 x 2 = 214 veh.

24-Hour volume = 214 x 14.71 = 3,148 veh.

24-Hour volume adjusted for Tuesday = 3,148 x 0.93 = 2,928

ADT = 2,928 x 0.962 = 2,817 veh.

$$\text{AVERAGE} = \frac{2{,}423 + 2{,}817}{2} = 2{,}620 \text{ ADT}$$

LOCATION C

10:00 A.M.-11:00 A.M.
Tuesday, April 13, 1982

(Figure already taken into account special condition of construction vehicles going into and coming out of the 1982 World's Fair site.)

Hourly volume = 114 x 2 = 228 veh.

24-Hour volume = 228 x 12.66 = 2,886 veh.

24-Hour volume adjusted for Tuesday = 2,886 x 0.93 = 2,684

ADT = 2,684 x 0.962 = 2,582 veh.

2:00 P.M.-3:00 P.M.
Tuesday, April 13, 1982

Hourly volume = 136 x 2 = 272 veh.

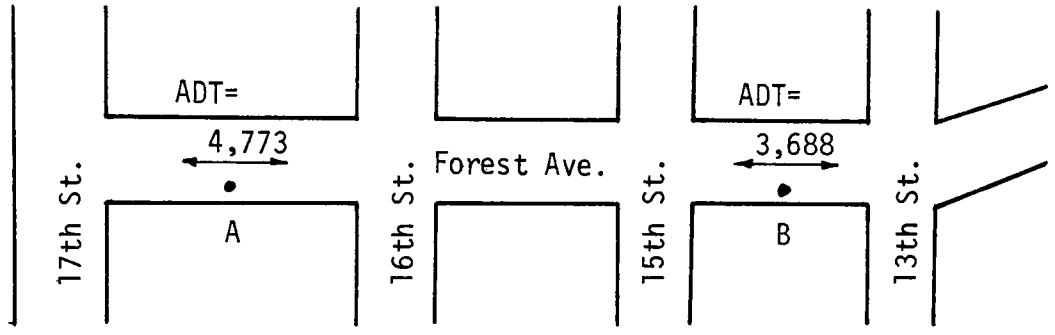
24-Hour volume = 272 x 14.71 = 4,001 veh.

24-Hour volume adjusted for Tuesday = 4,001 x 0.93 = 3,721

ADT = 3,721 x 0.962 = 3,580 veh.

$$\text{AVERAGE} = \frac{2,582 + 3,580}{2} = 3,081 \text{ ADT}$$

FOREST AVENUE



Not to Scale

LOCATION A

3:00 P.M.-4:00 P.M.
Tuesday, April 13, 1982
Collector

Hourly volume = 166 x 2 = 332 veh.

24-Hour volume = $332 \times \frac{1}{0.079} = 332 \times 12.66 = 4,203$ veh.

Daily volume adjusted for Tuesday = 4,203 x 0.93 = 3,909 veh.

Daily volume adjusted for April
(or Annual Average Daily
Traffic—ADT) = 3,909 x 0.962 = 3,760 veh.

10:00 A.M.-11:00 A.M.
Wednesday, April 14, 1982
Collector

Hourly volume = 137 x 2 = 274 veh.

24-Hour volume = 274 x 23.81 = 6,524 veh.

24-Hour volume adjusted for Wednesday = 6,524 x 0.922 = 6,015 veh.

24-Hour volume adjusted for April (or ADT) = 6,015 x 0.962 = 5,786 veh.

AVERAGE: $\frac{3,760 + 5,786}{2} = 4,773$ ADT

LOCATION B

3:00 P.M.-4:00 P.M.
Tuesday, April 13, 1982

Hourly volume = 128 x 2 = 256 veh.

24-Hour volume = 256 veh. x 12.66 = 3,241 veh.

Daily volume adjusted for Tuesday = 3,241 veh. x 0.93 = 3,014 veh.

Daily volume adjusted for April (or ADT) = 3,014 x 0.962 = 2,899 veh.

10:00 A.M.-11:00 A.M.
Wednesday, April 14, 1982

Hourly volume = 106 x 2 = 212 veh.

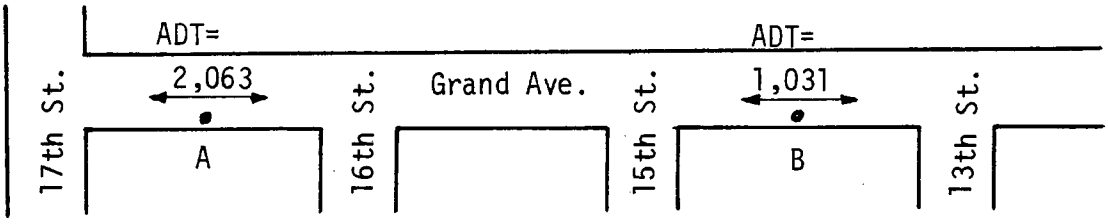
24-Hour volume = 212 x 23.81 = 5,048 veh.

24-Hour volume adjusted for Wednesday = 5,048 x 0.922 = 4,654 veh.

24-Hour volume adjusted for April (or ADT) = 4,654 x 0.962 = 4,477 veh.

AVERAGE: $\frac{2,899 + 4,477}{2}$ = 3,688 ADT

GRAND AVENUE



Not to Scale

LOCATION A

3:00 P.M.-4:00 P.M.
Tuesday, April 13, 1982
Minor Collector

Hourly volume = 58 x 2 = 116 veh.

24-Hour volume = 116 x 12.66 = 1,469 veh.

Daily volume adjusted for Tuesday = 1,469 x 0.93 = 1,366 veh.

Daily volume adjusted for April (or ADT) = 1,366 x 0.962 = 1,314 veh.

10:00 A.M.-11:00 A.M.
Wednesday, April 14, 1982
Minor Collector

Hourly volume = 65 x 2 = 130 veh.

24-Hour volume = $130 \times \frac{1}{0.041} = 130 \times 24.39 = 3,171$ veh.

Daily volume adjusted for Wednesday = 3,171 x 0.922 = 2,924 veh.

Daily volume adjusted for April (or ADT) = 2,924 x 0.962 = 2,813 veh.

AVERAGE: $\frac{1,314 + 2,813}{2} = 2,063$ ADT

LOCATION B

3:00 P.M.-4:00 P.M.
Tuesday, Apirl 13, 1982

Hourly volume = 28 x 2 = 56 veh.

24-Hour volume = 56 x 12.66 = 709 veh.

Daily volume adjusted for Tuesday = 709 x 0.93 = 659 veh.

Daily volume adjusted for April (or ADT) = 659 x 0.962 = 634 veh.

10:00 A.M.-11:00 A.M.
Wednesday, April 14, 1982

Hourly volume = 33 x 2 = 66 veh.

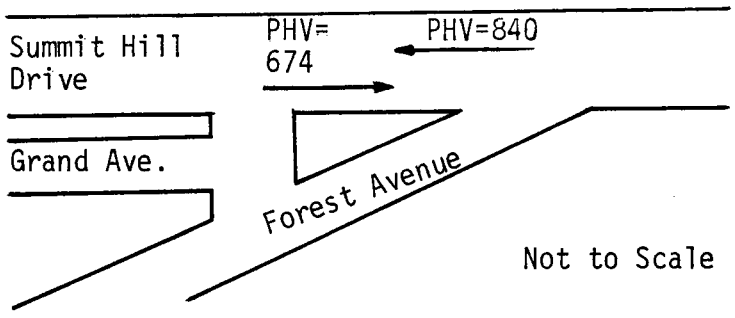
24-Hour volume = 66 x 24.39 = 1,610 veh.

Daily volume adjusted for Wednesday = 1,610 x 0.922 = 1,484 veh.

Daily volume adjusted for April (or ADT) = 1,484 x 0.962 = 1,428 veh.

AVERAGE: $\frac{634 + 1,428}{2}$ = 1,031 ADT

SUMMIT HILL DRIVE



4:40 P.M.-5:10 P.M.
Monday, April 26, 1982
Arterial

Assuming PHV = 8.2 percent (same as for Forest Avenue), therefore ADT = $\frac{840}{0.082}$ = 10,244 VPD in westbound direction and $\frac{674}{0.082}$ = 8,220 VPD in eastbound direction. Assuming normal traffic growth of 4.57 percent for 5-year period, projected traffic would be 10,712 ADT in one direction.

APPENDIX C

TRIP GENERATION

TABLE C-1

TRIP GENERATION BY DIFFERENT LAND USE

Tract No.	Proposed Land Use	No. of Units	Trip Generation Rates	Total Daily Vehicle Trip-Ends
1	Shops, studios, offices (L&N Station & Depot)	30 x 1,000 sq. ft.	18.5 per 1,000 sq. ft.	555
	Restaurant (Foundry Building)	6 x 1,000 sq. ft.	237 per 1,000 sq. ft.	1,422
2	Public use along Second Creek (City of Knoxville)	0.4 acre	-	-
3	Parking garage (Miller's 300-car garage & warehouse)	320 parking spaces	1.3 per space	416
4	Hotel (299-room Holiday Inn)	300 rooms	9 per room	2,700
5	Convention center	88 x 1,000 sq. ft.	31.3 per 1,000 sq. ft.	2,754
	Office building	90 x 1,000 sq. ft.	17 per 1,000 sq. ft.	1,530
6	Park (City of Knoxville)	8.8 acres	5 per acre	44
	State amphitheater	1,500 seats	0.4 per seat	600
7	Restaurant (dining)	496 seats	0.67 per seat	332
	Restaurant (fast food)	3.8 x 1,000 sq. ft.	237 per 1,000 sq. ft.	901
8	Substation (KUB)	0.9 acres	-	-

TABLE C-1 (continued)

Tract No.	Proposed Land Use	No. of Units	Trip Generation Rates	Total Daily Vehicle Trip-Ends
9	Commercial center, including office building	2.5 x 1,000 sq. ft.	20 per 1,000 sq. ft.	5,000
10	U.S. Pavillion	-	-	-
11	Office building	100 x 1,000 sq. ft.	17 per 1,000 sq. ft.	1,700
12	Southern Railway	4.3 acres	-	-
13 & 14	Residential Use: Medium to high density apts., condo., townhouses	800 units	8.1 per unit	6,480
15	Public use (not specifically defined) University of Tennessee	7 acres	-	-
16	Office building	140 x 1,000 sq. ft.	17 per 1,000 sq. ft.	2,380
			TOTAL	26,814

APPENDIX D

TRIP DISTRIBUTION

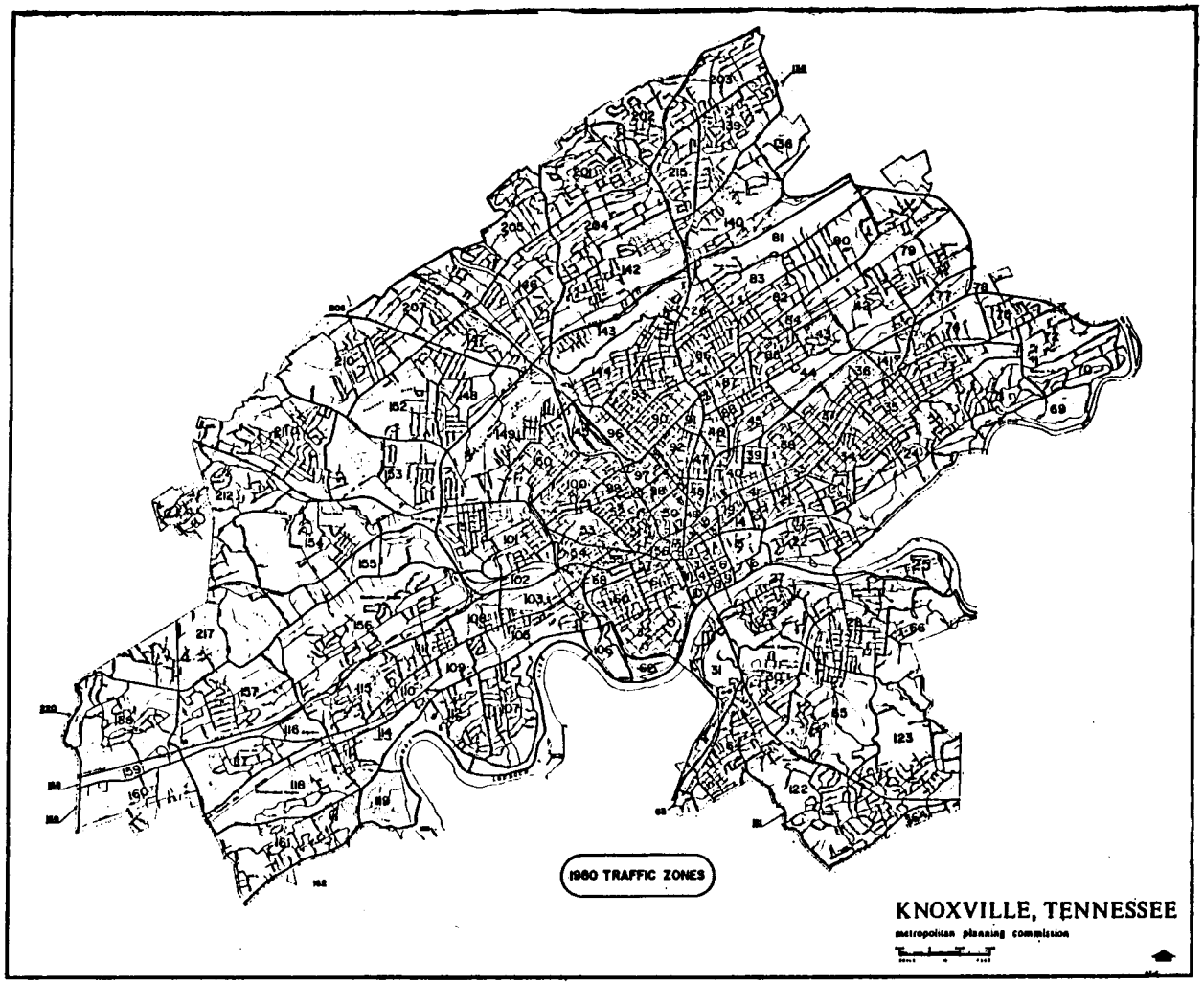


Figure D-1. Traffic zones for the City of Knoxville.

Source: The Knoxville-Knox County Metropolitan Planning Commission.

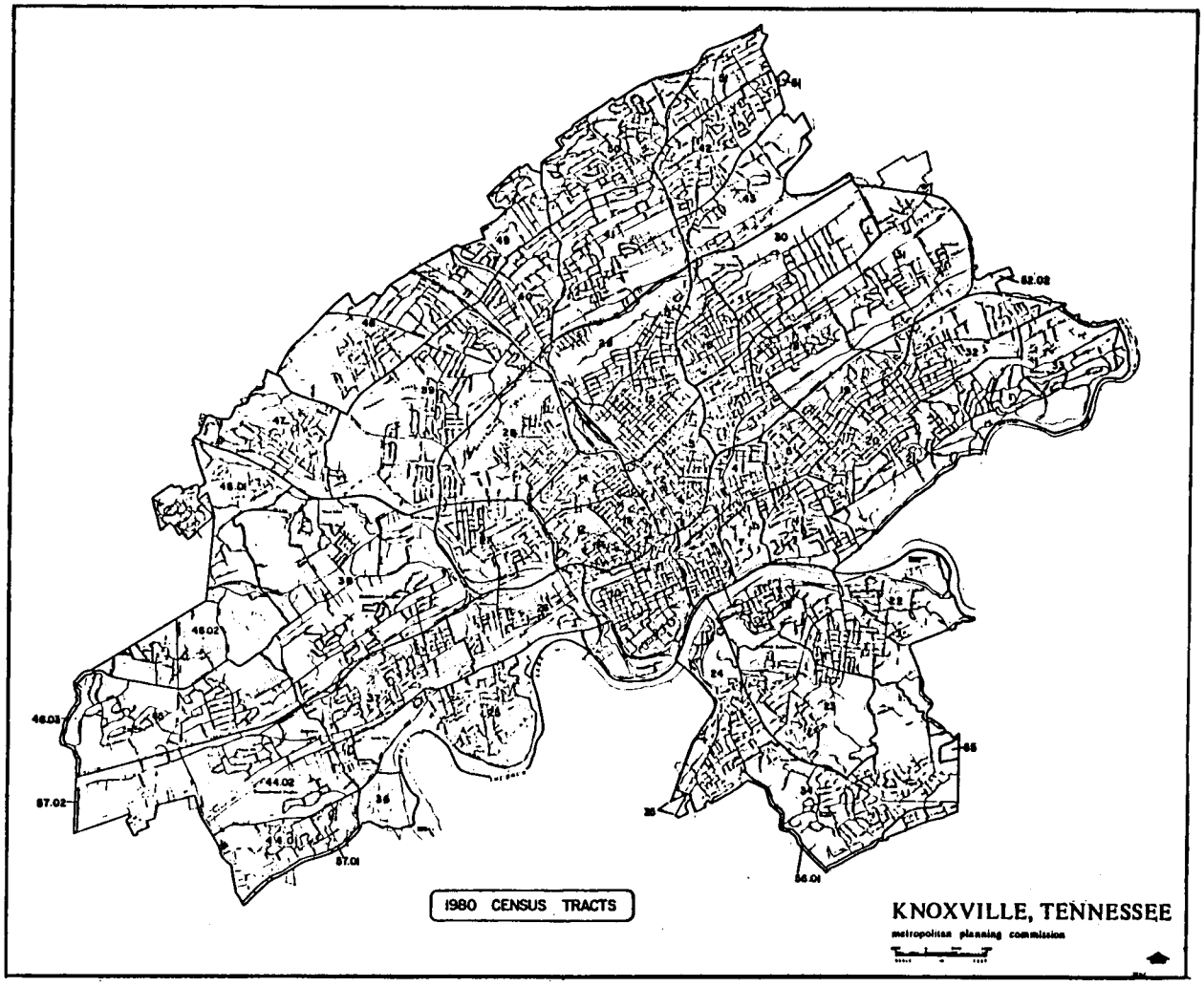


Figure D-2. Census tracts for the City of Knoxville.

Source: The Knoxville-Knox County Metropolitan Planning Commission.

TABLE D-1

ANALYSIS AREAS AND THEIR SOCIOECONOMIC DATA (1985)

Census Tract (Analysis Area)	Traffic Zone	Population	Employment
1	1, 2, 3, 4, 5, 6 7, 8, 9, 10, 12, 13, 17, 18, 131	1,648	30,996
2	48, 49, 50, 94, 95, 97, 98	1,664	5,750
3	47, 91, 92	2,424	939
4	19, 39, 40, 41	933	8,784
5	33, 38	3,364	501
6	21, 22	4,027	269
7	14, 15, 16, 20	2,020	1,884
8	27, 29	2,631	3,825
9	32, 62, 106	8,382	10,215
10	58, 60	1,830	5,962
11	56, 57, 61	3,256	795
12	53, 54, 55	3,018	1,442
13	51, 52	1,996	291
14	99, 100	4,176	279
15	90, 93, 96, 145	4,567	3,333
16	26, 86	3,359	1,788
17	45, 46, 87, 88, 89	3,272	1,118
18 + 19	36, 37, 43, 44, 84, 85, 141	5,395	3,337
20	34, 35	4,631	273

TABLE D-1 (continued)

Census Tract (Analysis Area)	Traffic Zone	Population	Employment
21	24	2,712	1,429
22	25, 28, 66	5,015	143
23 + 24	30, 31, 64, 65	8,496	2,501
25	107, 112, 114	2,839	778
26	103, 104, 105, 108	2,805	1,969
27	101, 102, 151	3,273	522
28	149, 150	4,592	2,294
29	143, 144	3,923	845
30 + 43	80, 81, 82, 83, 136, 140	6,233	2,203
31 + 32	73, 74, 75, 77, 79	5,822	2,253
33	69, 70, 71, 72	2,244	84
34	122, 123	4,491	451
35	63	3,126	2,917
36	119	891	1,318
37	109, 110, 111, 115	4,820	3,032
38	154, 155, 156	5,469	3,359
39	147, 148, 152, 153	6,430	2,292
40 + 41	142, 146, 204	7,634	1,441
42 + 50 + 51	139, 201, 202, 203, 215	9,802	898
44.01	161	3,488	121
44.02 + 45	116, 117, 118, 157, 158, 159, 160	12,362	8,296

TABLE D-1 (continued)

Census Tract (Analysis Area)	Traffic Zone	Population	Employment
46.01 + 47	211, 212	7,582	346
46.02	217	7,457	960
48 + 49	205, 207, 210	6,347	1,334
GRAND TOTAL		190,446	123,567

Source: Knoxville-Knox County Metropolitan Planning Commission. Compiled from original data.

TABLE D-2

TRAVEL TIMES BETWEEN STUDY AREA AND ANALYSIS AREAS

Census Tract (Analysis Area)	Travel Time to Study Area (in minutes)	Census Tract (Analysis Area)	Travel Time to Study Area (in minutes)
1	5	25	12
2	12	26	10
3	14	27	12
4	14	28	16
5	16	29	18
6	14	30 + 43	22
7	10	31 + 32	22
8	8	33	30
9	4	34	22
10	7	35	20
11	3	36	15
12	8	37	15
13	6	38	22
14	12	39	22
15	16	30 + 41	25
16	17	42 + 50 + 51	32
17	16	44.01	20
18 + 19	16	44.02 + 45	25
20	21	46.01 + 47	30
21	24	46.02	25
22	18	48 + 49	30
23 + 24	17		

TABLE D-3

TRIP DISTRIBUTION FOR RESIDENTIAL AREA

$$T_{ij} = P_i \times \frac{(P + E)\frac{1}{t^2_{ij}}}{\sum(P + E)\frac{1}{t^2_{ij}}}$$

where

P_i = productions from residential area
= 6,500
P = population
E = employment

Analysis Area	Relative Attractiveness	Total T_{ij} (Vehicle Trips)
1	31.9	2,074
2	1.2	78
3	0.4	26
4	1.2	78
5	0.4	26
6	0.5	33
7	1.0	65
8	2.5	163
9	28.4	1,846
10	3.9	254
11	11.0	715
12	1.7	111
13	1.6	104
14	0.8	52
15	0.8	52
16	0.4	26
17	0.4	26
18 + 19	0.8	52
20	0.3	20
21	0.2	13
22	0.4	26

TABLE D-3 (continued)

Analysis Area	Relative Attractiveness	Total T_{ij} (Vehicle Trips)
23 + 24	1.0	65
25	0.6	39
26	1.2	78
27	0.6	39
28	0.6	39
29	0.4	26
30 + 43	0.4	26
31 + 32	0.4	26
33	0.1	7
34	0.3	20
35	0.4	26
36	0.3	20
37	0.9	59
38	0.4	26
39	0.4	26
40 + 41	0.4	26
42 + 50 + 51	0.3	20
44.01	0.3	20
44.02 + 45	0.8	52
46.01 + 47	0.3	20
46.02	0.3	20
48 + 49	0.3	20

TABLE D-4

TRIP DISTRIBUTION FOR COMMERCIAL AREA

$$T_{ij} = P_i \times \frac{(P + E)\ \frac{1}{t_{ij}^2}}{\sum (P + E)\ \frac{1}{t_{ij}^2}}$$

where $P_i = A_j = 20{,}500$
P = population
E = employment

Analysis Area	Attractiveness	Relative Attractiveness (%)	Total T_{ij} (Vehicle Trips)
1	1,305	31.9	6,540
2	51	1.2	246
3	17	0.4	82
4	50	1.2	246
5	15	0.4	82
6	22	0.5	103
7	39	1.0	205
8	101	2.5	513
9	1,162	28.4	5,822
10	159	3.9	800
11	450	11.0	2,255
12	70	1.7	349
13	64	1.6	328
14	31	0.8	164
15	31	0.8	164
16	18	0.4	82
17	17	0.4	82
18 + 19	34	0.8	164
20	11	0.3	62
21	7	0.2	41

TABLE D-4 (continued)

Analysis Area	Attractiveness	Relative Attractiveness (%)	Total T_{ij} (Vehicle Trips)
22	16	0.4	82
23 + 24	38	1.0	205
25	25	0.6	123
26	48	1.2	246
27	26	0.6	123
28	27	0.6	123
29	15	0.4	82
30 + 43	17	0.4	82
31 + 32	17	0.4	82
33	3	0.1	21
34	10	0.3	62
35	15	0.4	82
36	10	0.3	62
37	35	0.9	185
38	18	0.4	82
39	18	0.4	82
40 + 41	15	0.4	82
42 + 50 + 51	10	0.3	62
44.01	9	0.3	62
44.02 + 45	33	0.8	164
46.01 + 47	9	0.3	62
46.02	13	0.3	62
48 + 49	9	0.3	62

APPENDIX E

TRAFFIC ASSIGNMENT

TABLE E-1

TRAFFIC ASSIGNMENT FOR PLAN "A"

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest Ave.	Clinch Ave. West of 11th St.	Forest Ave.	Highland Ave.
1	1,037 (R) 0 (C)	1,037 0	1,037 0	-	-	-
2	29 0	25 0	49 0	-	-	-
3	10 0	8 0	16 0	-	-	-
4	29 0	25 0	49 0	-	-	-
5	16 0	10 0	10 0	-	-	-
6	21 0	12 0	12 0	-	-	-
7	65 0	41 0	41 0	-	-	-
8	163 0	102 0	0 0	-	-	-
9	615 0	615 0	0	615 0	-	-
10	0 0	0 0	0 0	169 0	0 400	85 0

TABLE E-1 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest Ave.	Clinch Ave. West of 11th St.	Forest Ave.	Highland Ave.
11	0 (R)	0	0	358	179	179
	0 (C)	0	0	0	564	0
12	42	111	111			
	0	0	0	-	-	-
13	39	104	104			
	0	0	0	-	-	-
14	20	52	52			
	0	0	0	-	-	-
15	20	52	52			
	0	0	0	-	-	-
16	10	26	26			
	0	0	0	-	-	-
17	10	26	26			
	0	0	0	-	-	-
18 + 19	20	52	52			
	0	0	0	-	-	-
20	7	13	13			
	0	0	0	-	-	-
21	5	8	8			
	0	0	0	-	-	-
22	26	16	0			
	0	0	0	-	-	-

TABLE E-1 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest Ave.	Clinch Ave. West of 11th St.	Forest Ave.	Highland Ave.
23 + 24	65 (R) 0 (C)	41 0	0	-	-	-
25	39 0	24 0	0	-	-	-
26	39 0	39 0	39 0	-	-	-
27	15 0	39 0	39 0	-	-	-
28	15 0	24 0	24 0	-	-	-
29	10 0	26 0	26 0	-	-	-
30 + 43	13 0	13 0	13 0	-	-	-
31 + 32	13 0	13 0	13 0	-	-	-
33	3 0	3 0	3 0	-	-	-
34	20 0	13 0	0 0	-	-	-
35	26 0	16 0	0 0	-	-	-

TABLE E-1 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland Forest Ave.	Clinch Ave. West of 11th St.	Forest Ave.	Highland Ave.
36	10 (R)	10	0			
	0 (C)	0	0	-	-	-
37	30	30	0			
	0	0	0	-	-	-
38	10	26	26			
	0	0	0	-	-	-
39	10	26	26			
	0	0	0	-	-	-
40 + 41	13	13	13			
	0	0	0	-	-	-
42 + 50 + 51	10	10	10			
	0	0	0	-	-	-
44.01	10	10	0			
	0	0	0	-	-	-
44.02 + 45	26	26	26			
	0	0	0	-	-	-
46.01 + 47	8	20	20			
	0	0	0	-	-	-
46.02	8	20	20			
	0	0	0	-	-	-

TABLE E-1 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest Ave.	Clinch Ave. West of 11th St.	Forest Ave.	Highland Ave.
48 + 49	8 (R) 0 (C)	20 0	20 0	-	-	-
Totals	2,585	2,921	2,044	1,142	1,143	264

Explanation of cell values: Upper Value (R) = assigned volume from Residential Area;
Lower Value (C) = assigned volume from Commercial Area.

TABLE E-2

TRAFFIC ASSIGNMENT FOR PLAN "B"

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)						
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Clinch Ave. East of 11th St.	Forest Ave.	Highland Ave.
1	389 (R)	324	648	-	389 + 648	-	-
	0 (C)	0	0	-	0	-	-
2	0	25	49	-	29	-	-
	0	0	0	-	0	-	-
3	0	8	16	-	10	-	-
	0	0	0	-	0	-	-
4	0	25	49	-	29	-	-
	0	0	0	-	-	-	-
5	0	8	16	-	10	-	-
	0	0	0	-	0	-	-
6	0	10	21	-	12	-	-
	0	0	0	-	0	-	-
7	0	20	41	-	24	-	-
	0	0	0	-	0	-	-
8	163	102	0	-	0	-	-
	0	0	0	-	-	-	-
9	692	385	0	769	0	-	385
	0	0	0	1,456	1,456	-	-
10	0	0	0	169	0	-	85
	-	-	-	400	400	0	0

TABLE E-2 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips) 11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Clinch Ave. East of 11th St.	Forest Ave.	Highland Ave.
11	0 (R)	0	0	358	0	179	179
	0 (C)	0	0	564	564	564	0
12	42	45	111	0	0	-	-
	0	0	0	0	0	-	-
13	39	52	104	0	0	-	-
	0	0	0	0	0	-	-
14	-	26	52	-	20	-	-
	-	-	-	-	-	-	-
15	-	26	52	-	20	-	-
	-	-	-	-	-	-	-
16	-	13	26	-	10	-	-
	-	-	-	-	-	-	-
17	-	13	26	-	10	-	-
	-	-	-	-	-	-	-
18 + 19	-	-	-	-	-	-	-
20	-	7	13	-	7	-	-
	-	-	-	-	-	-	-
21	-	4	8	0	5	-	-
	-	-	-	-	-	-	-
22	26	16	0	-	-	-	-
	-	-	-	-	-	-	-

TABLE E-2 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips) 11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Clinch Ave. East of 11th St.	Forest Ave.	Highland Ave.
23 + 24	65 (R)	41	-	-	-	-	-
	-	-	-	-	-	-	-
25	15	-	-	12	-	6	6
	0	-	-	41	41	-	-
26	29	-	-	25	-	12	13
	-	-	-	82	82	-	-
27	15	20	39	-	-	-	-
	-	-	-	-	-	-	-
28	-	12	24	-	15	-	-
	-	-	-	-	-	-	-
29	-	8	16	-	10	-	-
	-	-	-	-	-	-	-
30 + 43	-	8	16	-	10	-	-
	-	-	-	-	-	-	-
31 + 32	-	8	16	-	10	-	-
	-	-	-	-	-	-	-
33	2	-	2	-	3	-	-
	-	-	-	-	-	-	-
34	20	13	0	-	-	-	-
	-	-	-	-	-	-	-
35	26	16	0	-	-	-	-
	-	-	-	-	-	-	-

TABLE E-2 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)						
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Clinch Ave. East of 11th St.	Forest Ave.	Highland Ave.
36	8 (R)	-	-	6	-	3	3
	- (C)	-	-	21	21	-	-
37	22	-	-	19	0	8	8
	-	-	-	62	62	-	-
38	0	13	26	-	10	-	-
	-	-	-	-	-	-	-
39	-	13	26	-	10	-	-
	-	-	-	-	-	-	-
40 + 41	-	13	26	-	10	-	-
	-	-	-	-	-	-	-
42 + 50 + 51	-	6	12	-	8	-	-
	-	-	-	-	-	-	-
44.01	8	0	0	6	-	3	3
	-	-	-	21	21	-	-
44.02 + 45	-	16	32	-	20	-	-
	-	-	-	-	-	-	-
46.01 + 47	-	6	12	-	8	-	-
	-	-	-	-	-	-	-
46.02	-	6	12	-	8	-	-
	-	-	-	-	-	-	-

TABLE E-2 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)						
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Clinch Ave. East of 11th St.	Forest Ave.	Highland Ave.
48 + 49	- (R)	6	12	-	8	-	-
	- (C)	-	-	-	-	-	-
Totals	1,561	1,351	1,555	4,011	4,020	775	682

Explanation of cell values: Upper Value (R) = assigned volume from Residential Area;
Lower Value (C) = assigned volume from Commercial Area.

TABLE E-3

TRAFFIC ASSIGNMENT FOR PLAN "C"

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St.. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Highland Ave.	Forest Ave.
1	2,074 (R) 0 (C)	1,296 0	648 0	- -	- -	- -
2	78 0	49 0	25 0	- -	- -	- -
3	26 0	16 0	8 0	- -	- -	- -
4	78 0	49 0	25 0	- -	- -	- -
5	10 0	4 0	8 + 4 0	4 0	4 0	8 0
6	33 0	21 0	11 0	- -	- -	- -
7	65 0	41 0	21 0	- -	- -	- -
8	163 0	102 0	51 0	- -	- -	- -
9	692 0	577 0	577 0	577 0	577 0	0 0
10	48 0	39 0	79 + 40 0	95 + 39 0	40 0	79 0

TABLE E-3 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips) 11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Highland Ave.	Forest Ave.
11	0 (R) 564 (C)	179 282	179 + 179 141	358 282	179 141	179 141
12	42 0	17 0	35 + 18 0	17 0	18 0	35 0
13	39 0	16 0	33 + 16 0	16 0	16 0	33 0
14	20 0	8 0	16 + 8 0	8 0	8 0	16 0
15	20 0	8 0	16 + 8 0	8 0	8 0	16 0
16	10 0	4 0	8 + 4 0	4 0	4 0	8 0
17	26 0	16 0	8 0	- -	- -	- -
18 + 19	20 0	8 0	16 + 8 0	8 0	8 0	16 0
20	8 0	3 0	6 + 3 0	3 0	3 0	6 0
21	13 0	8 0	4 0	- -	- -	- -
22	26 0	16 0	8 0	- -	- -	- -

TABLE E-3 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Highland Ave.	Forest Ave.
23 + 24	65 (R) 0 (C)	41 0	21 0	- -	- -	- -
25	39 0	24 0	12 0	- -	- -	- -
26	78 0	49 0	25 0	- -	- -	- -
27	15 0	6 0	12 + 6 0	6 0	12 0	6 0
28	15 0	6 0	12 + 6 0	6 0	12 0	6 0
29	10 0	4 0	8 + 4 0	4 0	8 0	4 0
30 + 43	10 0	4 0	8 + 4 0	4 0	8 0	4 0
31 + 32	10 0	4 0	8 + 4 0	4 0	8 0	4 0
33	3 0	1 0	2 + 1 0	1 0	2 0	1 0
34	20 0	13 0	6 0	- -	- -	- -
35	10 0	4 0	8 + 4 0	4 0	8 0	4 0

TABLE E-3 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips) 11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Highland Ave.	Forest Ave.
36	20 (R)	13	6	-	-	-
	0 (C)	0	0	-	-	-
37	59	37	19	-	-	-
	0	0	0	-	-	-
38	10	4	12	4	8	4
	0	0	0	0	0	0
39	10	4	12	4	8	4
	0	0	0	0	0	0
40 + 41	10	4	12	4	8	4
	0	0	0	0	0	0
42 + 50 + 51	8	3	9	3	6	3
	0	0	0	0	0	0
44.01	20	13	6	-	-	-
	0	0	0	-	-	-
44.02 + 45	20	8	24	8	16	8
	0	0	0	0	0	0
46.01 + 47	8	3	9	3	6	3
	0	0	0	0	0	0
46.02	8	3	9	3	6	3
	0	0	0	0	0	0

TABLE E-3 (continued)

From Study Area to Analysis Areas	Assigned Volume (Average Daily Vehicle Trips)					
	11th St. South of Clinch Ave.	11th St. Clinch to Highland	11th St. Highland to Forest	Clinch Ave. West of 11th St.	Highland Ave.	Forest Ave.
48 + 49	8 (R) 0	3 0	9 0	3 0	6 0	3 0
Totals	4,511	3,010	2,489	1,480	659	1,067

Explanation of cell values: Upper Value (R) = assigned volume from Residential Area;
Lower Value (C) = assigned volume from Commercial Area.

APPENDIX F

INTERSECTION CAPACITY ANALYSIS

A. CAPACITY ANALYSIS FOR PLAN "A"

Plan "A" assumed (1) the intersection of Eleventh Street and Summit Hill Drive to be open, and (2) Clinch Avenue viaduct to be closed.

The first step involved obtaining the future traffic loadings on the specific route links of interest. These volumes are shown in Figure F-1 below.

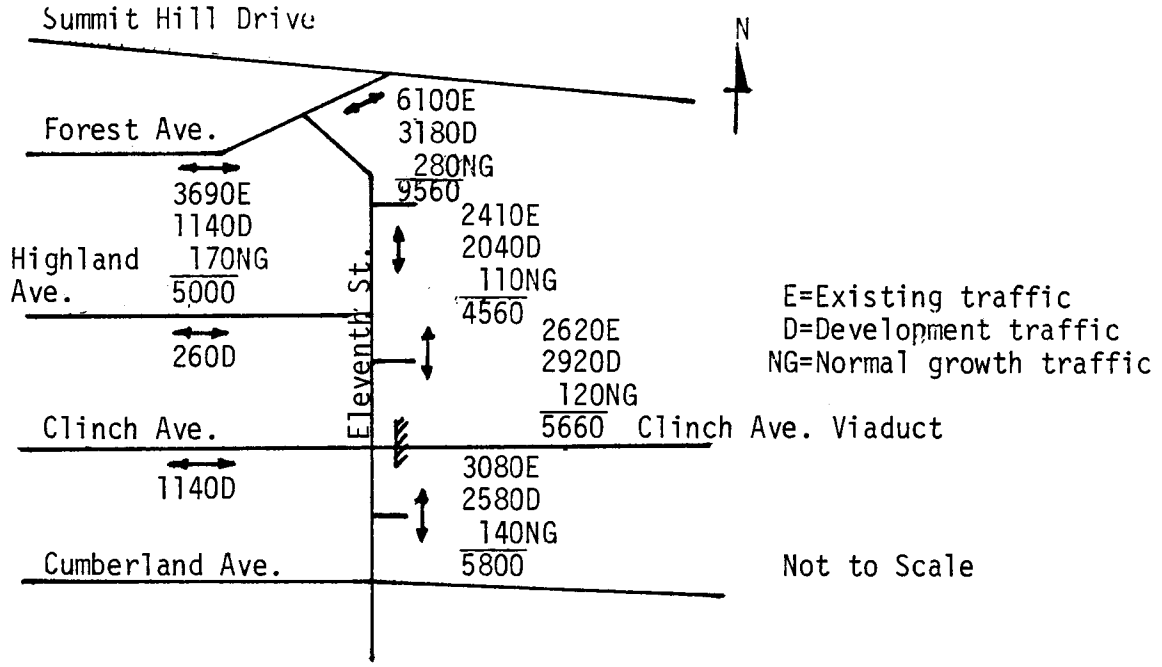


Figure F-1. Future traffic volumes—Plan "A."

Next, capacity analyses were carried out for the two key intersections.

1. The Intersection of Eleventh Street and Summit Hill Drive

The existing peak-hour turning movements were obtained from actual traffic counts (1982 data) and are shown in Figure F-2. The peak-hour volume (PHV) was found to equal 8.2 percent ADT volume. Based on this factor and the current directional splits, the future ADT volume was converted to the future peak-hour turning movements. This was for the purpose of intersection capacity analysis. The peak-hour turning movements are shown in Figure F-3. Finally, capacity analysis was performed (Figure F-4) for the intersection based on the procedures of the 1965 Highway Capacity Manual (HCM).

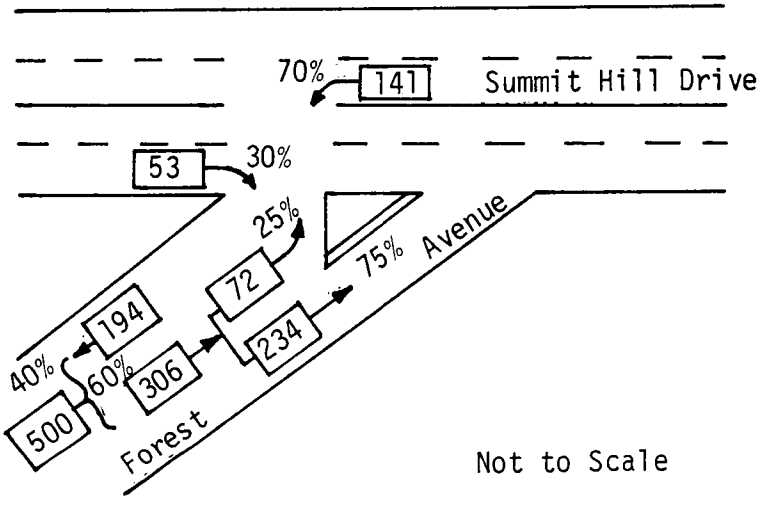


Figure F-2. Existing peak-hour volumes (1982) at the intersection of Summit Hill Drive and Forest Avenue.

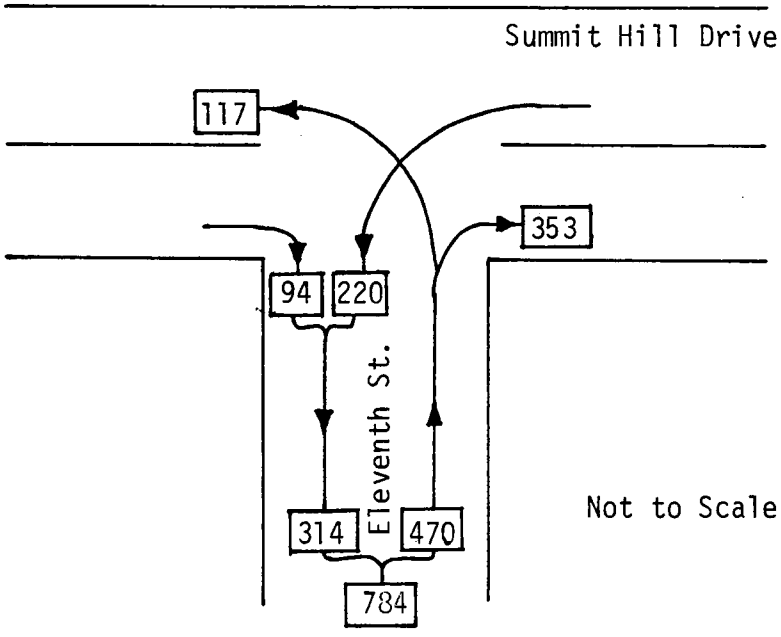


Figure F-3. Future peak-hour volumes (1988) at the intersection of Eleventh Street and Summit Hill Drive.

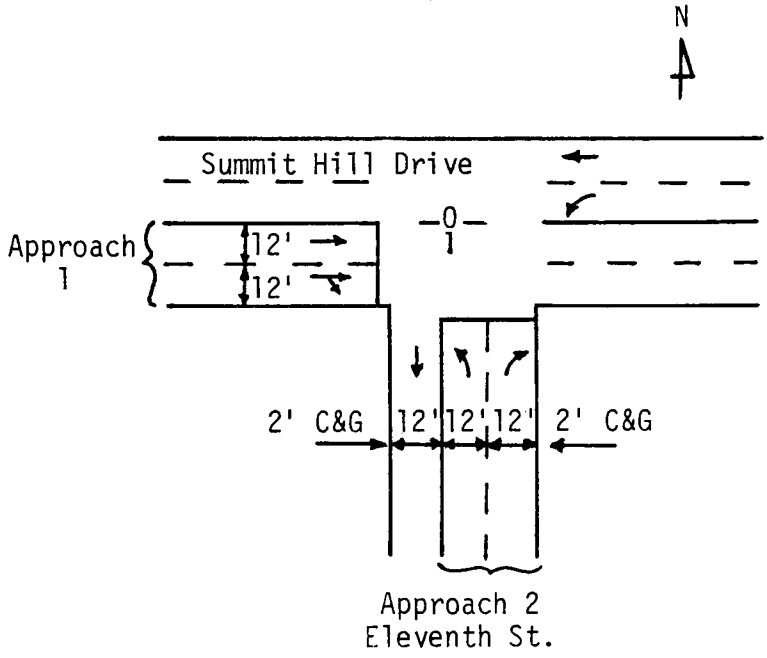


Figure F-4. Capacity analysis for the intersection of Eleventh Street and Summit Hill Drive.

Assumptions:

-T intersections, with widths on Eleventh Street as shown.

-Two-way traffic on all legs. No parking on any leg.

-Eleventh Street provides one separate left-turn lane and one separate right-turn lane northbound, and one lane southbound.

-Fringe area.

-Metropolitan area population = 350,000.

-In the absence of data, use peak-hour factor = 0.85 (PHF).

-Assume a cycle split as follows: approach 2 governs Eleventh Street, approach 1 governs Summit Hill Drive.

-Assumed volume for approach 1 = 11,000 VPD (1976 count plus growth factor) and volume for approach 2 = 5,700 VPD.

Therefore, estimated signal split ratio =

$$\frac{\text{Green 1}}{\text{Green 2}} = \frac{\text{Volume 1}}{\text{Volume 2}} \times \frac{\text{Width 2}}{\text{Width 1}} .$$

-Assume a cycle time of 90 seconds, 2 phase, and yellow time of 3 seconds, both phases, then

$C = G_1 + G_2 + Y_1 + Y_2 = 90$ sec. Therefore, $G_1 + G_2 = 84$ sec.

$$\frac{G_1}{G_2} = \frac{11{,}000 \text{ VPD}}{5{,}700 \text{ VPD}} \times \frac{24'}{24'} \text{, therefore, } G_1 = 55 \text{ sec.}$$

$G_2 = 29$ sec.

-Right turn: south leg = 75 percent, on reserved lane.

-Left turn: south leg = 25 percent, on reserved lane.

-Trucks = 0 percent.

-Local buses = none.

The objective was to determine service volume of south leg for level of service C. Level of service C is the level typically associated with urban design practice. The flow is stable but most drivers feel somewhat restricted, although not objectionably so.

At a T intersection the heavier turning movement is considered as a through movement. First, for through lane (i.e., right-turn lane) use 12' + 2' curb and gutter = 14' width. With load factor (L.F.) equals 0.3 and 14' width, Figure 6.8 of HCM gives service volume (S.V.) of 950 vphg.

Adjustments: 1.0 for PHF = 0.85 and 350,000 population

1.25 for fringe area

G/C ratio = 29/90 = 0.32

0 percent turning movements
Right turns (0 percent) = 1.2
Left turns (0 percent) = 1.3

No trucks or through buses = 1.05, therefore,

S.V. of right lane for level C = 950 x 1.0 x

1.25 x 0.32 x 1.2 x 1.3 x 1.05 = 622 vph.

Second, for left-turn lane, use "Separate Turning Lanes and Separate Signal Control" criteria since this lane was considered as having its own phase.

At level C and 12' width, S.V. = 800 vphg x $\frac{12'}{10}$.

Adjust for 0 percent of truck, S.V. = 800 x $\frac{12}{10}$ x 1.05 = 1008 vphg.

Therefore, S.V. = 1008 vphg x G/C = 1008 x $\frac{29}{90}$ = 325 vph

(maximum volume for level C).

Determination of controlling volume:

Right turns: 622 vph = 75 percent of total demand volume,

therefore, $\frac{622}{0.75}$ = 829 vph, demand volume.

Left turns: 829 vph x 0.25 = 207 vph

207 < 325, thus the through flow (i.e., right turns) controls. Therefore, final service volume for south leg (Eleventh Street) at level C is 622 + 207 = 829 vph, given 25 percent left turns and 75 percent right turns. Comparing this with projected volume of 470 vph, it is concluded that the demand volume can be handled at level of service "C" or better, at the improved intersection between Eleventh Street and Summit Hill Drive.

2. The Intersection of Eleventh Street and Cumberland Avenue

From traffic assignment, volume from Eleventh Street onto Cumberland Avenue westbound was found to be 812 ADT (770 development traffic plus 42 normal-growth traffic); and volume between Eleventh Street and Cumberland eastbound was 1908 ADT (1810 development plus 98 normal-growth).

-Assume 50 percent directional distribution.

-Assume PHV = 12 percent AADT.

The following ADT volumes were obtained for the Eleventh Street leg of the intersection as shown in Figure F-5.

Assume existing ADT on Cumberland Avenue of 24,000 vehicles and assume a 50 percent directional distribution. From traffic assignment, it was determined that there will be approximately 7,674 ADT generated from the commercial area in both directions. Hence, a total of

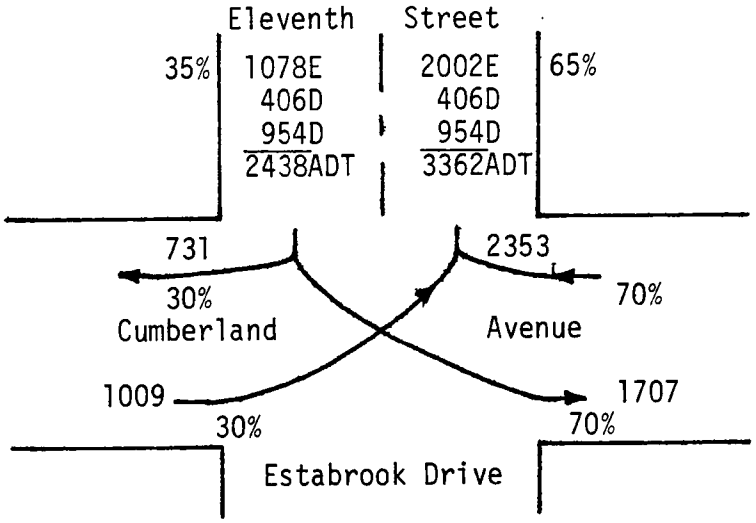


Figure F-5. Future ADT volumes on Eleventh Street at Cumberland Avenue.

3,837 ADT in one direction. Assume PH volume equals 12 percent ADT volume. The following peak-hour volumes were obtained for the intersection of Eleventh Street and Cumberland Avenue, as shown in Figure F-6. Capacity analysis was performed for the intersection (Figure F-7).

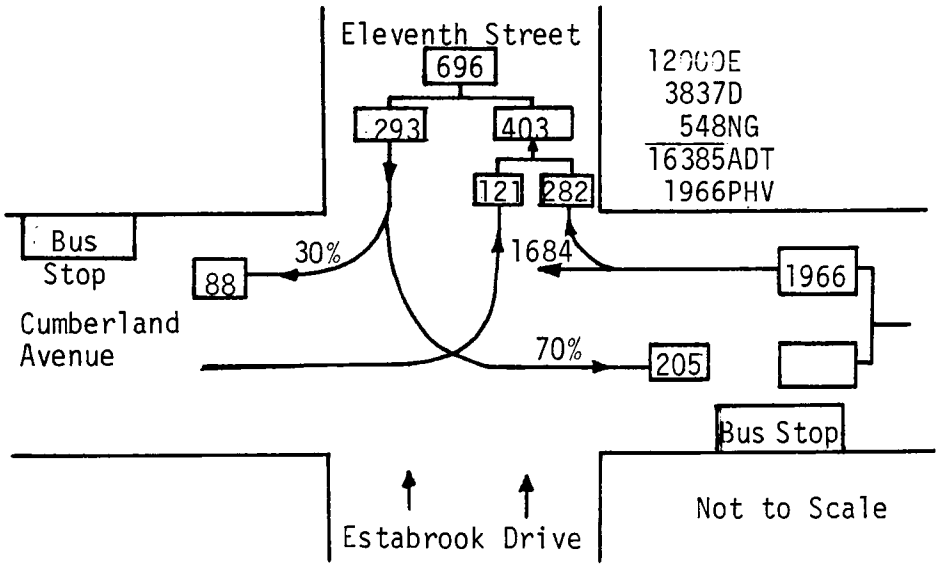


Figure F-6. Future peak-hour volumes at the intersection of Eleventh Street and Cumberland Avenue.

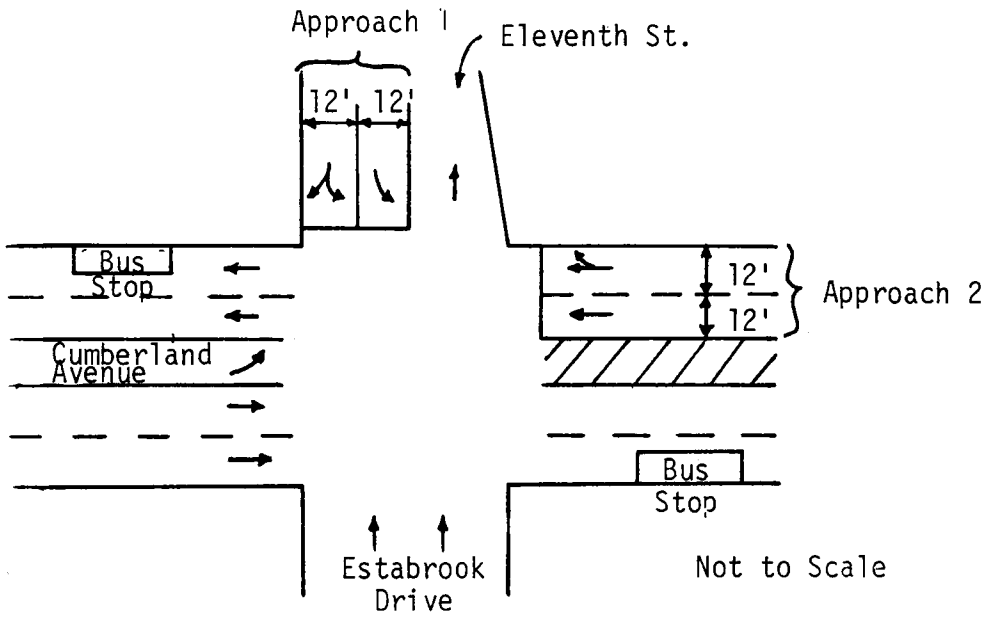


Figure F-7. Capacity analysis for the intersection of Eleventh Street and Cumberland Avenue.

Approach 1

Consider the intersection as a T-intersection, with widths as shown on Figure F-7. The following assumptions were made:

-Two-way traffic on all legs. No parking on any leg.

-Eleventh Street provides one separate left-turn lane.

-The intersection is in the fringe area.

-Metropolitan area population = 350,000.

-Use PHF = 0.85, in the absence of data.

-Approach 1 governs Eleventh Street. Approach 2 governs Cumberland. Based on demand volume on each approach, it is assumed that signal split ratio is $G_1 = 0.20\ G_2$.

-Assume a cycle time of 90 seconds, 2 phases, and yellow time of 3 seconds for both phases. Then,

$C = G_1 + G_2 + Y_1 + Y_2 = 90$ seconds

therefore, $1.20\ G_2 = 84$ seconds

therefore, $G_1 = 14$ seconds

$G_2 = 70$ seconds.

-Left-turn approach 1 = 47 percent, on reserved lane.

-Truck = 0 percent.

-Local buses = 10 per hour; far-side stops.

-Assume a desired level of service "C," which would be typical for urban intersections. At level of service "C," the flow is still stable, but most drivers feel somewhat restricted, although not objectionably so.

The objective was to determine service volume of approach 1 at level of service "C."

At T-intersections the heavier turning movement is considered as a through movement. Use 14-feet of width. First consider the through lane (i.e., left- and right-turn lane). With 14' width and 0.3 L.F., Figure 6.8 of HCM gives a service volume of 950 vphg.

Adjustment factors: 1.0 for PHF = 0.85 and 350,000 population

1.25 fringe area

$\frac{G}{C} = \frac{14 \text{ sec.}}{90 \text{ sec.}} = 0.16$

Percent of turning movements:

Right turn (0 percent) = 1.2

Left turn (0 percent) = 1.3

Percent of trucks and through buses (0 percent) = 1.05

10 local buses per hour, far-side stop = 0.98. Therefore, service volume of left- and right-turn lane, approach 1, level of service "C" = 950 vphg x 1.0 x 1.25 x 0.16 x 1.2 x 1.3 x 1.05 x 0.98 = 305 vph

Secondly, for left-turn on reserved lane, approach 1, apply criteria "Separate Turning Lanes—Separate Signal Control" since the left-turning lane has its own signal phase.

12-Foot lane: S.V. = 800 x $\frac{12}{10}$ = 960 vphg.

Adjust for 0 percent trucks = 960 vphg x 1.05 = 1008 vphg, therefore, S.V. = 1008 vphg x $\frac{G}{C}$ = 1008 x $\frac{14}{90}$ = 161 vph (maximum for L.O.S. "C").

Determination of controlling volume: 305 vph through = 53 percent of total demand volume; therefore, demand volume based on through flow = $\frac{305}{.53}$ = 575 vph. Left turns = 47 percent x 575 = 270 vph. Compare with maximum S.V. of 161 vph, 270 > 161. Therefore, it is not acceptable. And, the left-turn lane, rather than the "through" lane (i.e., right- and left-turn lane) will govern. Thus, $\frac{161}{0.47}$ vph (limiting capacity at L.O.S. "C") = 343 vph and the final service volume for approach 1, level C, is 343 vph.

A demand volume of about 343 vph can be accommodated at approach 1; meanwhile the projected traffic volume was about 293 vph in peak hours. Therefore, the Eleventh Street-Cumberland Avenue intersection is expected to handle the demand volume at level of service "C" or better under the assumption that the proposed geometric improvements are included.

Approach 2

Cycle time C = 90 seconds

G_2 = 70 seconds

Left turns = 0 percent

Right turns = 14 percent

Width = 26 feet, L.O.S. = "C" with L.F. = 0.3, S.V. = 1,850 vphg

Adjustment factors: P.H.F. and population = 1.0

Location = 1.25

$\frac{G}{C} = \frac{70 \text{ sec.}}{90 \text{ sec.}}$

Left turns = 1.10

Right turns = 0.99

Trucks and through buses (0 percent) = 1.05

Local buses (10/hr., far-side stops) = 0.98

$$S.V. = 1{,}850 \text{ vphg} \times 1.0 \times 1.25 \times \frac{70}{90} \times 1.19 \times 0.99 \times 1.05 \times 0.98$$

$$= 2{,}015 \text{ vph (maximum S.V.).}$$

The capacity on approach 2 at level of service "C" is about 2,015 vph. The projected demand volume is estimated to be about 1,966 vph. Therefore, Cumberland Avenue at the interaction with Eleventh Street will be heavily utilized. It might even be approaching level "D." That is, delays may be substantial during short peaks within the peak period.

B. CAPACITY ANALYSIS FOR PLAN "B"

Plan "B" assumed (1) the intersection of Eleventh Street and Summit Hill to be open, and (2) Clinch Avenue viaduct also to be open.

First, the future traffic loadings on specific road segments were obtained from the results of Step 1 through Step 5 of the simplified travel estimation process discussed previously. These volumes are shown in Figure F-8.

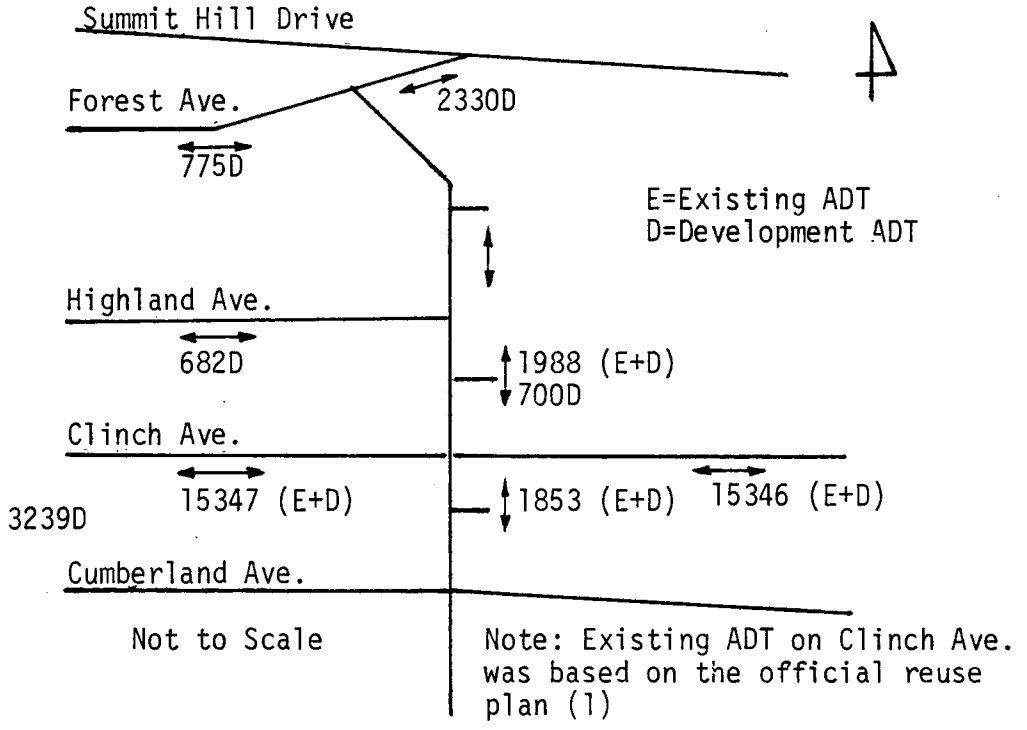


Figure F-8. Future traffic volumes—Plan "B."

Next, capacity analyses were performed for the key intersections. Capacity analyses for the two intersections of (a) Eleventh Street and Summit Hill Drive, and (b) Eleventh Street and Cumberland Avenue were not necessary because the proposed development ADT volumes on the Eleventh Street approach were much less than those of Plan "A," which had been analyzed previously and subsequently concluded that the intersections are expected to handle the demand volume at level of service "C" or better. However, capacity analysis for the

intersection of Eleventh Street and Clinch Avenue was performed by first establishing the turning movements at the intersection and then applying the HCM's analysis procedures. It is noted here that since the existing ADT and turning movements for the intersection prior to the temporary closing of Clinch Avenue viaduct were not available, estimated existing turning movements were obtained from the official reuse plan (1). The projected ADT was derived by adding the existing ADT and the normal-growth traffic and the development traffic. Then, the ADT was converted into the peak-hour volumes by assuming that PHV approximately equals 12 percent of ADT. The results are shown in Figure F-9. The Clinch Avenue-Eleventh Street intersection capacity analysis is shown in Figure F-10.

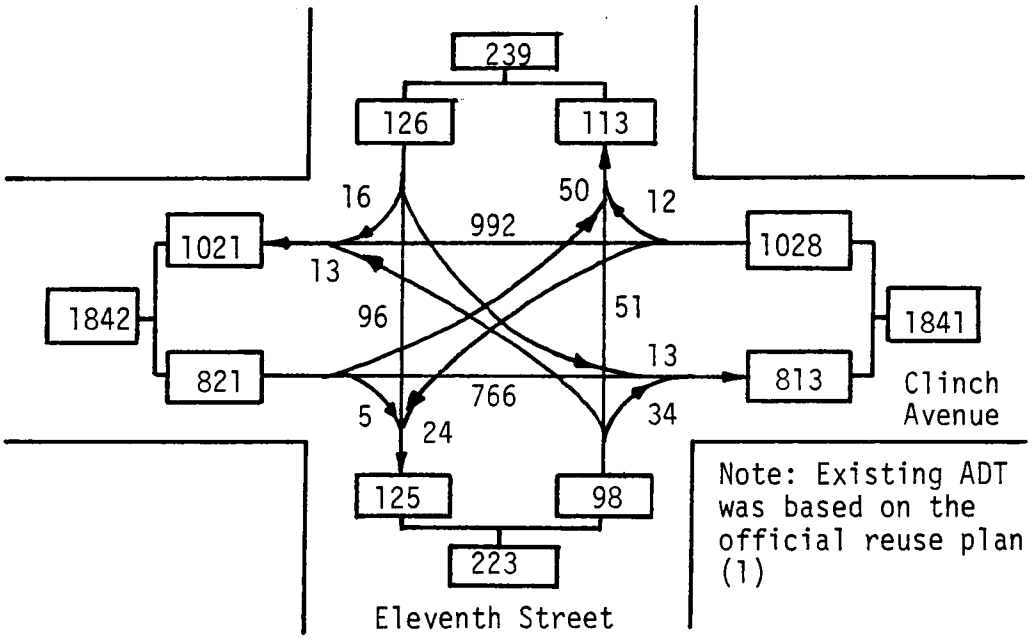


Figure F-9. Future peak-hour volumes (1988) at the intersection of Eleventh Street and Clinch Avenue.

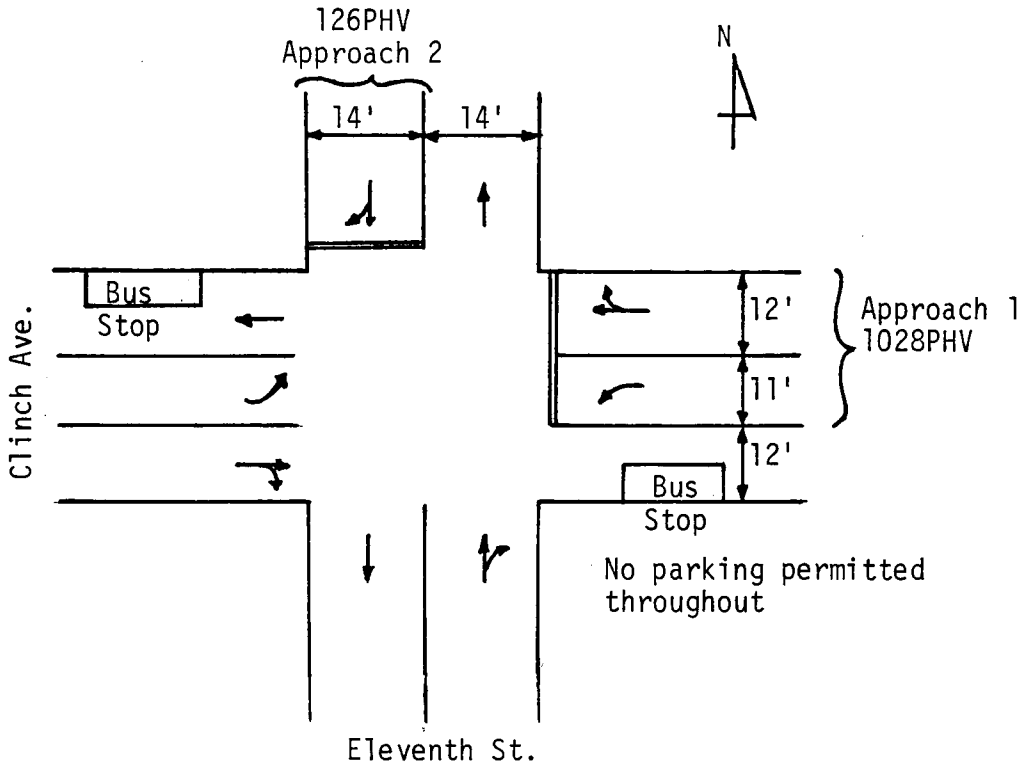


Figure F-10. Capacity analysis for the intersection of Eleventh Street and Clinch Avenue.

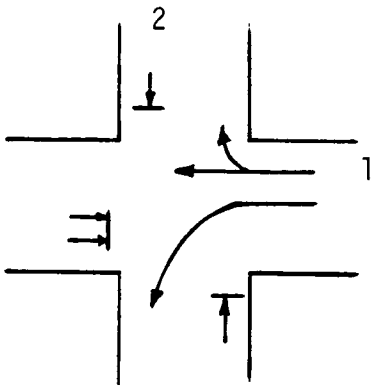
Assume 72-second cycle, 2 phases, 3 second yellow for both phases. Controlling approaches are 1 and 2 as shown. Assume split ratio of green times proportionate to volumes on approaches and inversely proportional to widths,

$$\frac{G_1}{G_2} = \frac{\text{Volume 1}}{\text{Volume 2}} \times \frac{\text{Width 2}}{\text{Width 1}} = \frac{1028}{126} \times \frac{14'}{23} = 5, \text{ therefore}$$

G_2 = 11 seconds,

G_1 = 55 seconds.

Additionally, assume, for approach 1, separate left-turn green interval with no opposing traffic equals 6 seconds, and through green interval equals 49 seconds.



Approach 1:

Right turns = 1 percent

Left turns = 2 percent

Approach 2:

Right turns = 13 percent

Left turns = 10 percent

Trucks = 0 percent

Local buses = 10 buses per hour, far-side stop for approach 1. No bus stops near intersection for approach 2.

The objective was to determine service volumes at level of service "C" on approach 1 and 2.

Approach 1

(a) Through lane: (Separate Signal Control)

Width = 12', L.F. = 0.3, therefore S.V. = 800 vphg

Adjustment factors: PHF = 0.85 and 350,000 population = 1.0

Location = 1.25

$\frac{G}{C} = \frac{49}{72}$

Right-turns (1 percent) = 1.18

Left-turns (0 percent) = 1.30

0 Percent truck = 1.05

Local buses ≈ 1.0, therefore

S.V. = 800 x 1.0 x 1.25 x $\frac{49}{72}$ x 1.18 x 1.30 x 1.05 x 1 = 1,096 vph through.

(b) Left-turn lane (Separate Lane—Separate Signal Control Condition)

$$S.V. = 800 \text{ vphg} \times \frac{11'}{10'} \times \frac{6}{72 \text{ sec.}} \times 1.05 = 77 \text{ vph (max.)}$$

Determine controlling volume:

1096 vph through lane = 80 percent of total demand volume,

therefore, $\frac{1096}{0.80}$ = 1,370 vph based on through flow condition.

Now, left turns = 0.02 x 1,370 = 27 vph

$27 < 77_{max}$, therefore, it is acceptable, and the through lane will govern.

Final service volume for approach 1 at level of services "C" is: 1096 vph + 27 vph = 1,123 vph, given 2 percent left turns. Comparing this capacity, at level C, of 1,123 vph with the projected demand volume of 1,028 vph, it is concluded that the intersection can handle the demand traffic at level C. However, the closeness of the two figures indicates it may be approaching level D, in which case delays may be substantial during short peaks within the peak period.

Overall, Clinch Avenue will be heavily utilized. The street, generally speaking, will be near the level of service D judging by the projected demand volume on it and by the estimated level of service of its intersection with Eleventh Street.

Approach 2

"No Separate Turning Lanes or Signals" condition. This is a basic case of simple approach problem.

Width = 14', L.F. = 0.3 for Level C, therefore, S.V. = 950 vphg.

Adjustment factors: $\frac{G}{C} = \frac{11 \text{ sec.}}{72 \text{ sec.}}$

Right turns (13 percent) = 0.97

Left turns (10 percent) = 1.00

0 Percent trucks or through buses = 1.05

Local buses 0 = none, therefore

S.V. = 950 x 1.0 x 1.25 x $\frac{11}{72}$ x 0.97 x 1.0 x 1.05 = 185 vph (max.)

This is the limiting intersection service volume for Level C for approach 2. The projected demand volume is 126 vph.

Therefore, approach 2 (north leg of Eleventh Street) will be able to handle the demand volume at level C. However, the mid-block driveways which connect the Expo site's residential areas to Eleventh Street might pose as serious "spot" interferences. Thus, these driveways, rather than the signalized intersections, control the capacity of Eleventh Street.

C. CAPACITY ANALYSIS FOR PLAN "C"

Plan "C" assumed both the intersection of Eleventh Street and Summit Hill Drive and the Clinch Avenue viaduct to be closed.

The future traffic loadings on specific route segments were obtained based on the previous results of step 1 through step 5 and are shown in Figure F-11.

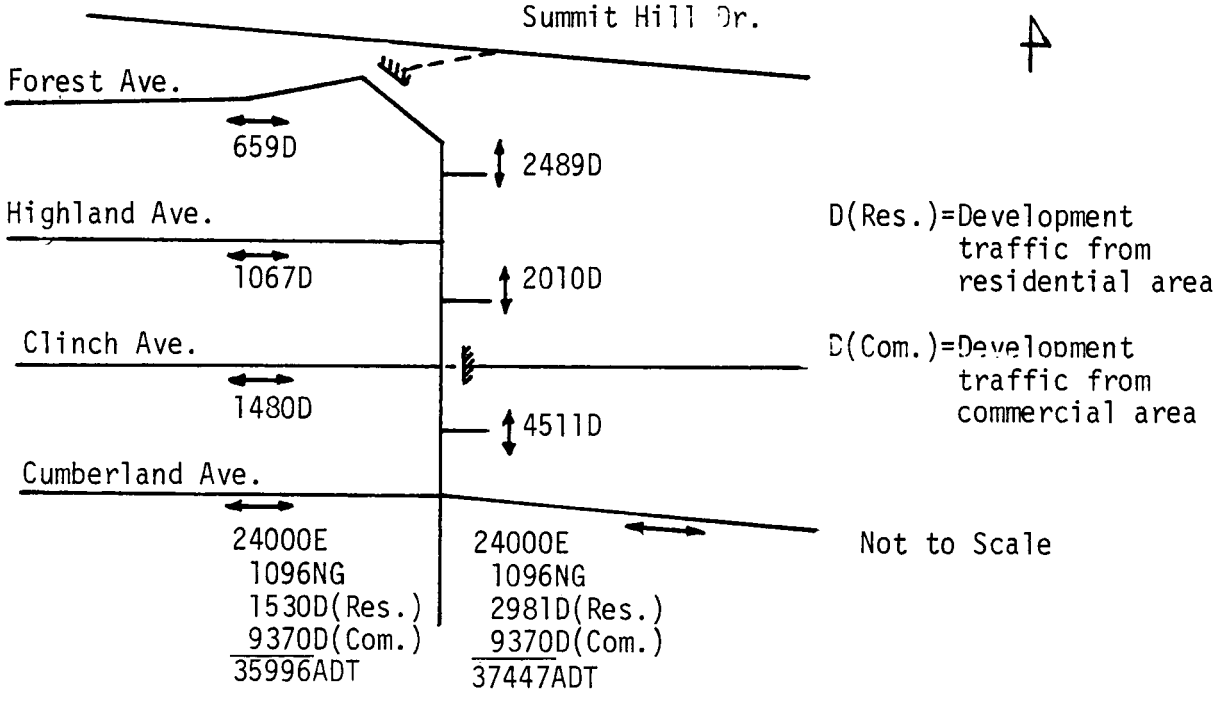


Figure F-11. Future traffic volumes—Plan "C."

Next, capacity analysis for the intersection of Eleventh Street and Cumberland Avenue was performed by first establishing the turning movements at the intersection (Figure F-12) and then applying the HCM's analysis procedures (Figure F-13 and the subsequent computations).

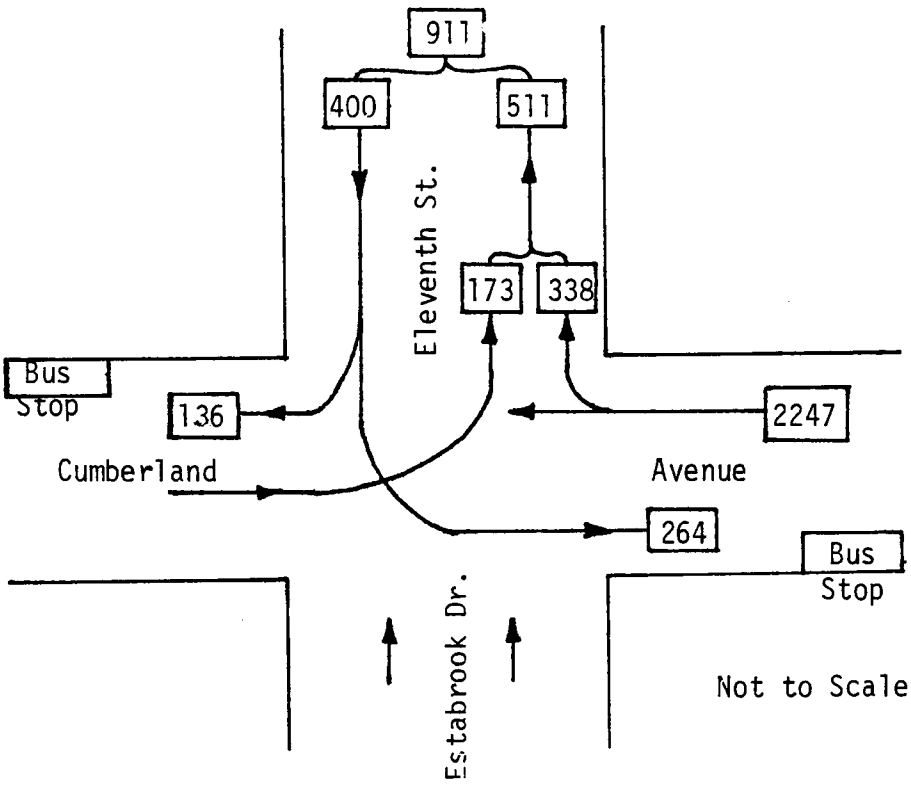


Figure F-12. Future peak-hour volumes (1988) at the intersection of Eleventh Street and Cumberland Avenue.

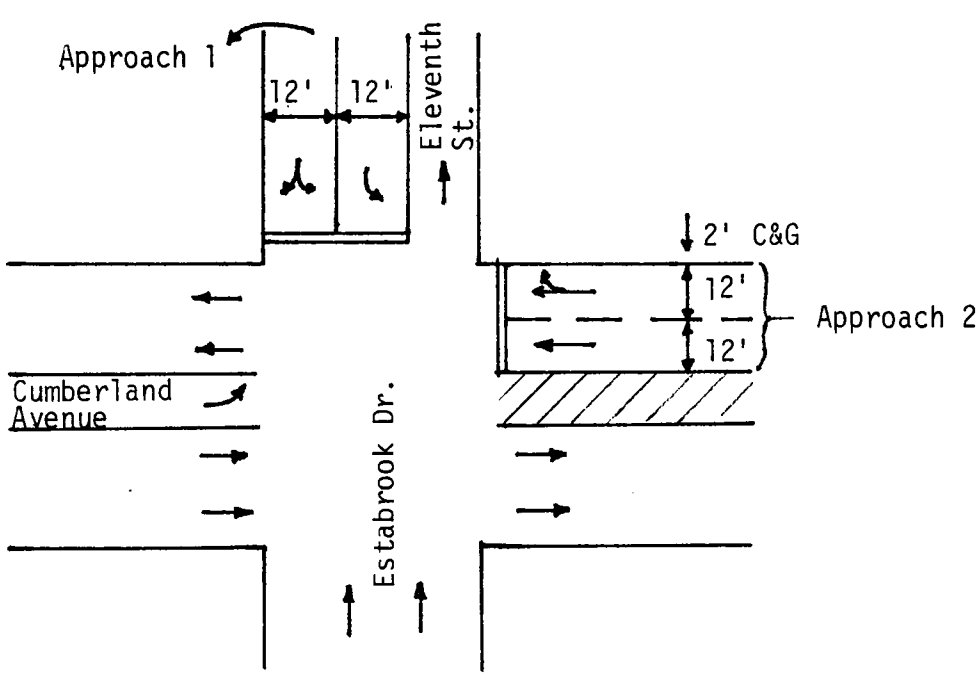


Figure F-13. Sketch for capacity analysis for the intersection of Eleventh Street and Cumberland Avenue.

Approach 1

From the results of the previous capacity analysis for plan "A" the capacity volume at level of service "C" for approach 1 has been determined as 343 vph. The projected traffic volume on approach 1 for this plan now was 400 vph. Therefore, even with the implementation of the proposed geometric improvements, approach 1 can only handle the demand volume at level of service "D." Level "D" indicates increasing traffic flow restriction approaching instability. Although excessive back-ups may not occur, delays for approaching vehicles can be expected to be substantial. Average overall speed is between 15 and 20 mph.

Approach 2

Width = 26', Level "D" with L.F. = 0.7, therefore, S.V. = 2,050 vphg.

Applying adjustment factors: S.V. = 2,233 vph (at level of service D).

With the projected traffic demand at 2,247 vph, approach 2 is expected to operate at level of service "E." At capacity, traffic flow becomes unstable, resulting in congestion and intolerable delay. Continuous back-up is expected to occur on all approaches to the intersection. Some vehicles may have to wait two or more signal cycles to pass through the intersection. The average overall speed is about 15 mph.

APPENDIX G

OPINION SURVEY

TABLE G-1

NEIGHBORHOOD ATTITUDES ON CLOSING CLINCH AVENUE VIADUCT
(FROM ELEVENTH STREET TO HENLEY STREET)
RESIDENTIAL SURVEY

Residency Group	Strongly Agree	Agree	Disagree	Strongly Disagree	No Opinion
Students	7 (14%)	15 (31%)	11 (22%)	(0%)	16 (33%)
Professionals	4 (12%)	10 (29%)	12 (35%)	1 (3%)	7 (21%)
Housewives	(0%)	(0%)	4 (80%)	(0%)	1 (20%)
Retirees	(0%)	2 (15%)	7 (54%)	3 (23%)	1 (8%)
Totals	11	27	34	4	25
Percents	11%	27%	34%	4%	24%

TABLE G-2

NEIGHBORHOOD ATTITUDES ON CLOSING CLINCH AVENUE VIADUCT
(FROM ELEVENTH STREET TO HENLEY STREET)
MERCHANT SURVEY

Business Owners Managers Group	Agree	Disagree	No Opinion
Owners and Employees	5 (10%)	37 (76%)	7 (14%)
Totals	5	37	7
Percents	10%	76%	14%

TABLE G-3

SUMMARY OF COMMUNITY ATTITUDE ON CLOSING
CLINCH AVENUE VIADUCT

Survey Group	Agreed	Disagreed	No Opinion
Home Interview			
Students	45%	22%	33%
Professionals	41%	38%	21%
Housewives	0%	80%	20%
Retired	15%	77%	8%
In General:	38%	38%	24%
Merchant Interview			
Business Owners/Managers	10%	76%	14%

VITA

Thanh Chi Duong was born in Vinh Phuc Yen, Viet Nam, on May 10, 1945. He attended elementary schools and high schools in Saigon. In 1962 he was selected to be an American Field Service exchange student at Fulton High School in Knoxville, Tennessee, and was graduated from Fulton High in June 1963. While in the United States, he lived with his host American family, the Reverend and Mrs. John H. Bull. After returning to his native country for two years, he graduated from Chu Van An High School in Saigon in 1965. After graduation, he was awarded the Colombo Plan Scholarship to New Zealand to attend the University of Auckland in Auckland. In May 1970 he received a Bachelor of Engineering degree in Civil Engineering. After graduation, he worked for the New Zealand Ministry of Works at Auckland's Central Residency for one year before returning to Viet Nam. He was then employed by the Viet Nam Engineering and Construction Company, Ministry of Public Works, in Saigon in 1971. In 1975 he came back to the United States and settled permanently there. From 1975 to 1977 he worked for the Tennessee Department of Transportation in Knoxville. In 1978 he was then employed by Hensley-Schmidt, Inc.; since then he is continuing to work for the firm as a Design Engineer. In the summer of 1977 he entered the Graduate Program in Civil Engineering of The University of Tennessee, Knoxville. He studied on a part-time basis toward a Master of Science degree in Civil Engineering with Transportation as the major area. He received the M.S. degree in March 1983.

The author is a member of the National Society of Professional Engineers, the Tennessee Society of Professional Engineers, and the American Society of Civil Engineers.

He married the former Loan Kim Chu of Saigon, Viet Nam in 1970 and has three children. They are David Truong Thanh, born in 1972; Joy L. Kim Phuong, born in 1975; and Sarah Kim Anh, born in 1977.